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中国华能集团有限公司
CHINA HUANENG GROUP CO., LTD.

POWER MARKET DESIGNS FOR ENERGY TRANSITION IN THE EU AND CHINA

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Foreword

Giuseppe Montesano and Mirko Armiento[1]

This paper is a joint effort between the *Fondazione Centro Studi Enel* (Enel Foundation) and the *Huaneng Technical Economics Research Institute* (HTERI) within the framework of a Memorandum of Understanding signed by the two Organization in 2016 to collaborate on research activities about energy transition.

During the last two decades, the electricity sector has embarked in a deep process of change in both the European Union (EU) and China.

In both geographies, common themes emerge, such as the integration of renewables in the electricity market and the key role of electrification to pursue environmental and decarbonization objectives.

This paper aims to address how power market design have been and are being reformed over time. Progress is at different stages between Europe and China, due to different contexts, which make the energy transition take different shapes and paces, although inspired by similar principles of environmental and cost efficiency.

A relevant difference emerges between the European advanced degrees of interconnection and integration of national electricity systems as well as competitiveness of wholesale and retail power markets, and the Chinese system, in which market elements are now being introduced and interconnections between regions are being developed. A European peculiarity lies also in the relevance of distributed resources, including renewables connected at low- and medium-voltage levels, as well as active roles played by consumers. Consequently, the role of distribution networks and of demand aggregators is paramount, illustrating a trend, which may be interesting also for China.

In the EU, the process of liberalization started in the mid-1990s (First Energy Package, 1996) and continued with the 2003 Second Energy Package and the 2009 Third Energy Package. These packages progressively intro-

1 Enel Foundation

duced rules on consumer protection, as well as legal separation between transmission functions and the activities related to generation and trading. Common detailed rules for electricity markets were established later, with the aim of coupling markets and improving cross-border trading.

In China, since 1985 investments from multiple sources have been permitted into power generation industry to help alleviate shortages of electricity. From 1987 to 2002, within the power sector, government functions have been separated from business activities; most of the assets of the power industry were transferred from the Ministry of Electricity to the newly formed State Power Corporation (SPC). The most significant recent reform was the reorganization of the power sector started in 2002 with the aim to break the institutional monopoly and introduce competition, improving overall efficiency. The reform disaggregated SPC's generation assets and grid assets into five generation companies (Huaneng was the biggest), two grid companies, and four power service companies. Two grid companies: State Grid Company (covering 26 provinces) and Southern Grid Company (covering 5 southern provinces) were in charge of transmission, distribution, system operation and retail. Nevertheless, the process was slow and complex and many obstacles showed up; hence, power transmission, distribution and retail activities continued to be fully vertically integrated and controlled by the two companies within their respective jurisdictions. The latest round of reform began in 2015 and is ongoing with the aim of establishing a competitive wholesale and retail power markets in order to encourage private investments in distribution networks.

During the last decade both the EU and China have embraced the global challenge of decarbonizing their economy: EU introduced a cap and trade system for emissions (the so-called EU ETS) as well as binding national targets for renewable energy sources (RES).In 2016, the EU presented the latest package of measures to proceed with the clean energy transition, aiming at the long-term target of being fully decarbonized by 2050; the so-called Clean Energy Package has three main goals: putting energy efficiency first, achieving global leadership in renewable energies and providing a fair deal for consumers. In parallel, China has continued to implement environmental-friendly policies, actively promoting the revolution of energy production and consumption with the aim of building clean, low-carbon, safe and efficient energy systems.

It should be highlighted that, in order to speed up energy transition, interconnections are crucial both in the EU (between Member States) and in China (between provinces) to improve both market efficiency and integration of renewables by better coping with their intrinsic variability.

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by Andrea Villa[2]

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The Liberalization of the electricity sector in Europe – The First Energy Package

In the last thirty years, the European Union has embarked in a profound process of liberalization and decarbonization of its electricity sector. During the 60s and the 70s, the majority of European Member States decided to centralize in Vertical Integrated Companies the generation, transmission, distribution and sales of electricity. In the majority of European Member States, the Governments were the sole owners of Vertical integrated companies. Generation of electricity was centralized in big central power plants fueled by hydro, nuclear and oil. Government planned electricity networks (distribution and transmission) and generation capacity addition based on continuously increasing demand forecasts. Tariffs for final customers were not always cost reflective, and in some cases, they reflect industrial and social policies. For example, in Italy, after the Oil Shocks of the 70s and 80s, the residential tariffs became progressive in order to foster energy efficiency and oil savings.

After the subsequent stagflation, European countries ended up with inefficient electricity industries with high prices and excess generation capacity. For these reasons, during the '80s, the European Commission, with its power entrusted by the European Treaties, published the "White Paper on the Internal Energy Market" as the first step towards the Single European Market, identifying monopolies as the main obstacle to improved competition and reduced prices.

2 Enel SpA; Enel Foundation's fellow

To pull forward, the European Union released the "First Energy package". Thanks to this first set of measures, generation and supply of electricity were opened to competition. The sale of electricity to industrial customers, with consumption above 20 GWh/year, was immediately liberalized, while sales to small industrial, commercial and residential customers remained regulated and supplied by a default suppliers, generally an arm of the distribution companies.

During the first years of the liberalization in Italy, thanks to the liberalization and the deployment of new generation technologies (OCGT and CCGT), the energy mix shifted from expensive oil power plants to more efficient gas power plants. These new power plants reduced prices and increased security of supply. Only after the liberalization and the deployment of these power plants, Italy was able to cover its peak annual electricity demand solely with national capacity.

In order to improve competition in the generation sector further, different Governments introduced forced divestments on the incumbent. For example, in Italy the *Bersani Decree* 79/99, which transposed the First Electricity Package (1996) into the national legislation, imposed to Enel (the integrated incumbent) the disposal of at least 15 GW. The Ministerial Decree of 4 August 1999 approved the plan through the creation of three new Generation Companies (GenCos) which were sold to private investors: Eurogen, Elettrogen, and Interpower.

The introduction of these GenCos allowed the internationalization of the Italian generation sector - Elettrogen was bought by Endesa (and after sold to E.On when Enel later acquired Endesa) and Interpower was bought by Electrabel.

Transmission and distribution were considered regulated activities and subject to scrutiny of the new energy National Regulatory Authorities (NRAs). Under the first Electricity Package, connection agreements to these public grids could be either regulated or negotiated between the generation/demand facilities and the transmission/distribution operator. The Italian government was the first to create a single National Regulatory Authority for electricity and gas and to empower it with the definition of regulated access tariffs.

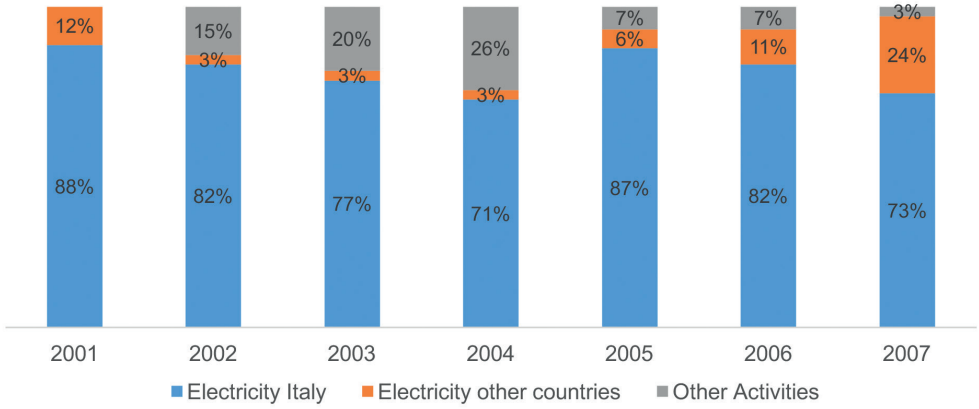
In order to help the correct definition of tariffs, the first EU electricity package introduced accounting unbundling for transmission and distribution activities. Many former incumbents kept the ownership and continued operating transmission and distribution assets. In Italy, Enel owned above 80% of distribution assets - distribution grids in big Italian cities were owned by city councils. Transmission assets were given to Enel, but its operation was given to an independent company, GRTN.

The internationalization of the electricity sector - The Second Energy Package

Considering the first positive results, the European Commission decided to push forward with additional liberalization measures in 2003, the so-called Second Energy Package. Thanks to these measures, the unbundling of transmission and distribution activities had been improved with functional unbundling. Also in this case, Italy went further; Enel's transmission assets were sold to an independent company, Terna. In addition, in order to improve transparency and competition, a day-ahead wholesale market was introduced in 2004 in order to define dispatching orders for power plants. Also the retail market was further liberalized, since 1 July 2007 all customer have been able to choose their own supplier. Customers that have not chosen their supplier continued to be supplied through a regulated tariff offered by default suppliers.

During the same period, Enel continued increasing its international presence. Between 2007 and 2009, Enel bought the control of Endesa and assets in Russia, Bulgaria and Romania, transforming the group from national to an international company.

Figure 1 – Share of EBITDA Enel S.p.A. 2001-2007



Common detailed rules for electricity markets - The Third Energy Package

Considering the persistence of high level of concentration in the electricity markets, the European Commission introduced in 2009 the "Third Energy Package." This package pushed forward the ownership unbundling of transmission system operator and tried to improve cross-border trading. Until that moment, the interconnections between Member States had been utilized as a security measure, not to exchange electricity also during normal operation conditions from areas with low prices to areas with high costs of electricity. In order to achieve to aim, the European Commission introduced a new legal framework, so called European Network Codes, in order to define the technical rules for a single market for electricity, the so-called European Target Model.

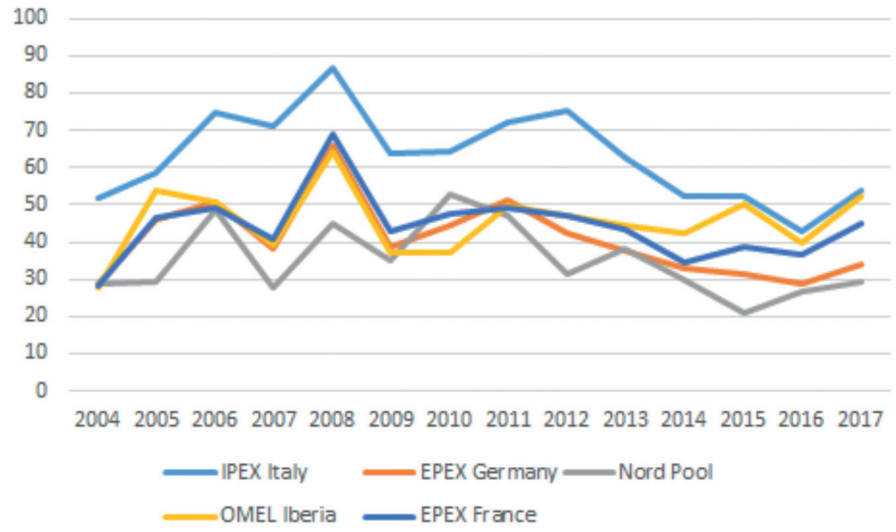
During the last few years, eight European Network Codes have been introduced. Three of them shape the structure of the markets: Forward Capacity Allocation, Capacity Allocation and Congestion Management (CACM) and Balancing Markets Network Codes. Three network codes define common requirements: high voltage direct current, requirements for generators and demand connection codes. The last two Network Codes define how System Operators must operate during normal and emergency situations The Third Energy Package and the introduction of European Network Code brought to fruition the European Target Model for electricity. Under the

EU target model, cross-border capacity between market zones (generally two Member States) is allocated in pan-European markets for different timeframes (long term, day-ahead, intraday and balancing). In addition, the calculation of available cross-border capacity is coordinated between Transmission System Operators (TSOs).

