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A Brief Introduction of Wind Energy Development in China

State Grid Energy Research Institute

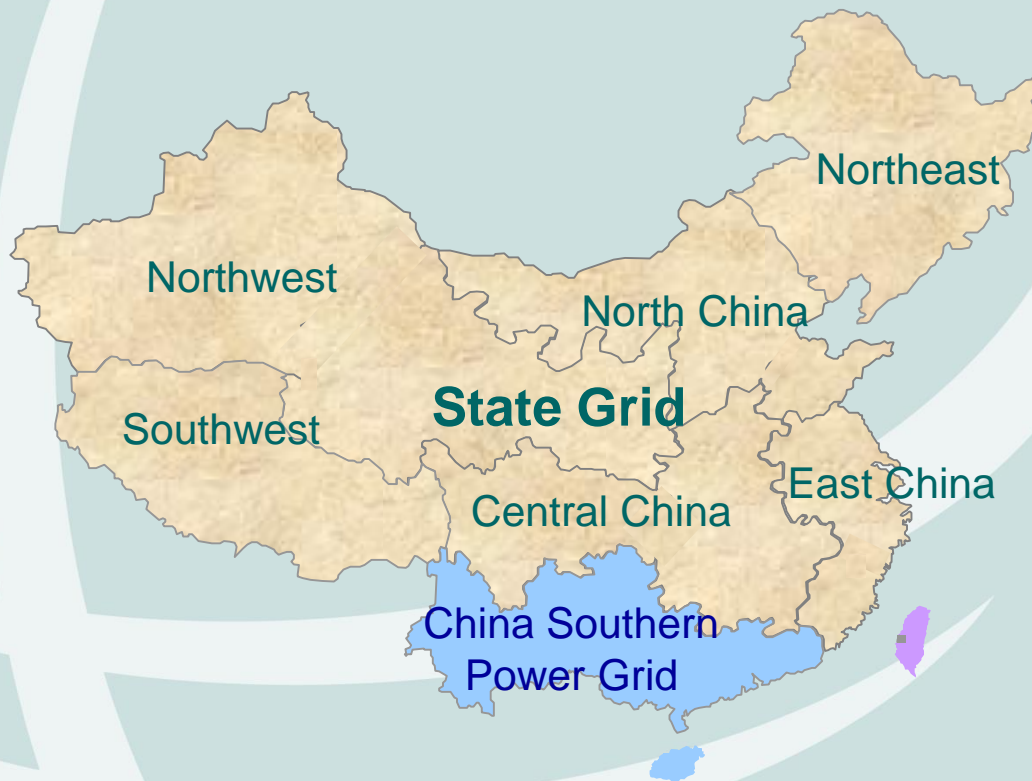
2018.1.25



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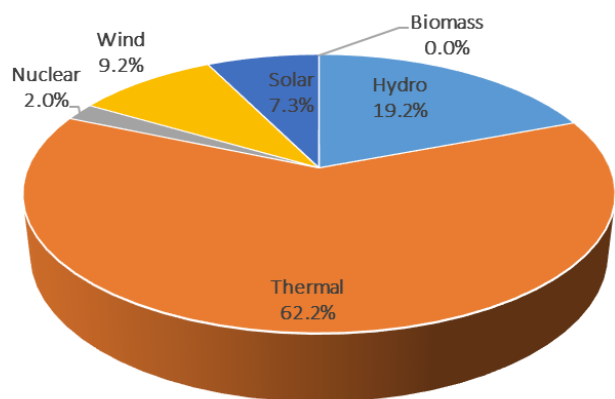
Outline

- 1. Current Status of Wind Development in China**
- 2. RE Policies and RE Planning in China**
- 3. RE Integration Issues in China**
- 4. RE Future and Practices to Facilitate RE Integration in China**

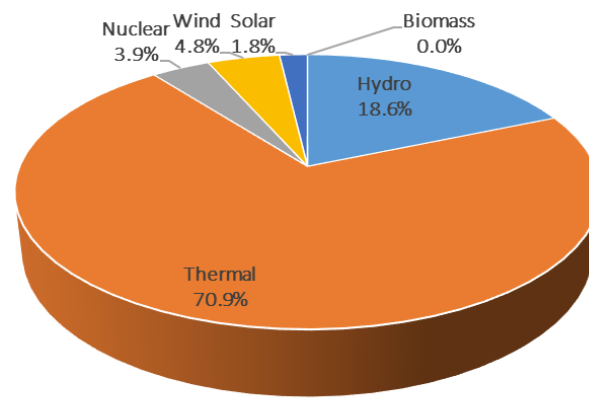


RE Development : Capacity and Energy

- Installed capacity of wind and solar generation: 293.93 GW (by the end of 2017)
- Capacity share: 16.5%
- Energy from wind and solar: 423.8TWh (2017)
- Energy share:6.6%