Given the necessity to bring forward investments in CCGT, a technology with marginal costs that are private information (due to the secrecy of prices of long-term gas contracts), and to reduce information advantages of former incumbents, the European Target model has focused on short-term energy markets. Short-term energy markets, thanks to auctions, are able to discover private information on short-term marginal costs (e.g. gas costs). In addition, they allow the integration of national day-ahead markets and the efficient allocation of cross-border interconnection capacity.

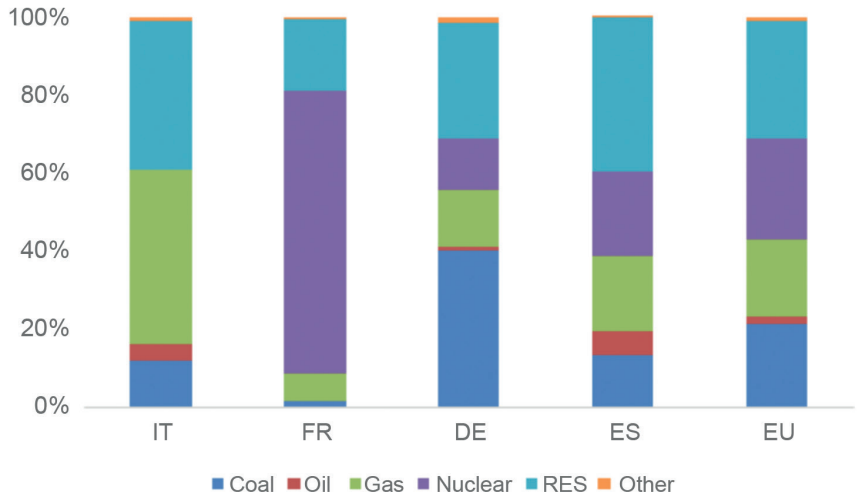
This mechanism has born fruits - electricity prices in Europe have started to converge, even if structural differences remain due to different generation mixes.

Figure 2 - Annual Wholesale Average Electricity Market (€/MWh)



Source: EPEX SPOT-France– Phelix, N2EX – NORD POOL SPOT, IPEX – GME, MIBEL – OMIE.

Figure 3 - Energy Mix 2016 (%)



Today, in most EU countries, transmission capacity is implicitly allocated jointly with energy in the day-ahead market (so called market coupling). Market coupling is the auctioning process that simultaneously matches orders and allocate cross-zonal capacity in an efficient way. For this reason, in any given moment interconnection capacity is used to export from a market zone with low marginal price towards a higher marginal price. In addition, in order to update the expected production and consumption schedule and maintain the system in balance, there is also a continuous cross-border intraday market.

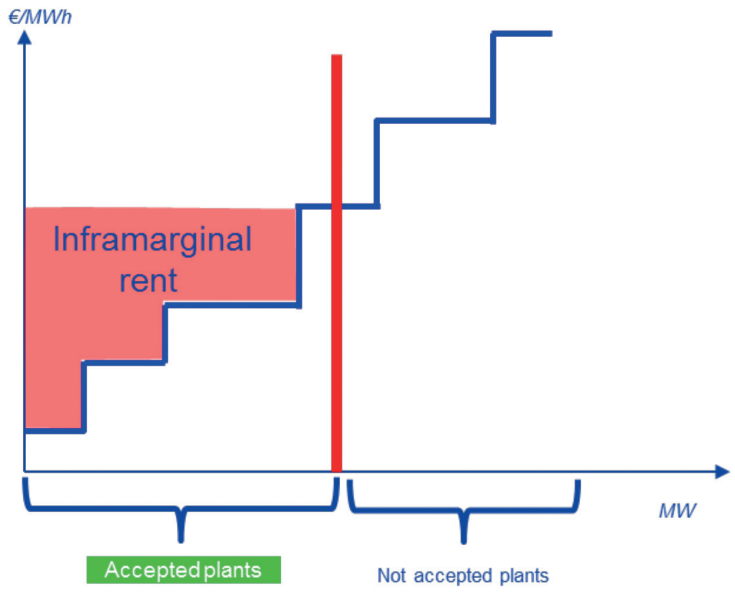
Finally, balancing markets are used by TSOs to maintain in balance the system when it is near real time of delivery; they are still national but starting in 2021, TSO will start exchanging standard European products for secondary and tertiary reserve, these reserves are products which allow the system to maintain the continuous balance between consumption and production of electricity.

Box 1 - How Competition Works in Day-ahead and Intraday Markets in E-urope

Day-ahead and intraday markets are short-term marketplaces where generators and Demand Side Management offer their capacity. Considering the high number of competitors and the oversight of anti-trust authority, operators bid their marginal costs. For conventional power plants, this means they bid their fuel, CO2 and variable O&M costs. Demand Side Management bid their Value of Lost Load, i.e. their willingness of not consuming electricity. Renewable resources, considering the absence of fuel costs, bid at zero (or very low in case they incur variable O&M).

For each hour, market operators match bids with the expected system demand, thus identifying a marginal price. Each selected bid, i.e. stacked bids on the right of demand curve, is entitled to generate and receive the system marginal price.

Power plants recover their fixed costs with inframarginal rents, i.e. the difference between their marginal costs and the system marginal price, and with capacity payment/markets in case the Member State has introduced one.



The Decarbonization of the European Power Sectors: Renewable Targets

Even if the European Target Model has brought important results in terms of competition and price convergence, it is now under scrutiny in order to understand if it is able to deliver adequate results in the future years.

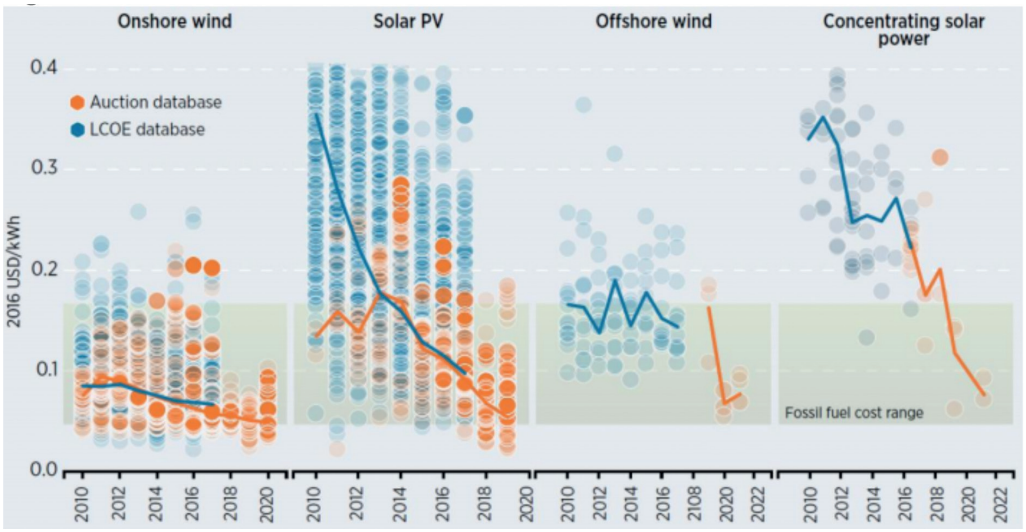
Starting in the middle of 2000s, the European Union has fully embraced the decarbonization of its economy. After having signed the Kyoto Protocol (adopted in 1997 and entered into force in 2005), it introduced a cap and trade system for its emission (the so called EU ETS) as well as binding national target for renewable energy sources in 2005 (2009/28/EC). The European Union fixed the so called 20-20-20 targets: the EU set a target for 2020 of -20% of CO2 emission compared to 1990 level, 20% of electricity from renewable energy sources and a reduction of 20% of energy consumption compared to the business as usual scenario. Those targets haven now been updated for 2030: 32% of renewables, 32.5% of energy efficiency and a reduction of CO2 of at least 40% compared to 1990 level. The long-term target in 2050 is for the European Union to be fully decarbonized.

In order to achieve these goals, in addition to the EU ETS (the price for carbon emissions), Member States have introduced support mechanisms in order to facilitate production from renewable energy sources, especially in the electricity sector.

At the beginning, these schemes were based on Feed in Tariffs (FiTs): TSOs or DSOs purchased all RES production at a price previously defined by the central government. Soon, economy of scope and of scale brought RES costs down, especially for wind and PV power plants.

Thanks to these experience, Government were able to switch from administratively determined FiT to auctioned Feed in Premiums (FiPs) and Contract for Difference in which the price (i.e. the level of support) is determined as a result of a competitive procedure, i.e. the auction. These new mechanisms brought competitive force in the definition of the prices, further reducing the development costs of renewables. In addition, RES auctions, being generally based on a 2-way contract for difference, provided revenue stability for RES producers and eliminated inefficient incentives in dispatching these resources.

Figure 4 - Auction Results and LCOE



Source: European Commission

Thanks to these improvements in a short period, the European Union became the epicenter of the energy revolution. This revolution has profoundly changed European Utilities. At first, not all European Utilities embarked on renewables. In particular, Enel, Iberdrola, EDP were the first to develop important portfolio of RES projects. On the contrary, German and French companies did not embrace immediately the change. In particular, German companies were limited by fresh investment in costly new CCGTs and the closure of nuclear power plants after the Fukushima accident. Enel at first decide to deploy its long-dated RES knowhow in the Americas, where it was already present in the South after the acquisition of Endesa and started investing in the North and Central American Countries.

Box 2 - The Creation of Enel Green Power

Enel stayed at top of the green revolution, founding Enel Green Power on 2008 to concentrate all of Enel's activities in the production of renewable energy and becoming the largest European company in the field of renewable energy in terms of both installed capacity and international presence.

Enel Green Power is engaged in the production of electricity from renewable sources at a global level: in November 2018, with 1.200 active power plants, it is present in 30 countries. In every country, the activity is managed through a national division. The production mix includes geothermal energy, hydropower, solar energy, biomass, and wind power, with a total production capacity of 42 GW.

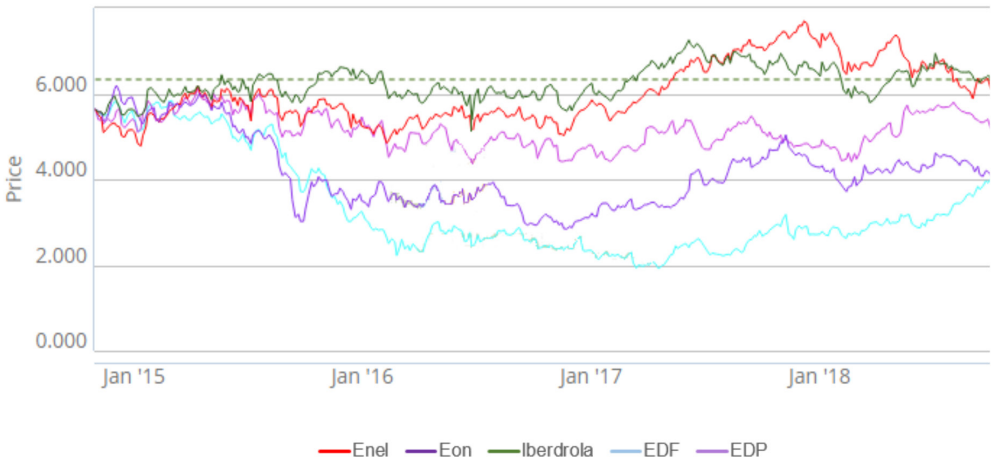
The effect of this revolution has been the shift in the EU energy mix. In few years, solar production moved from 0.7% in 2010 to 3.7% in 2017. Wind production moved from 4.4% in 2010[3] to 11.2% in 2017[4]. In 2017, renewables generated 30% of Europe's electricity that led to wind, solar and biomass generation surpassing coal generation for the first time.

At the same time, market-capitalization of European Utility has changed dramatically. Companies that did not soon embrace the decarbonization have suffered.

3 Source: https://ec.europa.eu/energy/sites/ener/files/documents/pocketbook_energy_2017_web.pdf

4 Source: Eurostat (https://sandbag.org.uk/wp-content/uploads/2018/01/EU-power-sector-report-2017.pdf)

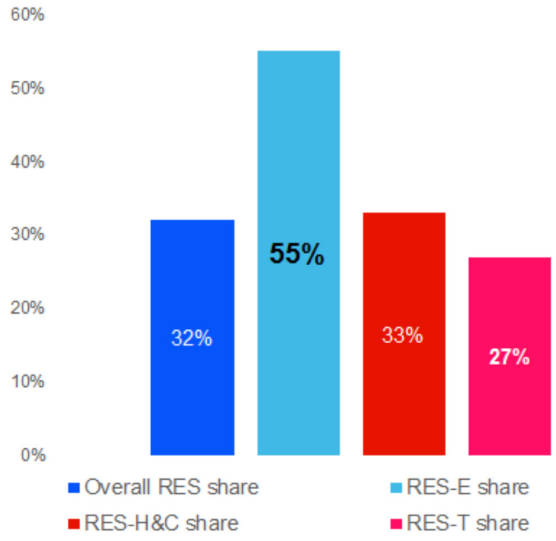
Figure 5 - Stock Prices of European Electricity Companies



Companies that soon embraced the energy transition,like Enel and Iberdrola, have seen their market capitalization grow in the last few years.

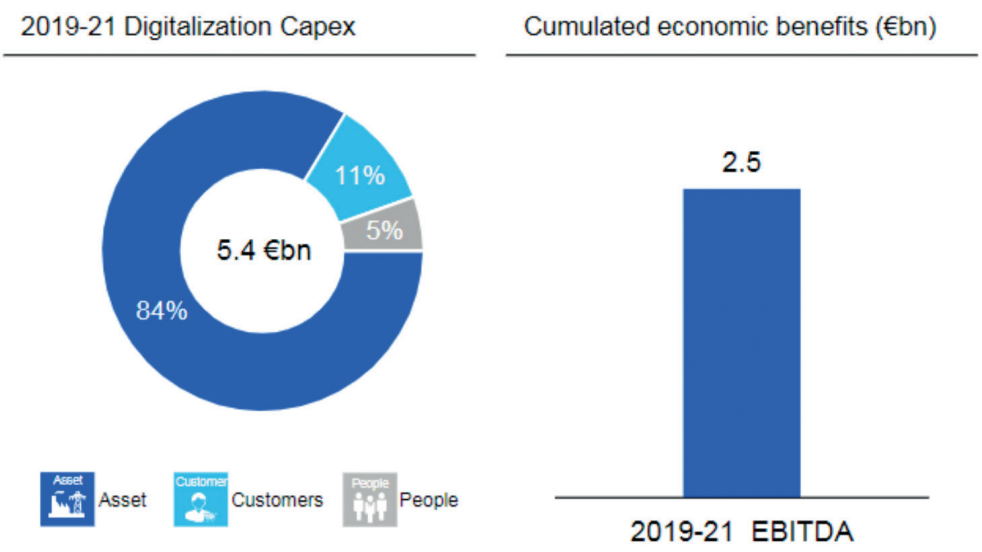
This process of decarbonization is not losing momentum - it is increasing. During 2018, the European Union approved the new 2030 decarbonization goal. By 2030, at least 32% of energy consumed in the EU will come from renewable resources, which represent a share of around 55% of electricity from renewable resources. This increase in RES production, especially decentralized resources like wind and PV, will have a profound effect on European markets.

Figure 6 - Overall and sectoral RES shares in 2030



First, the majority of the resources will be connected to the distribution network. In the last decade, DSOs have heavily invested in transforming distribution grid from passive to smart grids, and this process will continue in future years. For example, e-distribuzione, the Enel's Italian distribution company, has been the first company to roll out massively smart meters in 1990s. Investments in digitalization of the grid will continue in the next few years. Enel's investment plan is pushing for 5.4 billion investments in digitalization of its assets and clients for the following 3 years.

Figure 7 - Enel Investment Plan 2018



These investments will help to improve the deployment of renewables and the quality of the service. The majority of new RES power plants will be connected to distribution networks, therefore these networks will move from a passive role to an active role. In fact, until few years ago electricity flow from big power plants connected to the transmission grid to final customers connected to distribution grids. Now, with many renewable power plants connected to the distribution grids, during sunny or windy hours, electricity flows in the other direction, from distribution to transmission grids. In addition, customers, with the deployment of PV, Wind and electric vehicles move to the joint production and consumption of electricity. For this reason, distribution grids must be equipped with digital solutions that allow the management of electricity flows that are becoming more difficult to forecast.

These challenges will further increase due to the decarbonization effort. In fact, in order to reach 2030 targets and the final goal of complete decarbonization before 2050, we will require not only the massive deployment of renewables but also the electrification of the sectors that until now have

not played a major role in the decarbonization journey. In particular, if Europe wants to reach environmental goals, we will have to decarbonise the transport sector.

The deployment of non-programmable resources, like PV and wind, require the deployment of innovative technologies. For example, wind generators can deliver voltage and primary control with modifications of their inverters. In addition, in order to avoid ineffective investment in additional conventional peak capacity, we will have to invest in Demand Side Response (DSR). Also in this case Enel has been at the forefront. In 2017, Enel bought the one of the world's market leader in these services, Enernoc, which has a total of 5.7 GW of demand-response capacity globally alongside additional services in development. In Catania, Enel has opened 3Suns in order to produce advance PV modules, i.e. Bifacial Photovoltaic

To complete the energy transition, the European Union has to decarbonise other sectors that until now have not participated actively. In particular, there should be the decarbonization of the transport sector, through the introduction of the electric vehicles. This sector integration will bring additional benefits for the system: it can improve efficiency, strengthen security of supply and provide flexibility to the grid. EVs' batteries will be able to balance the system grid when renewable production is above or below system needs by modulating charging approaches.

In this sector, Enel group has been one of the first company to implement Vehicle Grid Integration (VGI) solutions, also thanks to the acquisition of eMotorWerks. The latter developed JuiceNet, an IoT aggregation platform, which is able to connect customers allowing them to become prosumers and to control their energy needs. JuiceNet, aggregating electric vehicle flexible loading and utilizing its smart charging techniques, increases the benefits for the power system as a whole and foster Enel strategy on smart grid technologies development and on the efficient integration of renewable generation. eMotorWerks provides valuable grid management services - such as demand response, frequency regulation, peak shaving, local load balancing, and many others - that help energy companies and system operators better manage the grid volatility and prepare for and fully leverage accelerating EV adoption.

Box 3 - Flexibility Services for C&I Customers

Enel Group, through Enel X its advanced energy services business line, pursues an Energy as a Service strategy for commercial and industrial clients, so that through its solutions they will be able to decarbonise their consumption and save money on their energy bills. Enel X offers flexibility services including energy storage, distributed energy resources, demand response, energy advisory services.

Since 2017, Enel X, through the acquisition of US based company EnerNOC, has become one of the world's largest aggregators of demand response and providers of flexibility services. Demand response allows C&I consumers to respond to market variations by increasing or reducing their energy consumption with the aim of responding to peaks in electricity supply and demand, resulting in greater grid flexibility and stability as well as more efficient use of energy infrastructures and resources. Enel X runs this business playing as an aggregator, putting active demand and demand response services into the hands of its C&I customers by digitalizing the management of their electricity consumption. Enel X counts a demand response capacity equal to 5.7 GW, managing customer sites in North America, Europe and South-East Asia.

How to make the European Electricity Market Fit for the Energy Transition

These improvements will not be enough if we do not improve the current EU market model. As mentioned above, the EU Target Model has focused on short-term efficiency, improving dispatching decisions of centralized conventional resources.

The massive deployment of renewable moves the focus on other issues. In addition, customers are shifting from a passive to an active approach, from consumers to prosumers and suppliers of distributed flexibility.

In other words, it is high time to find solutions for at least three set of questions. How to deploy technologies with zero marginal costs but significant fixed costs? How to dispatch a system in which dispatchable resources are not able to remain economically viable? How to engage with customers and unlock distributed resources of flexibility?

The Clean Energy Package

On 30 November 2016, the European Commission presented a package of measures to keep the European Union competitive as the clean energy transition changes global energy markets, the so-called Clean Energy Package. The proposals have three main goals: putting energy efficiency first, achieving global leadership in renewable energies and providing a fair deal for consumers. The Clean Energy Package covers energy efficiency, renewable energy, the design of the electricity market, security of electricity supply and governance rules for the Energy Union. The package also includes actions to accelerate clean energy innovation and to renovate Europe's buildings. The final version of the rules will be soon be published and will start to apply starting 2019.

Short-term vs Long-term markets

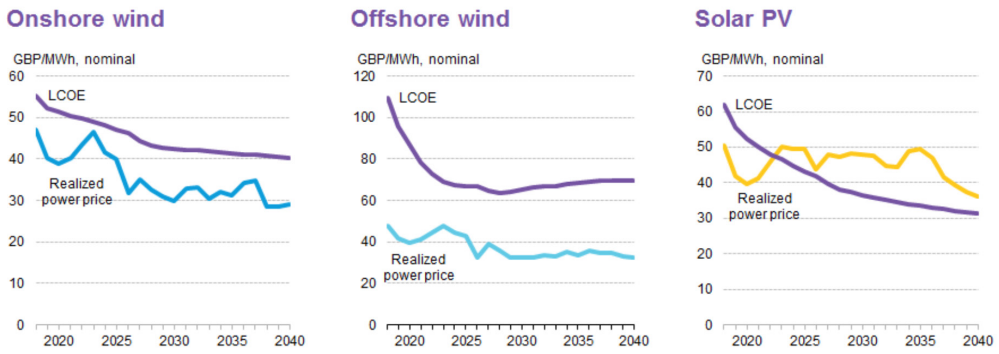
The past and present experiences have shown that a market design based exclusively on short-term energy prices is not able to deliver the required amount of RES investment. In fact, even if RES are able to fill the gap between Levelised Cost of Electricity (LCOE) with conventional resources, they suffer of the cannibalization effect.