Generation Capacity Structure in China in 2017

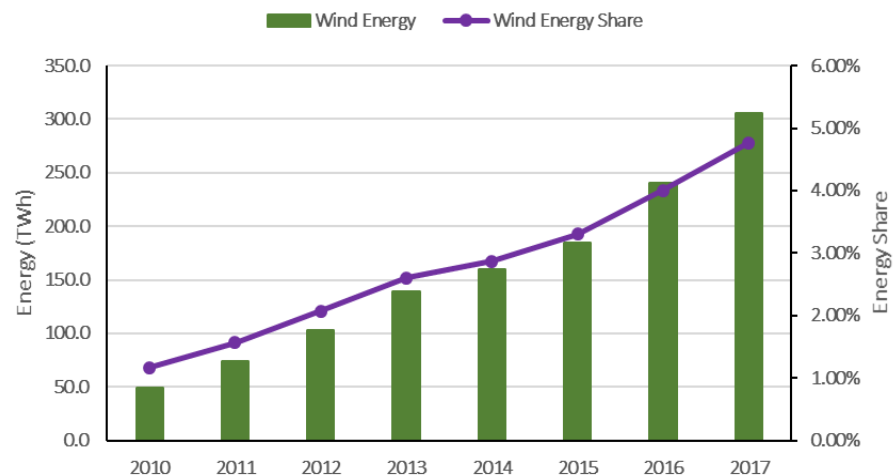
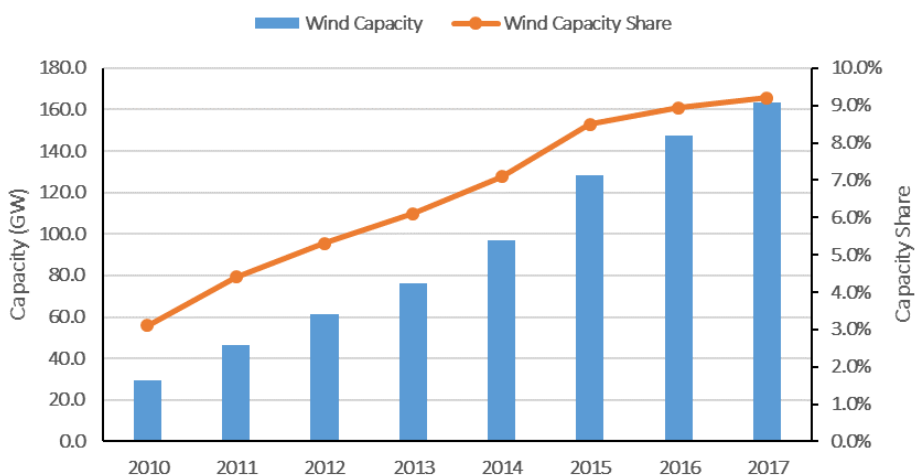


Generated Energy from each type of generation in 2017



RE Development : Wind

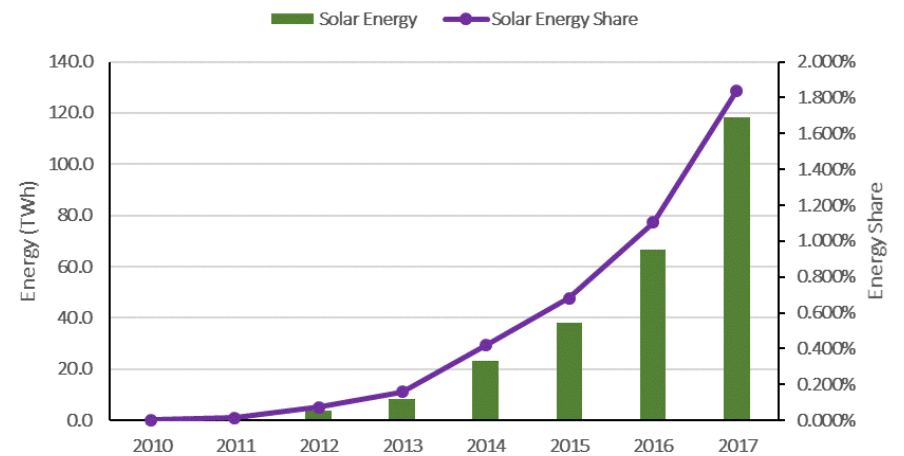
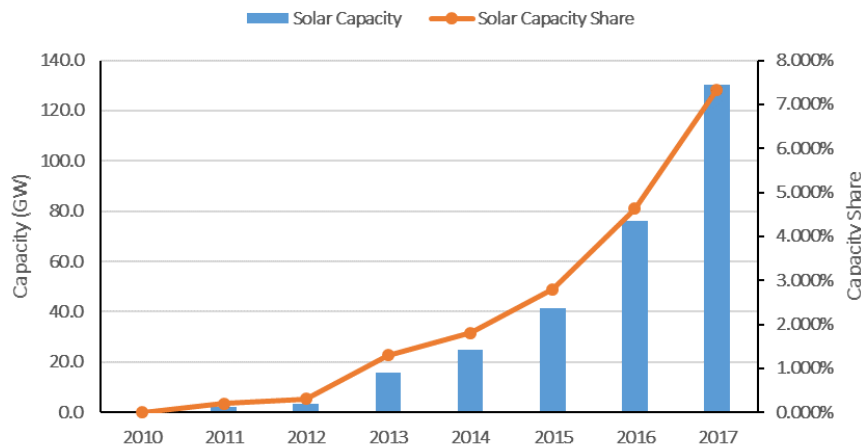
- Installed capacity of wind : 163.67 GW (by the end of 2017)
- Capacity share: 9.2%
- Energy from wind: 305.7 TWh (2017)
- Energy share:4.8%