Because of the presently expensive cost of storing electricity, all renewable operators inject electricity when the sun is shining and when the wind is blowing, depressing short-term prices; for this reason, their revenues are low even if their sales are high.

On the contrary, when the sun is not shining, their revenues are low, even if market prices are high. In addition, RES developers are extremely exposed to high costs of capital due to the fixed cost nature of their investments.

For this reason, although the LCOE of renewable is decreasing fast, they are not able to finance their deployment only with the participation in short-term (day-ahead, intraday and balancing markets).

Figure 8 - Realized Power Prices and LCOEs



Source: Bloomberg New Energy Finance

For these reasons, it is important to develop renewables under long-term agreements that are able to share the benefit of electricity from renewable resources. In other words, it is important to complement short term dispatching markets with additional long-term markets, e.g. RES auctions and RES PPAs.

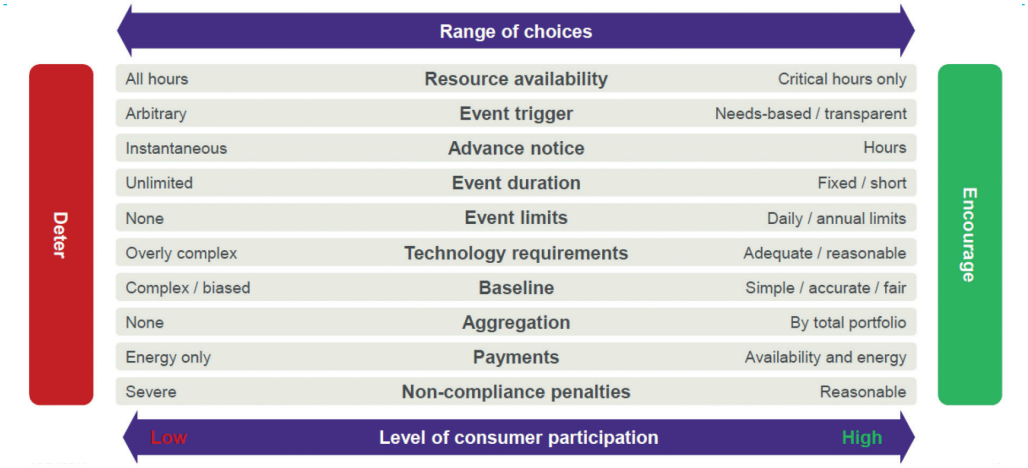
Improving short-term market operations

The future increase of PV and wind necessary to achieve the future decarbonization targets will require a strong overhaul of the short-term markets. Day-ahead, Intraday and balancing markets are being reorganized in order to allow a smooth transition from a system dominated by large dispatchable and centralized generators to a system in which variable RES (utility scale installations but also, and in particular, smaller decentralized units) will produce most of the needed electricity. This process of reform already started with the Third Energy Package, with the definition of the Network Codes, and it will be further developed with the entry into force of the Clean Energy Package.

An increased integration of the European Single Market for electricity will be beneficial to the penetration of additional variable energy sources in the European energy mix. In fact, larger markets spread on larger geographical areas better cope with the intrinsic variability of wind and solar sources, thanks to favorable statistic effects that could address shortages in one area with surplus in another one. This will require additional interconnectors and Europe, in this regard, has set ambitious targets to increase cross-border capacity: by 2030, every European Member State should have a cross-border capacity at least equal to the 15% of the installed capacity within its territory.

Harmonization of market rules is going into the direction of creating markets that are "fit for RES." This means that markets will have to accommodate the variability of RES and the reduced size of the average power plants by setting gate closure times closer to the real time andallowing aggregation in order to allow the participation of distributed resources (RES and DSM). RES will be able to provide services to the system, in particular downward reserve (remunerated curtailment of RES production) or downward and upward reserve when RES is coupled with storage devices. In addition, DSM will be able to provide contingency upward reserve. In order to do this, electricity markets should introduce products that have parameters that are in line with DSM capabilities, as shown in Figure 14. For example, products that require availability for all the hours disincentive DSM participation.

Figure 9 - Attributes that Facilitate DSM Participation



The overhaul of short-term energy markets, and in particular the increased value of dispatching services, allow the renovation of dispatchable power plants. In fact, with the development of new RES the residual demand, i.e. the difference between demand and generation from wind and PV, shrinks as shown in the figure below.

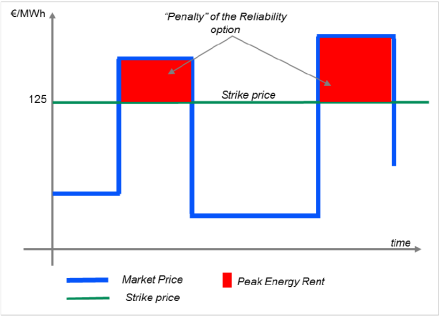
For this reason, Enel in the last 8 years has introduced a plan to refit its conventional fleet. Thanks to these investments, the minimum technical production has been reduced by 10%, its average start-up time has been reduced by 30%; its active power production gradient has been doubled; and its minimum production period has been reduced by 30%.

Energy-Only Markets vs Capacity Markets

The deployment of RES introduces questions on the need to introduce additional instruments to ensure security of supply. In other words, in Europe there is a strong debate whether capacity mechanisms are necessary or whether an energy-only market with time-variant scarcity pricing (based only on supply and demand) can provide sufficient incentives for the provision of spare capacity.

In the last few years, different Member States have introduced capacity remuneration mechanisms in their systems - in Italy, reliability options have been introduced recently.

Figure 10 - New Italian Capacity Market



- **Capacity market based on Reliability Options transforms peak energy rents** (energy sold at price above strike) **into a fixed, periodic instalment** (the result €/MW/year of the auction). Each time market prices are above strike price, capacity providers must pay the difference
- Capacity providers that are selected in the auction must **offer their capacity in energy and balancing markets**
- **First auction** will be likely held **1 year in advance**. In the **future**, auctions will be held **4 years** in advance
- **1-year delivery period**, in the future possible to have 3-year delivery period
- **New capacity will have 15-year delivery period**. Capacity is considered new whether its new investment is above **300 k€/MW**
- **Strike price** is indexed to the variable cost of an OCGT, now equal to **125 €/MWh**
- **Auction cap** for existing capacity between **25 and 45,000 €/MW;** between **75 and 95,000 €/MW** for new capacity
- Open to:
  - thermoelectric and large hydro with punitive derating (-15/20% and – 30/40% respectively)
  - incentivised renewables exiting their incentive schemes
  - demand that participate in the balancing market (pilot projects)
  - foreign capacity, ARERA must consult in the next day on the implementation

Centralised vs Decentralised Markets

In order to achieve the full decarbonization of the European economy, we will need a "democratization" of the energy revolution. Until recently, all the exchanges happened in centralized markets, where energy and services needed to keep the light on has been provided by big power plants. With the deployment of decentralized resources, i.e. DSR, wind, storage and PV, the need to exchange energy at local level increases. We are already living in a system where the average size of power plants is shrinking and the number of producers and prosumers is growing. In addition, electricity flows has changed from unidirectional (from big power plants to customers connected in distribution grids) to multidirectional (from big power plants to customers and storage devices, from prosumers to the grid).

The reform of the EU target model contained in the Clean Energy Package goes in this direction and introduces some new concepts such as demand response, self-consumption, renewable and local energy communities. In this sense, the new European framework requires Member States to develop framework to allow participation of new actors in the market on a level playing field. Such new actors, for instance independent aggregators, energy communities, will be playing a role in the energy transition by fostering new businesses models and new patterns of generation and consumption. These new actors will help the energy transition to succeed insofar they will bring forward clean power and advanced digital technologies.

With the development of the internet of things, customers are empowered to participate directly to the system. A prerequisite of this is the digitalization of the grid and the availability of interoperable communication technologies and open protocol communications.

The fourth industrial revolution, that will be underpinned by the development of ultrafast connectivity, 5G, machine-to-machine communication, artificial intelligence, will enable potentially every device to become a smart object, allowing energy companies and customers to monitor generation plants, power grids and appliances in an unprecedented way, leading the way to a new frontier of efficiency and decarbonization.

In this context, the grid managed by transmission and distribution operators still have a key role either in ensuring security of supply and in enabling and facilitating new markets and new businesses.

Distribution and transmission system operators will need to enhance their cooperation in order to grasp the maximum potential from distributed generation, ensuring security of supply and a reliable service to customers.In this context, the role of distribution system operators is even more crucial as the bulk of the democratization of the energy system occurs in low and medium voltage network.

Distribution system operators will play new roles in order to facilitate an efficient participation of distributed resources. In particular, distributed generation and other digital technologies could offer new approaches to perform the distribution activity. In order to incentivize DSOs to use new approaches, network regulation will evolve towards a new model, less based on traditional network expansion and more based on output based regulation, distributed resources become an important tool to optimize network planning (e.g. deferring investment in physical assets or increasing RES hosting capacity of grids).

The China case

by Wu Fan, Chen Dayu[5]

Latest Progress of China's Power Market Reform

Background to electricity reform in China

China has embarked on a prolonged progress of electricity reform since 1985, as outlined in Figure 1 and Table 1. It was not until 1985 that investment from multiple sources had been permitted into power generation industry to help alleviate shortages of electricity. From 1987 to 2002, separation of government functions from business activities had been performed in the power sector. Most of the assets of the power sector were transferred from the Ministry of Electricity to the newly formed State Power Corporation (SPC). The SPC owned approximately half of China's generation assets and almost all grid assets.

The most significant reform was the reorganization of the power sector in 2002 with the aim to break the institutional monopoly and introduce competition, improve overall efficiency. The reform disaggregated SPC's generation assets and grid assets into five generation companies (among which Huaneng was the biggest), two grid companies, and four power service companies. Two grid companies: State Grid Company (covering 26 provinces in China) and Southern Grid Company (covering 5 southern provinces) were in charge of transmission, distribution, system operation and retailing.

However, this reform stalled around 2007, generators continued to receive regulated prices for their power, network tariffs were not separately identified and all customers bought electricity from local grid companies. Thus power transmission/distribution/retail continued to be 100%vertically integrated and was totally controlled by two grid companies within their respective jurisdictions.