RE Development : Solar

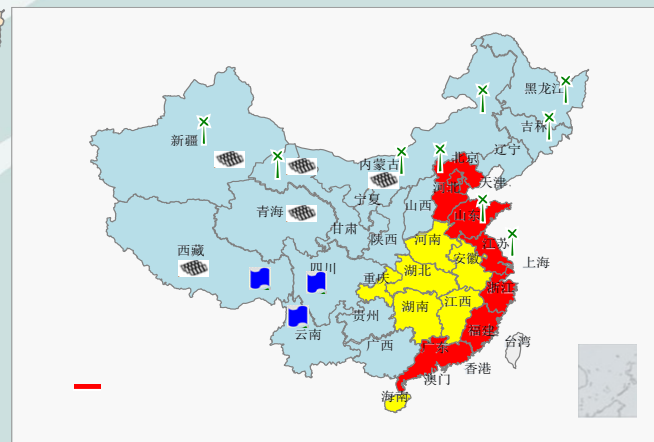
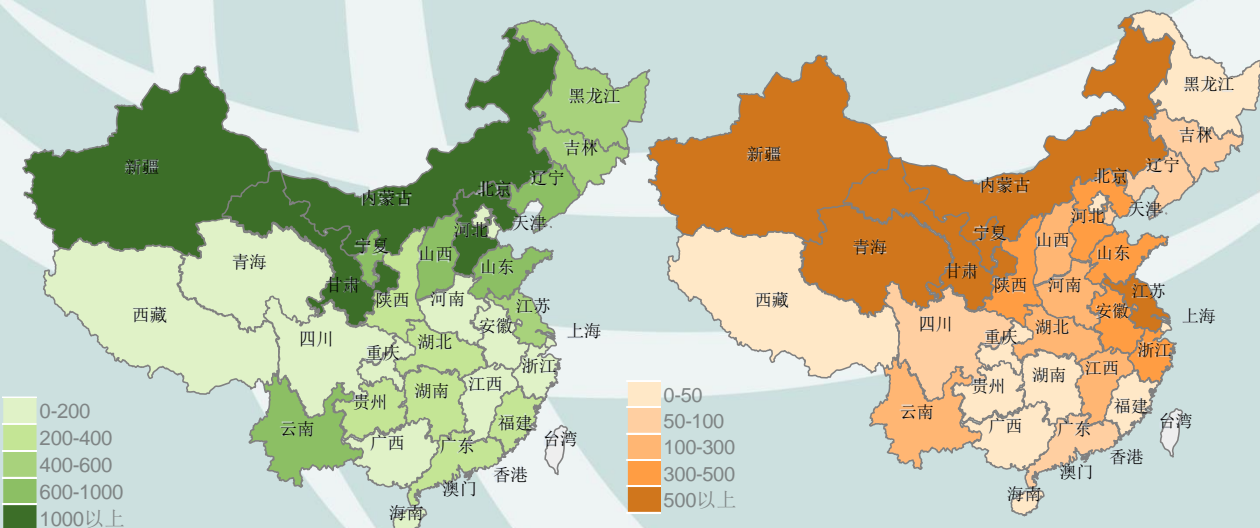
- Installed capacity of solar : 130.27 GW (by the end of 2017)
- Capacity share: 7.3%
- Energy from wind: 118.2 TWh (2017)
- Energy share:1.8%





RE Development : Characteristic

- Concentrated in the “Three North” regions: North China, Northeast China, and Northwest China, ~70% of the total capacity.
- Far from the load centers: Mainly in the central and eastern regions, ~65% of the total electricity consumption in China.