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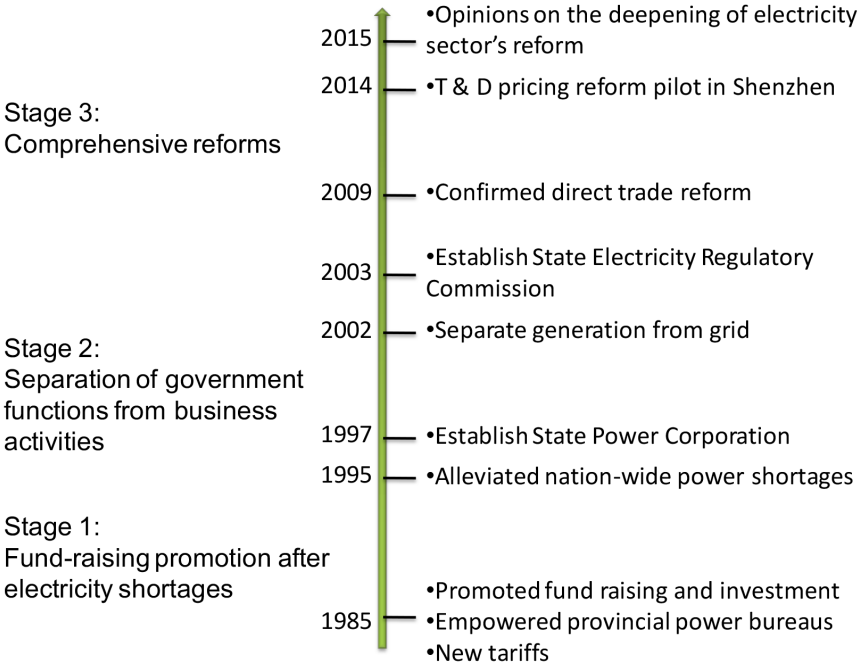
Table 1 - Reform timeline for electricity sector in China

	1980-1984	1985-2001	2002-2014	2015-Present
Industrial structure	Vertical integration	Vertical integration	Unbundled generation and transmission/ distribution (2002)	Unbundled generation and transmission/ distribution
Ownerships	Predominantly central government owned	Central and provincial government ownership Increase private investment in generation	Central and provincial government ownership. Decline share of private investment	Central and provincial government ownership Encourage private investment in generation, especially in renewable power generation (2015) Open distribution network investment to private capitals (2016)
Dispatch	Economic dispatch based on total embedded cost	Equal shares dispatch	Equal shares dispatch Pilot projects for energy efficient dispatch (2007)	Equal shares dispatch Energy efficient dispatch Pilots projects for clean-energy-priority dispatch (2016) Pilots projects for spot market based dispatch (2018)
Wholesale Generation Pricing	Internal transfer prices	Investment recovery based on financial lifetime (1985) Investment recovery based on operational lifetime (2001)	Benchmark price (2004) Fuel price-wholesale price co-movement (2004)	Benchmark price (2004) Revised fuel price-wholesale price co-movement (2016) Pricing through direct trading between generators and industrial customers (2015) Real-time pricing through spot market (2018)

Source: partly from Kahrl, F., Williams, J. H., & Hu, J. (2013). The political economy of electricity dispatch reform in China, Energy Policy, 53, 361-369.

Figure 11 - Reform timeline for electricity sector in China



Source: An, B., Lin, W., Zhou, A., & Zhou, W. (2015), China's Market-Oriented Reforms in the Energy and Environmental Sectors, Paper presented at the Pacific Energy Summit

The latest round of reform began in March 2015, promoted by the publication of the Central Committee and State Council No.9 Document (summarized in Table 2). This document proposes to establish a competitive wholesale and retail power markets especially for industrial customers and reinforcing scientific supervision of power transmission and distribution. In addition, social capitals are encouraged to invest in distribution networks and provide related services, thus breaking the monopoly of investment/construction/operation in power distribution which was exclusively belonged to grid companies before the reform.

Table 2 - Document No.9 of March 2015 and stated reform process

Key Policy Goals	Supporting Documents	Reform Process (mentioned in Document No.9)
Policy Goals No.1	Implementing Opinions on Document No. 9 Implementation Opinions on Promoting Transmission-Distribution Price Reform	Central Committee of CPC (Communist Party of China) and State Council of China issued the 'Opinions on Further Deepening Power Sector Reform' (Document No. 9) in March 2015. There are two main stages for this round of electricity reform in China. In the first stage (from March to June 2015), National Development and Reform Commission (NDRC) and other related governmental agencies announced five supporting documents. In the second stage (November 2015), NDRC and National Energy Administration (NEA) further issued another six supporting documents. These supporting documents provide the practical guidance for implementing the seven main policy goals set in the Document No.9, which cover the issues of electricity price, power trading system, wholesale side design, power grid and governmental supervision.
Policy Goal No.2 Reforming power trading systems and refining market-oriented trading systems	Notification of Perfecting Formation Mechanism of Trans-Provincial and Trans-Regional Power Trading Prices Implementation Opinions on Promoting Power Market Construction	
Policy Goal No.3 Reforming power generation, power utilization and the current market mechanisms	Notification of Perfecting Power Emergency Response Mechanism and Comprehensive City Pilots of Managing Power-Demand Side Implementation Opinions on Orderly Releasing Plans of Power Generation and Power Utilization	
Policy Goal No.4 Establishing independent electricity trading institutions and a fair and regulated trading platform	Implementation Opinions on Establishing Power Trading Institutions and Their Normative Operation	

Key Policy Goals	Supporting Documents	Reform Process (mentioned in Document No.9)
Policy Goal No.5 Steadily reforming power sales side and distribution	Implementation Opinions on Promoting Power-Sales Side Reform	Electricity ancillary services in China have long been provided by grid-connected power plants. Document No.9 changes this situation by establishing a new "shared responsibility" mechanism. This "shared responsibility, shared gains" mechanism improves the original compensation mechanism, and welcomes user participation in ancillary services by contracting with either generator companies or the grid. In March 2015, the supplement policy document - Guiding Opinions on Improving Electric Operation and Regulation to Promote Greater and Fuller Use of Clean Energy – was published, which aims to advance the ancillary services and promote renewable energy consumption at the same time.
Policy Goals No.6 Enhancing fair access to power grid and power transmission	Guidance Opinions on Improving Power Operation Adjustment to Facilitate Multiple and Full Development of Clean Energy Guidance Opinions on Reinforcing and Regulating Supervision and Management of Coal-Fired Self-Generation Power Plants	
Policy Goal No.7 Reinforcing electricity safety, scientific supervision and an integrated power planning system	Supervision and Examination Procedures for Pricing Costs of Power Transmission and Distribution (Trial)	

Source: Michael G. Pollitt, Chung-Han Yang, Hao Chen. (2017). Reforming the Chinese Electricity Supply Sector: Lessons from International Experience, Cambridge Working Paper in Economics.

It is important to acknowledge that the market economy has not been developed for a long time in China, especially in the electricity sector where planned generation and utilization, administrative pricing and monopoly for the power purchase and retail still exist. Therefore, a Pilots-First & Step-by-Step strategy is adopted in the reform. By 2018, pilots covering electricity price reform, power trading systems, wholesale side design as well as power grid and governmental supervision have been launched at the provincial level all over the country.

With the development of the reform pilots, problems arise and disputes over the problem exist, efforts and compromises have been made by each party in order to solve the problem and continue to promote reform pilots.

Efforts on establishing independent power trading institutions have been intensified

By the end of 2018, power trading institutions have been established in all provinces of the country. Besides, two regional power trading institutions (Beijing and Guangzhou Power Trading Institution)- responsible for the operation and regulation of trans-regional and trans-provincial power market within their respective jurisdictions have also been established.

Most established provincial power trading institutions originated from former trading departments of provincial grid companies. At the end of 2018, three-fourths of the provincial trading institutions are wholly owned subsidiaries of provincial grid companies, and shares of the other one-fourth of the provincial power trading institutions are mainly controlled by the provincial grid companies (over 80% share ratio).

In order to enhance the independent operation of power trading institutions, at the end of August 2018, NDRC and NEA, China's main government departments in charge of power market reform, jointly issued the "Notice on Promoting the Standardization Construction of Power Trading Institutions" which requires shareholding reform of power trading institutions in accordance with the principle of diversification and counterbalancing.

According to the notice, the share of grid companies in power trading institution should not exceed 80%, and the share of non-grid companies is encouraged to reach 50%. At present, this work has been pushed forward.

The coverage of transmission-distribution price reform has been expanded to regional power grids

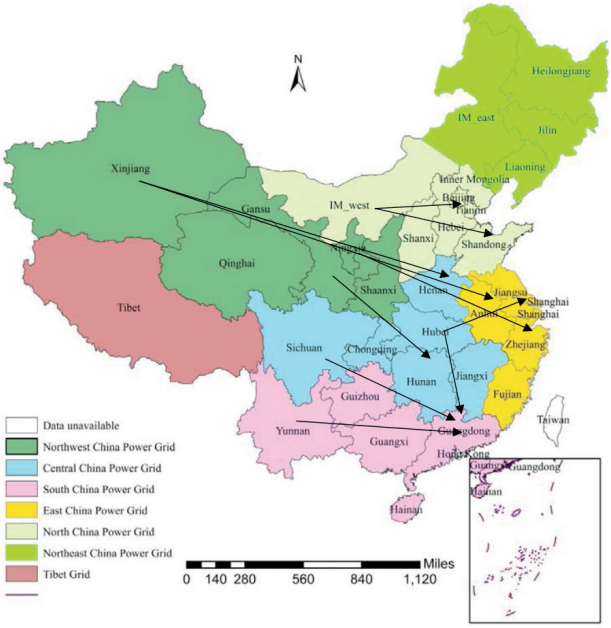
Establishing a separate transmission and distribution tariff is a crucial issue for the ongoing round of power sector reform. The transmission and distribution tariff should be clarified based on "allowable cost plus reasonable profit" according to Document No. 9.

After the completion of full coverage of power transmission-distribution price reform at the provincial level in 2017, transmission prices of five regional power grids (North China, Northeast China, East China, Central China and Northwest China) as well as 24 trans-provincial and trans-regional power transmission lines have been recalculated and identified in 2018.

Figure 12 - Regional and provincial grid control areas in China

Source: Wang, Q., & Chen, X. 2012. China's electricity market-oriented reform: From an absolute to a relative monopoly, Energy Policy, 51, 143-148

Figure 13 - Transmission prices of 24 trans-provincial and trans-regional lines have been reduced



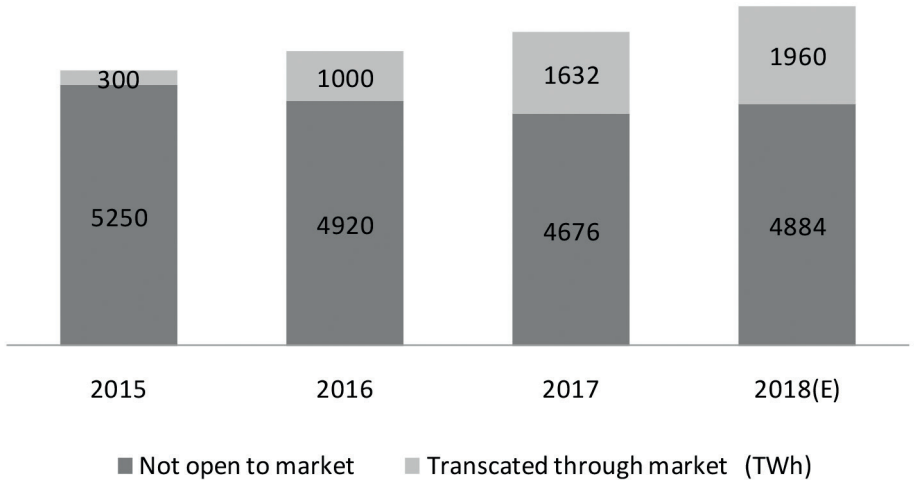
Based on the identified power transmission prices in 2018, the permitted revenue of power grid companies has been reduced by about CNY (Chinese Yuan) 60 billion, and the electricity prices for general industrial and commercial end users have been reduced by 10% compared with last year.