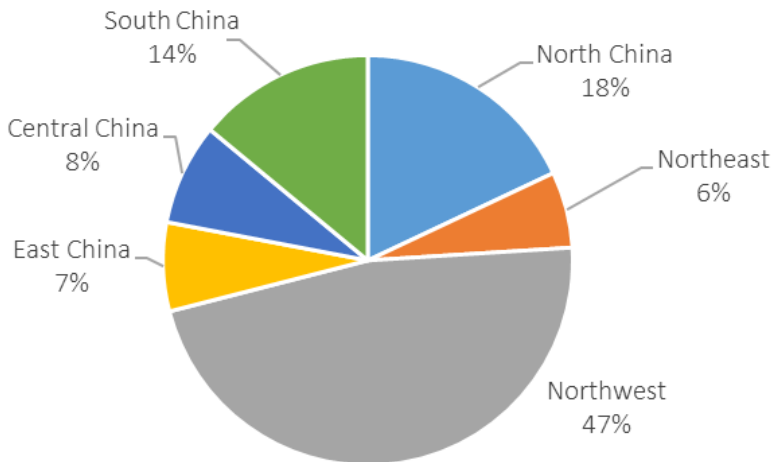
Distribution of Wind Resource in China

Distribution of Solar Resource in China

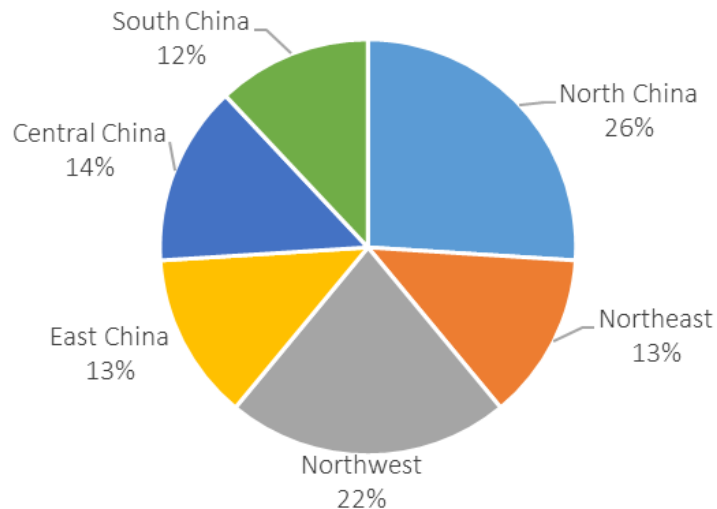
Distribution of Electric Load in China



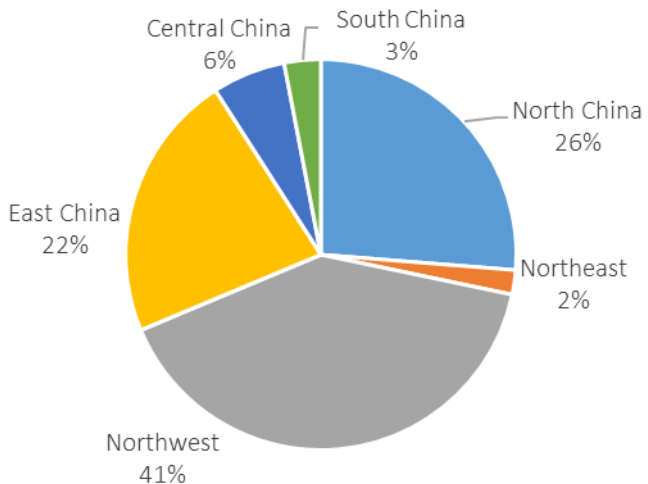
Distribution of Newly Installed Wind Capacity in 2015



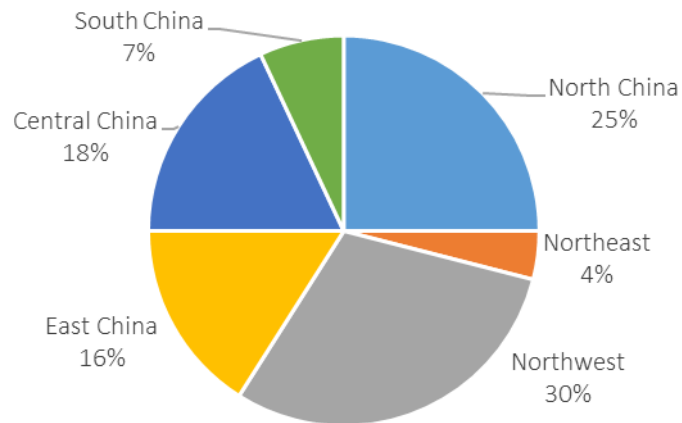
Distribution of Newly Installed Wind Capacity in 2016