Releasing of power generation and utilization plans has been accelerated

Currently, market-based generation and administrative generation plans coexist in China, while the former's share is growing significantly.

By the end of 2018, the quantity of direct trade (electricity transacted directly between the power producer and consumer) has reached 1.5 trillion kWh which accounts for 22% of the total electricity consumption, increased by 20% compared with last year. The quantity of electricity transacted through market has reached approximately 2 trillion kWh, nearly 30% of the total electricity consumption.

Figure 14 - Market transaction ratio keeps rising since the reform began in 2015



However, as China does not have short-term markets but does have a benchmark pricing system with a regulated on-grid price and retail price, the trading price does not include the time and location value of power and is always lower than the regulated price. Therefore, market trading has become a method for provincial governments to lower costs for their local industries.

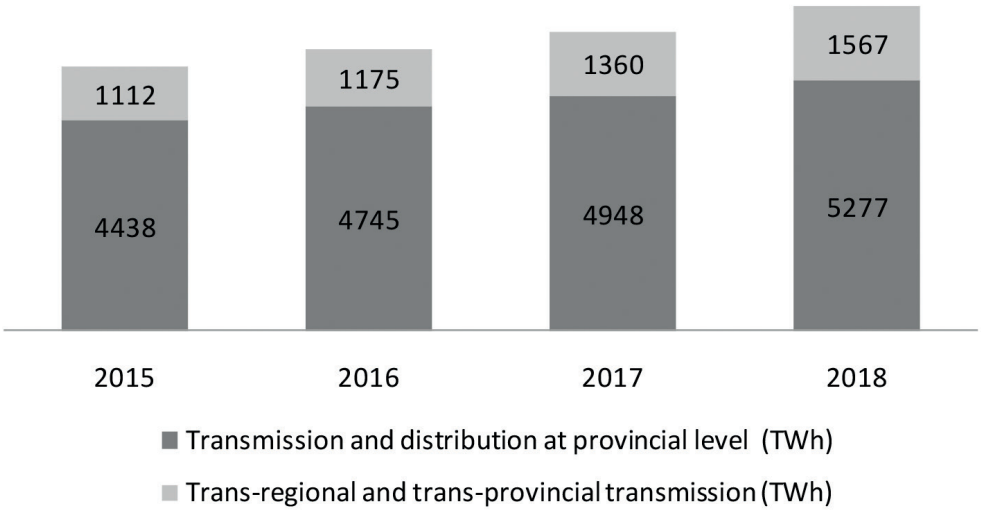
In July 2018, NDRC and NEA jointly issued the "Notice on Actively Promoting Power Trading and Further Perfecting the Transaction Mechanism" which clearly requires that the coverage of direct trade should be expanded. Since then, the power utilization plans for four large industrial users (coal industrial users, steel industrial users, non-ferrous metals industrial users and building materials industrial users) have been cancelled. These four industrial users have to purchase all the electricity through market. It is estimated that from July to December 2018, the increment of direct trade transaction within these four industries had exceeded 100 billion kWh.

Trans-regional and trans-provincial power trading has been increasingly emphasized

In China, energy sources like coal, wind, hydro etc., are significantly located in the north and west, a long way from the demand center in east and south. Trans-regional and trans-provincial power trading has been encouraged by the government to contribute to the consumption of conventional and renewable power in the west as well as the reduction of coal transportation/consumption to/in the east. Additionally, power generation rights transfer trading between coal-fired plants in the east and renewable power plants in the west has also been encouraged.

In the second half of 2018, Beijing and Guangdong Power Trading Institutions have respectively published trans-regional and trans-provincial power trading rules within their respective jurisdictions. Meanwhile, "Nationally Integrated Power Market Scheme" has been drafted. NDRC and NEA are trying to promote the construction of an integrated power market across the country. In 2018, the quantity of electricity transacted through trans-regional and trans-provincial power trading has reached 1.1 trillion kWh, increased by 11% compared with last year.

Figure 15 - Trans-regional and trans-provincial transmission has been promoted by power trading



Pilot projects of power distribution reform have been launched in each city

The competition has also been introduced on the power distribution side. From 2016 to 2018, three batches of pilot projects for constructing and operating incremental power distribution networks (distinguish from existing ones wholly owned by the power grid companies) have been launched and open to social investment. The total 320 projects were allocated across the country in such a way that each city has at least one pilot project.

The power distribution reform has affected the vested interests of grid companies, consequently encountering resistances. At the end of 2018, more than half of the pilot projects have not started yet.

Facing resistances, the government pushes the reform forward resolutely. In January 2019, NDRC and NEA jointly issued the "Notice on Further Promoting Power Distribution Reform" which offers guidelines to resolve problems that currently hinder the progress of pilots. These problems in-

clude how to deal with existing assets wholly owned by grid companies in the pilot area; how grid companies charge incremental power distribution networks for connecting to the grid, etc.

The development of spot market has been promoted steadily despite of disputes

In August 2018, power spot market in Guangdong (one of the 8 pilot spot markets set up by the government in 2017) has started its trial operation. This indicates an important step in the process of power market construction and forming electric price signals through market transactions in China.

However, disputes arise during the development of spot market. The disputes involve the choice of an applicable spot market model, the boundary between provincial and trans-provincial spot market (i.e. a clear definition of trading scope of spot markets at two different levels. This boils down to drawing the authority boundary between the provincial power trading institution and regional power trading institution for spot market implementation and regulation), the coupling between long term market transactions and spot market transactions (i.e. the physical settlement of long term transactions in the spot market) and the segregation of duties between power dispatching and trading.

In November 2018, NEA issued the "Notice on Improving and Perfecting the Pilot Operation Mechanism for Spot Markets" which requires that all 8 pilot spot markets should start the trial operation before the end of June 2019. NEA has also set up 8 inspectorate groups to establish a one-to-one linkage with 8 pilot spot markets to keep track of their progress.

Power Market Designs for Energy Transition in China

The Chinese government adheres to the parallel development of economy and improvement of environment, and actively promotes the revolution of energy production and consumption to construct a clean, low-carbon, safe and efficient energy system. In recent years, the installed capacity and electricity generation of renewable power as well as the shares with respect to the total installed capacity and electricity generation in China has been growing steadily.

Figure 16 - Installed capacities of total generation and renewable power in China

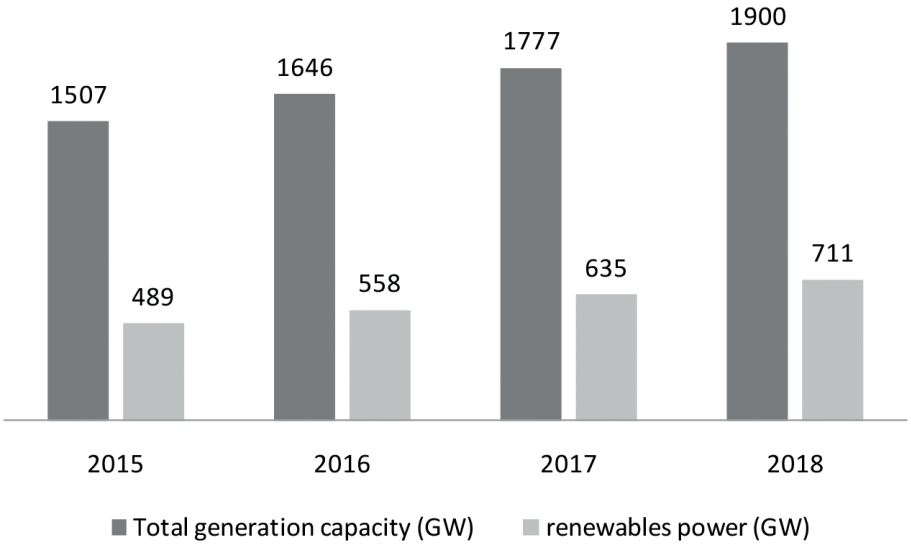
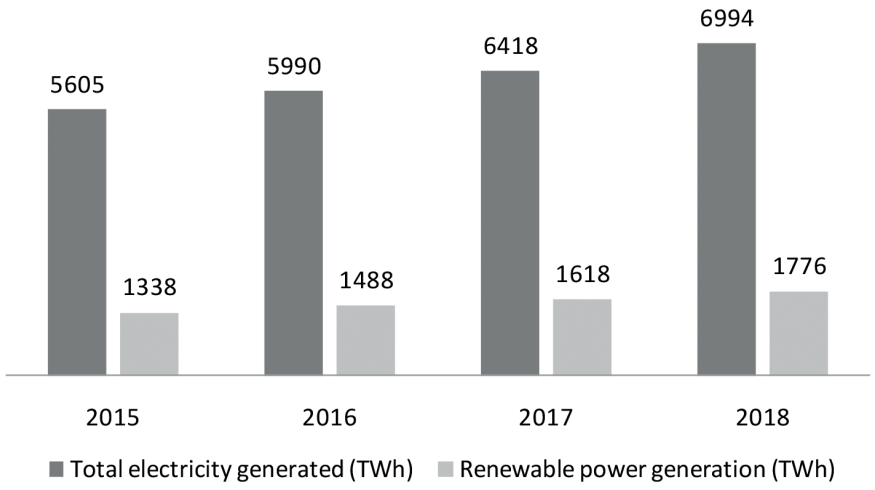


Figure 17 - Total electricity generation and renewable power generation in China



Integrated energy suppliers in China, like Huaneng Group, have shifted their investment priorities to the renewable and clean energy.

Figure 18 - Installed capacities of total generation and renewable power of Huaneng Group

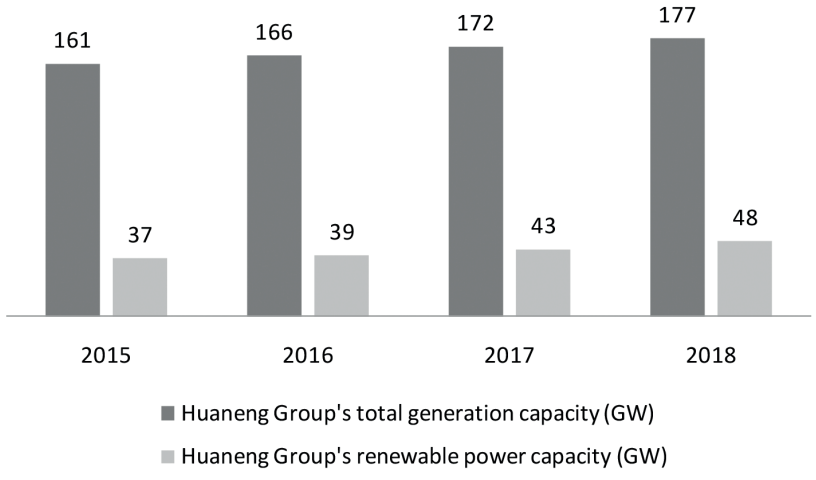
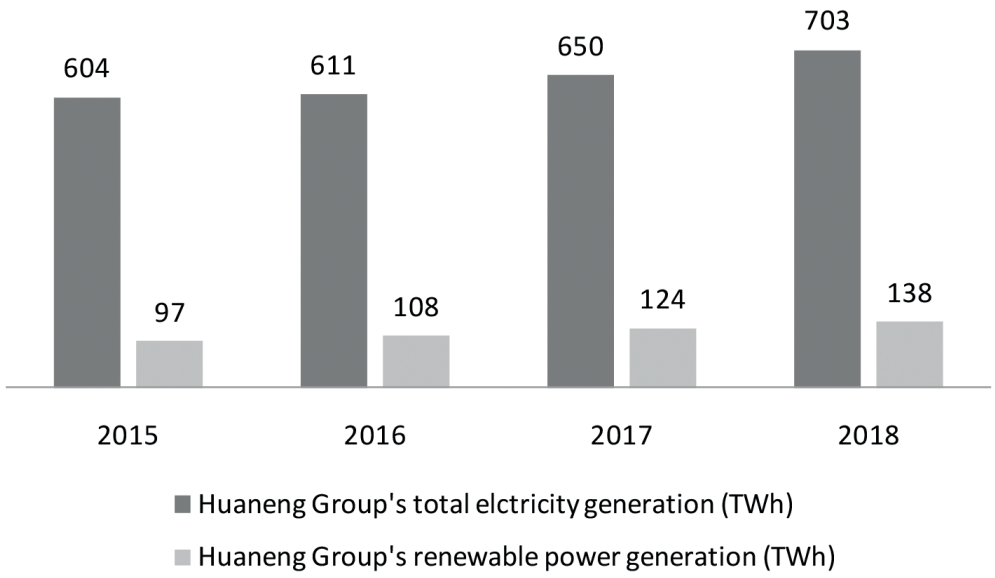


Figure 19 - Total electricity generation and renewable power generation of Huaneng Group

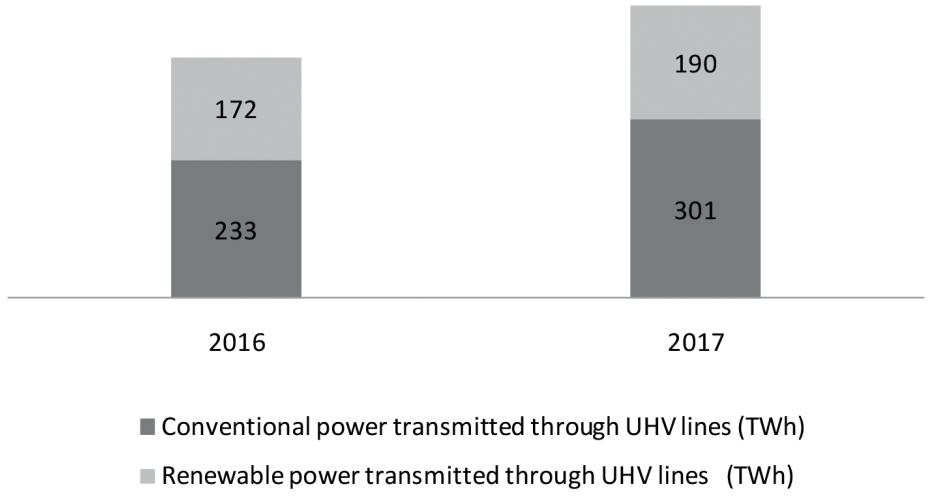


Promoting the electricity consumption of renewable energy is one of the main goals of the power market reform in China.

Emphasis has been placed on trans-regional and trans-provincial transmission for renewable energy

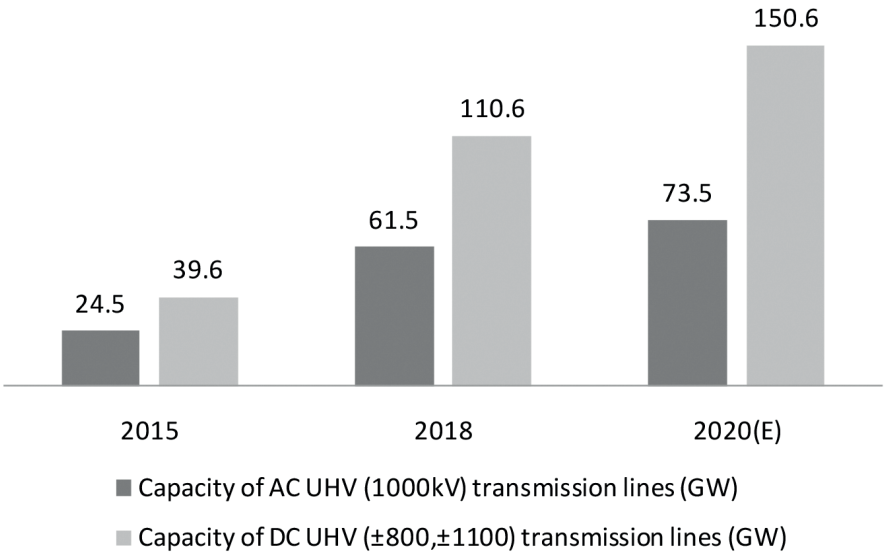
At present in China, the main obstacle for renewable energy to participate in trans-provincial and trans-regional power trading is the inadequate transmission capacity. One reason is that the investment in transmission lines construction has been lagging behind the rapid development of renewable energy, and the other reason is that a portion of the capacity of existing transmission lines has been occupied by conventional power (there's also abundant coal resources thus coal-fired power generation in West China).

Figure 20 - Conventional power transmission increases faster than renewable power transmission



In October 2018, NDRC and NEA jointly issued the "Notice on the Accelerating the Planning and Construction of a Batch of Key Power Transmission and Transfer Projects" which announces that from 2018 to 2020, 7 UHV (ultra high voltage) power transmission lines will be designed and approved to start construction. Specifically, 5 DC UHV lines (±800 kV) will be designed to promote renewable power transmission from West China to East China.

Figure 21 - Capacities of AC and DC UHV transmission lines put into operation



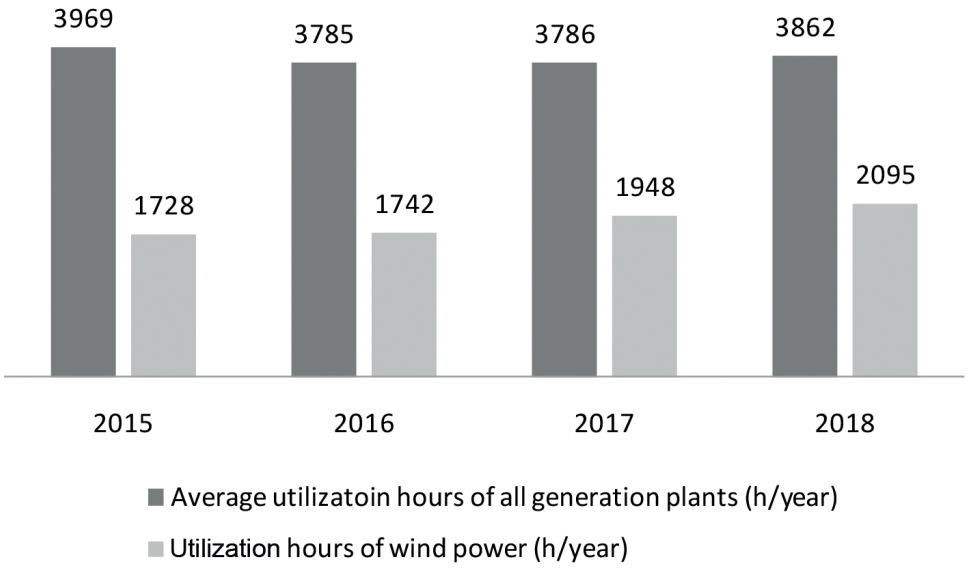
Generation right trading has been intensified to increase the consumption of renewable energy

Power generation right trade allows generation rights to be transferred from fossil fuel power plants to non-fossil fuel power plants; from coal-fired power plants with low energy efficiency and high emission to coal-fired power plants with high energy efficiency and low emission.

In 2017, the quantity of power generation right has reached 152.77 billion kWh, rising by 25% compared with the previous year, accounting for 2.4% of the total electricity consumption.

In 2018, the government encouraged trans-regional power generation right trade. In May 2018, Jiangsu Province in East China traded part of the generation rights of local coal-fired power plants to wind power plants in Gansu Province and Xinjiang Autonomous Region in Northwest China. The coal-fired power plants which sold the generation right could make a profit of CNY 0.04 per kWh. The wind power plants that purchased the generation right could make a profit of CNY 0.33 per kWh if the subsidies of renewable energy power generation were counted in.

Figure 22 - Utilization hours of wind power keeps increasing in recent years



Ancillary service market has been created to support real time balancing

For a long time, China's coal based power generation structure has minimized the need for ancillary service market. There are some payments to generators who must run for system support (voltage support or reactive power), however, there is, in general, no formal payment mechanism for ancillary services.

In recent years, the overall capacity of power supply has surpassed the overall power demand in China. At the same time, the curtailment of wind power, solar power and hydropower, as well as real-power balancing have become more and more serious. Currently, China has actively explored the ancillary service markets.

Establish compensation mechanism for ancillary services (2018-2020)

NEA has issued "Work Program for Improving Compensation (Market) Mechanism for Ancillary Services" which clarifies the general idea, basic principles, main objectives and main tasks of the next step to improve the compensation mechanism for ancillary services.

Launch reform pilots of the ancillary service markets

Based on situation in various areas, 10 reform pilots of ancillary service markets located in Northeast China (with a high proportion of combined heat power generation), East China (with large peak-valley difference at demand side) and Northwest China (with wind power curtailment) have been launched.

Electric energy storage is encouraged to participate in ancillary service compensation

Electric energy storage is encouraged to participate in the pilot projects of ancillary service market in Northwest China, North China, and Northeast China.