Distribution of Newly Installed Solar Capacity in 2015

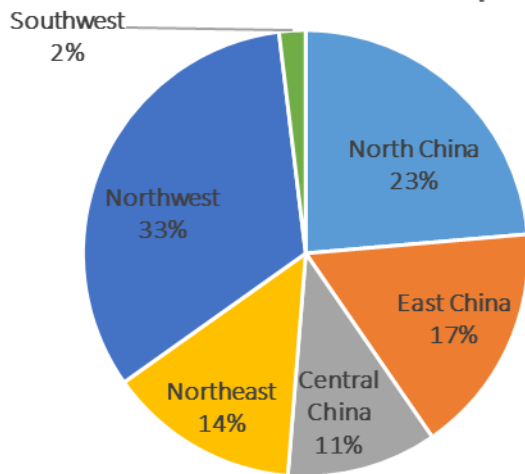


Distribution of Newly Installed Solar Capacity in 2016

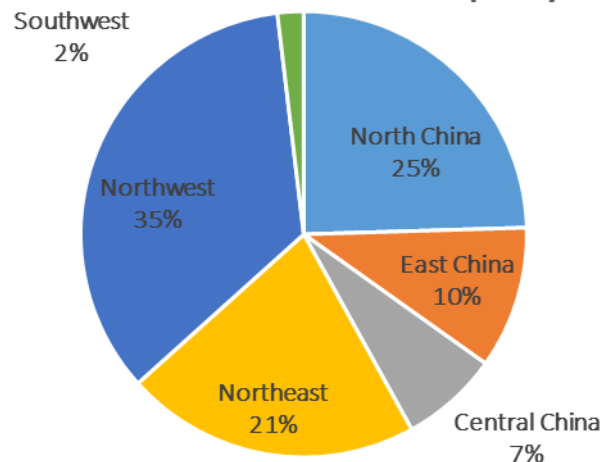




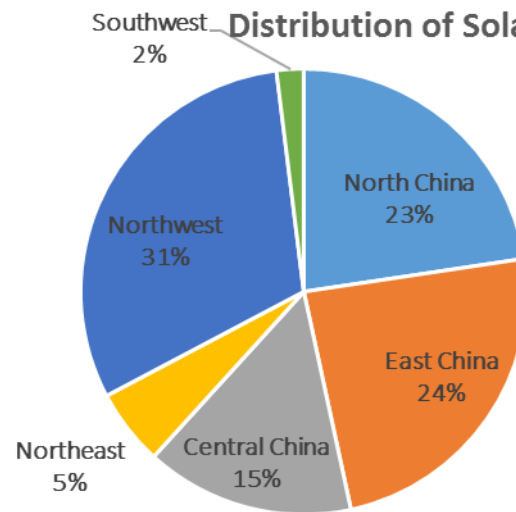
Distribution of Wind+Solar Capacity 2017