Table 3 Ancillary service pilots in different areas

Area	AGC	Paid real-power balancing	Remarks
Northeast China		√	Including real-power balancing, capacity reserve for thermal power outage, interruptible load peak regulation, real-power balancing using electric energy storage, emergency start, real-power balancing for thermal power, trans-provincial real-power balancing and other transactions
Fujian Province		√	Including real-power balancing, emergency start/stop, demand side real-power balancing, interruptible load peak regulation, real-power balancing using electric energy storage
Shanxi Province	√	√	Including frequency regulation and real-power balancing market transactions. The implementation of paid reactive power regulation and black start is carried out in accordance with the Two Rules (1. Implementation rules of ancillary service management for grid connected power plants. 2. Implementation rules of operation management for grid connected power plants.)
Xinjiang Autonomous Region		√	Including real-power balancing, regulation of interruptible load, real-power balancing using electric energy storage and other transactions
Shan dong Province	√	√	Including paid real-power balancing and AGC transactions
Ningxia Autonomous Region		√	Including real-power balancing, regulation of interruptible load, real-power balancing using electric energy storage and other transactions
Guangdong Province	√		Frequency regulation transactions aiming at adjusting excess frequency regulation resources
Gansu Province		√	Including real-power balancing, regulation of interruptible load, real-power balancing using electric energy storage and other transactions
Northern China	√	√	Including North China power grid real-power balancing market transactions and Beijing-Tianjin-Tangshan power grid frequency regulation market transactions
East China		√	Including medium and long term bilateral replacement, day-ahead ancillary service market for real-power balancing, intraday real time dispatching for real-power balancing and emergency intervention

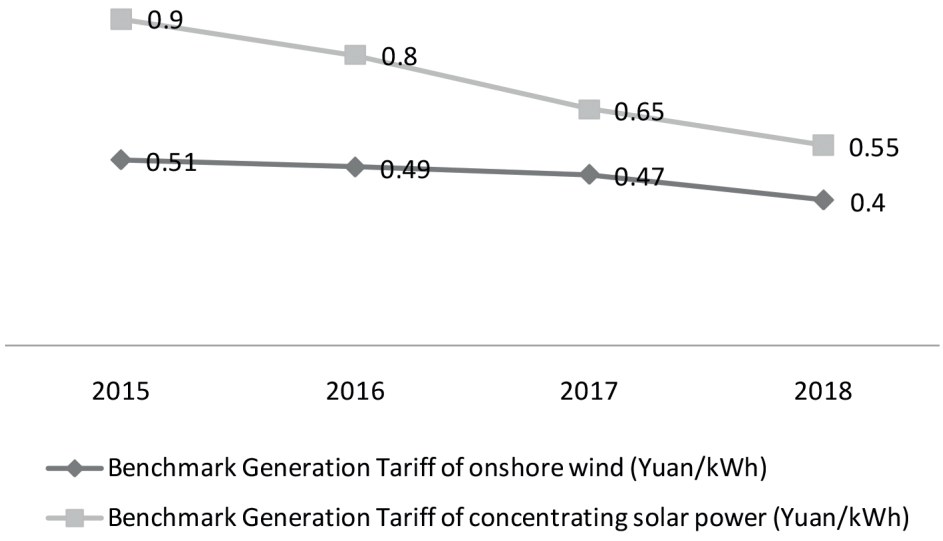
Spot market has played an important role in promoting renewable energy consumption

Due to the characteristics of short trading cycle and high trading frequency in the spot market, renewable energy power's intermittence and instability is relatively weakened. Besides, the variable cost of renewable energy power is often lower than that of conventional power generation. Thus it is advantageous for renewable energy power to compete in the spot market.

In addition, the spot market can provide effective and accurate data which is of great assistance in guiding the investment of power supply and power networks. Therefore, the Chinese government takes the development of the power spot market as an important measure to promote the electricity consumption of renewable energy.

In recent 4 years, the Benchmark Generation Tariffs (including subsidies) set by the government for onshore wind power and concentrating solar power have been decreasing continuously, which aim to alleviate the pressure of renewables' subsidies on finance, and meanwhile, force the industry to reduce generation cost thus enhancing the competitiveness of renewable power generation in the spot market.

Figure 23 - Benchmark Generation Tariffs of wind and solar power decrease



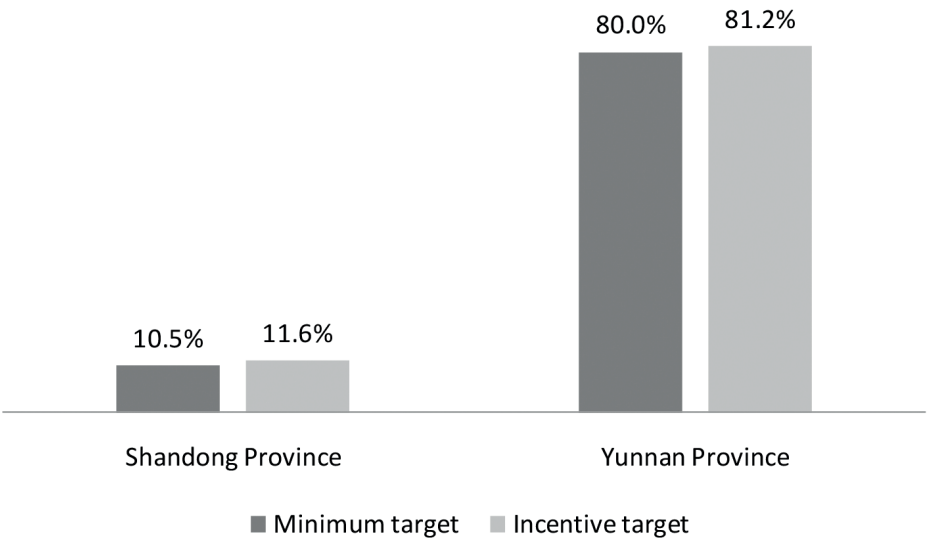
Considering the inverse distribution of renewable resources endowment and demand centers in China, tie-line spot trading has been conducted first to relieve wind power and solar power curtailment in Northwest China. By the end of 2017, 6 billion kWh surplus (after meeting local demand) renewable generations had been traded on the tie-line spot market across China. Gansu Province, with abundant wind and solar resources, was the largest provider in the renewable tie-line spot market, selling 2.35 billion kWh in the first half of 2018.

To support tie-line spot trading, UHV transmission lines which transmit renewable energy exclusively are under construction. The world first DC UHV renewable energy power transmission line starts from China's Qinghai Province which possesses a capacity of 21440 MW of renewable energy power plants, to China's Henan Province. This transmission line is 1587 km long, ±800 kV with the capacity of 8000 MW, and is expected to run in 2020.

Green energy certificate trading will start at the beginning of 2019

In November 2018, NEA issued the "Notice on Implementation of the Renewable Portfolio Standard (Draft for advice)". According to this edition of draft (also the third round of advice seeking in 2018), from the beginning of 2019, both minimum and incentive targets (the ratio of electricity consumption of renewable energy with respect to the total electricity consumption) will be set at each province. For example, the targets in Yunnan Province which is endowed with abundant hydropower are set around 80%, while the targets in Shandong Province which is equipped with abundant thermal power plants are set around 10%.

Figure 24 - Different RPS targets set at different provinces



The provincial government will allocate the target among obligators in the province. Obligators involve power sales companies (include power grid companies that directly supply power to users), electricity users who purchase electricity through the wholesale market and enterprises that possess non-utility power plants.

Meanwhile, a trading system of green energy certificates will be introduced to identify the quantity of the electricity generated/consumed from the renewable energy. In case that the obligator of Renewable Portfolio Standard fails to meet the minimum target, he can buy green certificates through the trading system to complement the difference, while the obligator who can exceed the minimum target or even achieve the incentive target, he may sell the green certificates through the trading system to gain profits.

Case Studies of Provincial Level Power Market Reform in China

So far, Zhejiang province (located at the east coast of China) and Guangdong Province (located at the southeast coast of China) has been two pioneers in provincial level market construction and activists in the market reform experiments.

Power market reform in Guangdong

"Scheduled dispatch + whole energy competition" is adopted in the spot market.

In Guangdong, about 70% of the local power generation plants, mainly coal-fired plants and gas-fired plants, are categorized as Class-B plants. The other 30% power generation plants consisting of nuclear power plants, hydropower plants, and water-pumping as well as energy-storage power stations are categorized as Class-A plants.

Class-B plants have to compete for their whole electricity through the spot market, while Class-A plants do not need to take part in electricity bidding and are dispatched according to the generation plan scheduled by the provincial government.

The scheduled generation plan is then decomposed into daily operation curve for each Class-A plant according to certain principles. Taking equal share dispatching principle as an example, power plants of a similar vintage are allocated an equal number of annual running hours per year and are dispatched on a daily basis in line with the need to achieve an equal number of total running hours.

"Scheduled dispatch + bilateral transaction" remains in the medium and long term power market.

Like in the spot market, Class-A plants do not need to compete for the medium and long term power generation through the market, while Class-B plants sign Contracts for Difference (CfDs) with customers for the medium and long term power trading. The power trading institution is responsible for the transactions.

In 2018, according to the guidance of the provincial government, the quantity of electricity transacted through the power market, whether through the spot market or the medium and long term market, would exceed 160 billion kWh, about 25% of the total quantity of electricity consumed in Guangdong.

Local marginal prices are adopted on the power generation side.

The problem of network congestion in Guangdong is more serious than in other provinces, therefore, location marginal prices (LMP) calculation is adopted on the power generation side.

Marketization is introduced in frequency regulation ancillary services.

Automatic generation control (AGC) is implemented in a market oriented way, but without the consideration of joint optimization with electricity generation. The service of real-power balancing and the way of payment remain the same as before.

For the first time in Guangdong, power consumers start to pay for AGC services. This is a significant progress which indicates the end of the situation that the ancillary service payments have always been paid by generators.

The capacity market or compensation mechanism is missing.

Usually, a "price cap" or capacity market is introduced to compensate for the long term reliability capacity value provided by certain power plants to maintain the long term adequacy of generation capacity. However, this kind of compensation mechanism is missing at the present stage in Guangdong's power market.

Power market reform in Zhejiang

"Day ahead + intraday" full power pool mode is adopted in the spot market.

In Zhejiang, all electricity (electricity generated locally and transmitted from outside) has to bid in the power pool at marginal prices. As for electricity transmitted from outside the province, the result of clearing in the day-ahead power pool takes effect. As for electricity generated locally, the result of clearing in the day-ahead power pool only acts as a pre-cleared price, and the final clearing price is form in the intraday real time balancing power market which consists of 48 price signals or more at different times per day (every 30 minutes or more dense).

Entities in the spot market include electricity producers (local coal-fired power plants, hydropower plants, nuclear power plants, and power transmitted from outside), transmission and distribution operators (grid companies) and electricity users that connect directly to an 110kV or higher voltage level network (except residential electricity users, utility electricity

users and welfare service electricity users). Electricity users that connect directly to a 35kV or higher voltage level network would be allowed to participate in spot trading in the near future.

"Authorized contract + bilateral contracts" is adopted in the medium and long term power market.

In the medium and long term power market, there are two types of contracts: government authorized contracts (price regulated and approved by the government) and bilateral contracts (price negotiated between two parties). All contracts in essence are CfDs with time scale and can be settled only in cash. The settlement of contracts imposes no impaction on the operation of the power grid.

According to the guidance of the provincial government, more than 60% of the electricity generated locally would be traded through the power market up until 2020, whether it is in the spot market or the long term market.

Zonal pricing mechanism is adopted on the power generation side.

Robust as the power grid in Zhejiang is, due to the influence of UHV power transmission, cross sectional congestion happens from time to time. Therefore, zonal pricing mechanism is adopted on the power generation side, while a unified price is adopted on the electricity users' side across the whole province.

Ancillary services consist of frequency regulation and capacity compensation.

It is initially set that price of AGC and reserve capacity is coupled with spot market trading.

The capacity compensation is realized by allocating a high proportion of government authorized contracts.

At the current stage, the ratio of two types of CfDs in the medium and long term market (government authorized contracts vs. bilateral contracts) is set as 9:1. That is, 90% of the medium and long term contracts are signed with fixed prices which are identified and regulated by the government. Usually, the identified prices can cover the generation cost and are acceptable by the generation side.

The high proportion of government authorized contracts in the medium and long term market can be seen as an alternative way to the compensation for the long term reliability capacity value to maintain the adequacy of generation capacity.

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