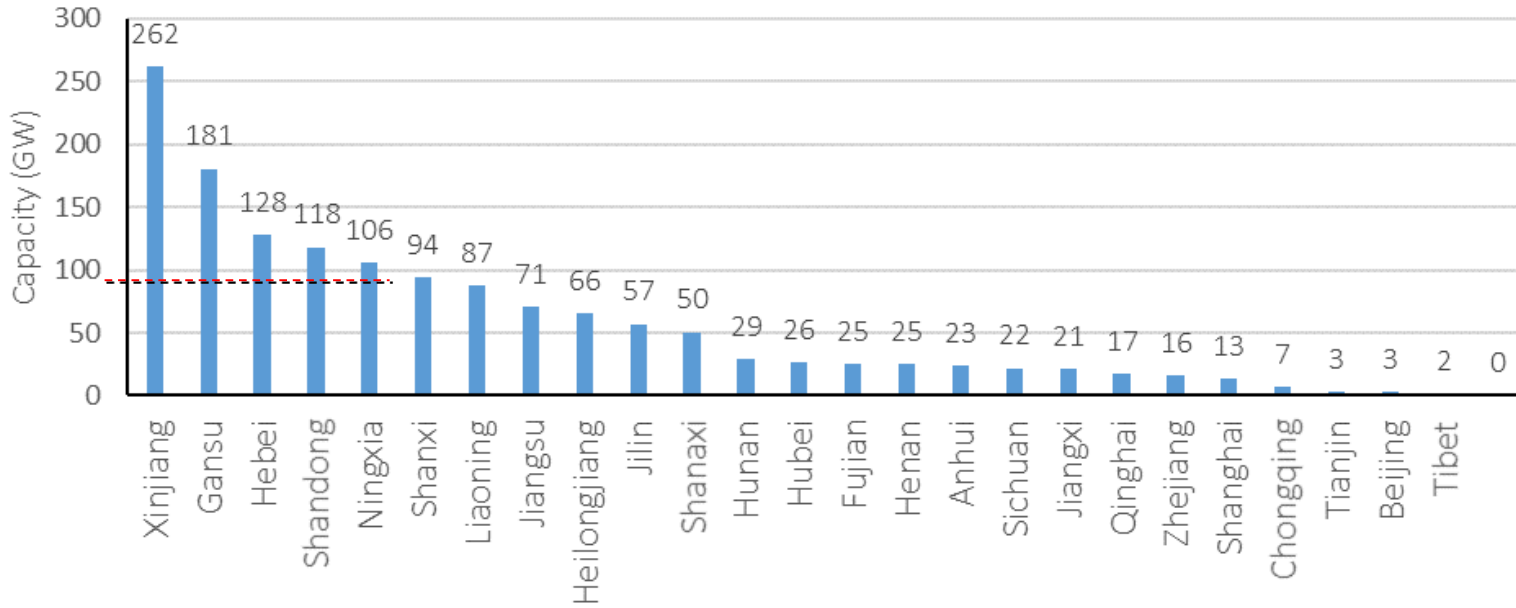
Distribution of Wind Capacity 2017



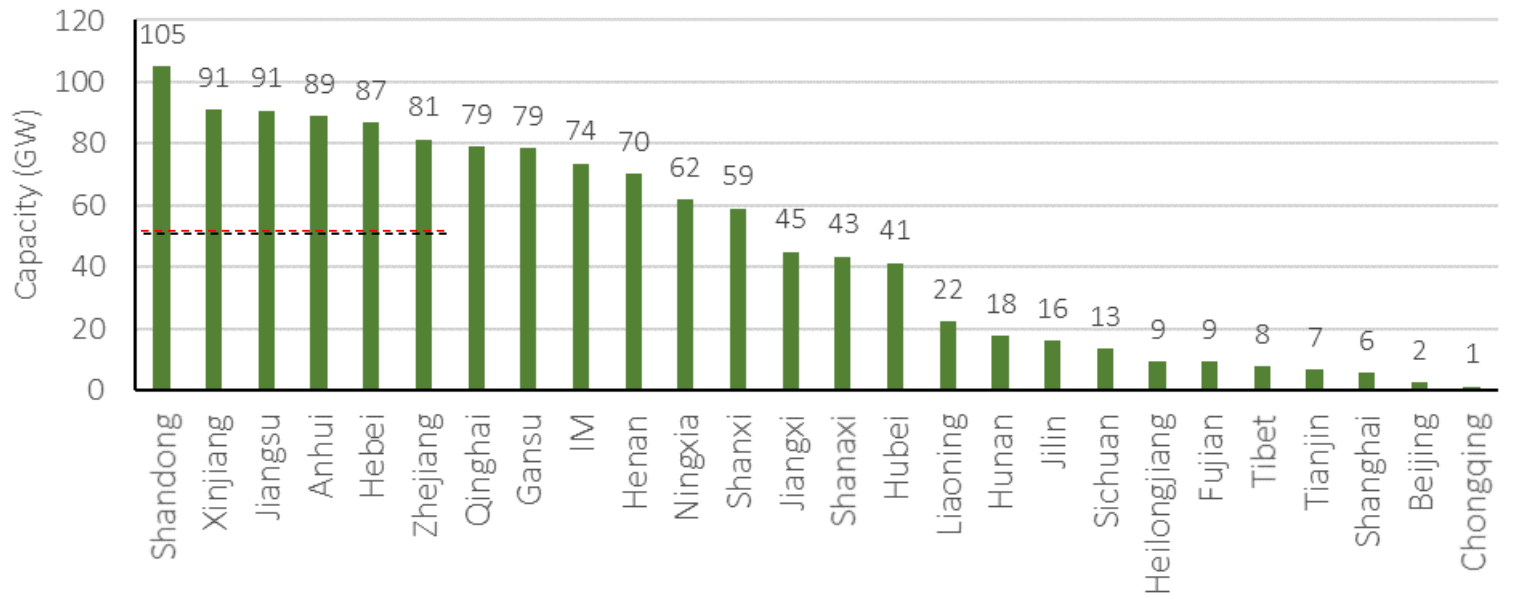
Distribution of Solar Capacity 2017



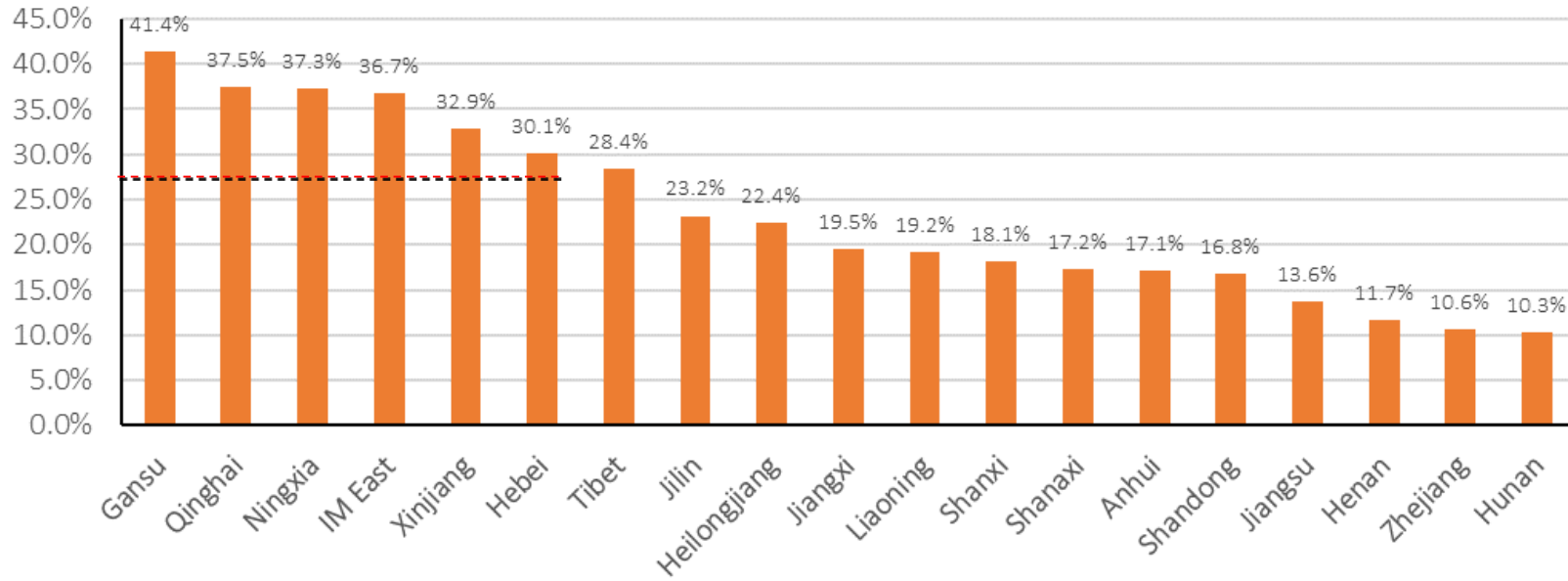
Wind Capacity



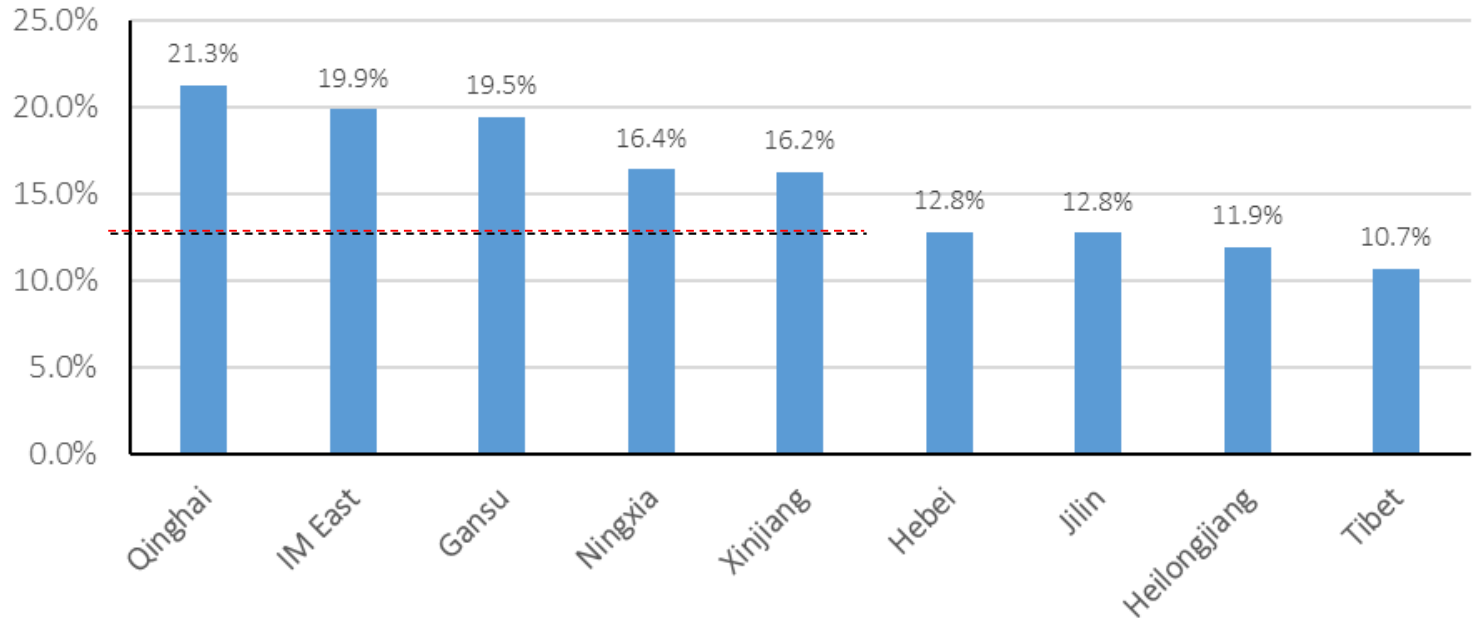
Solar Capacity



RE Capacity Share



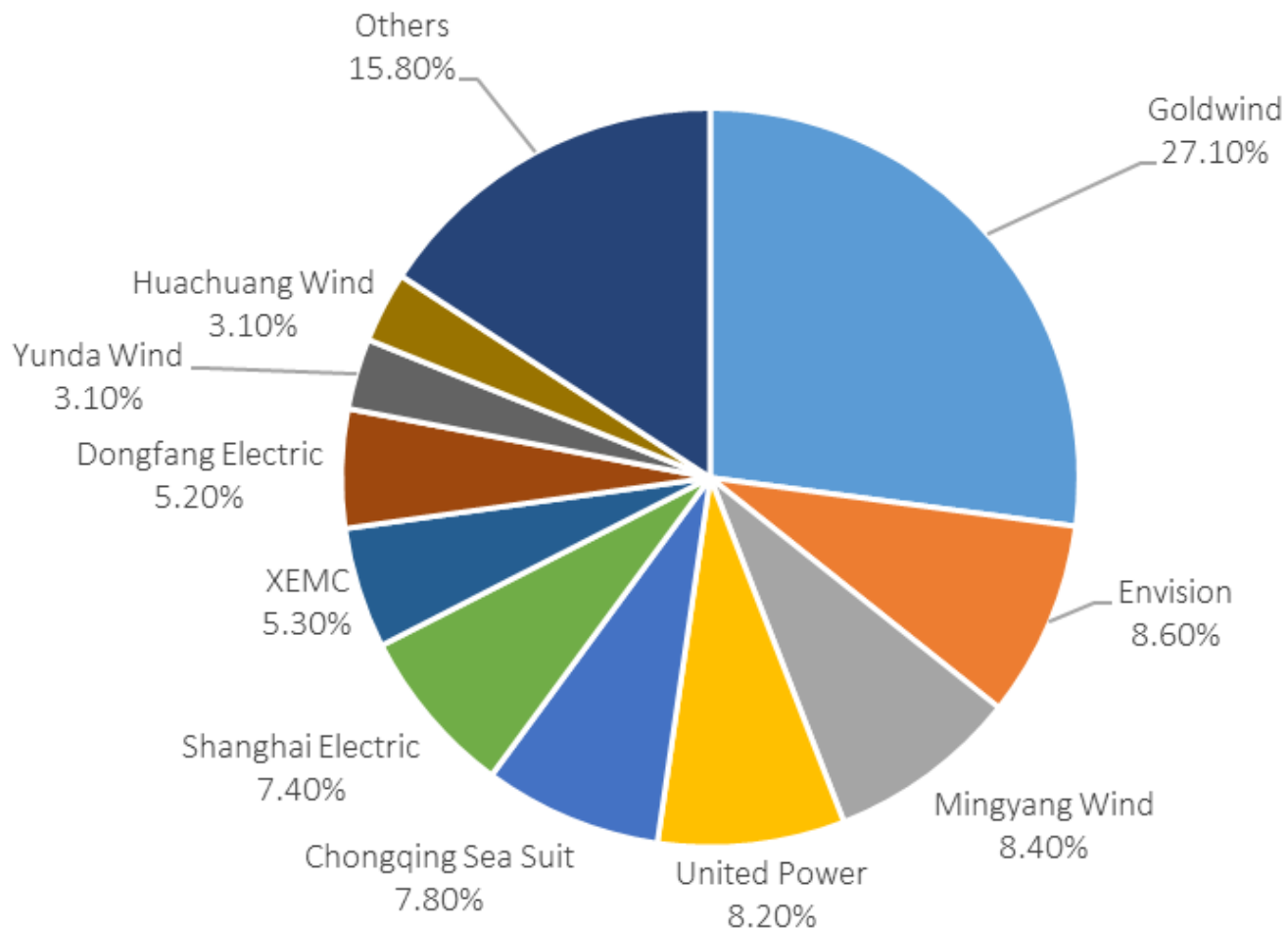
RE Energy Share





Wind Technologies

Market Share of Wind Turbine Manufacturers





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The Renewable Energy Law in China set the foundation for Renewable Energy Development.

Renewable Energy Law

“Full Purchase of Renewable Energy”

Notice on the Strengthening of Wind Power Development and Operation Management – by NEA

Notice on the Requirement of Wind Power Integration– by NEA



Renewable Energy Law(Revised)

“ Guaranteed Purchase of Renewable Energy”

Administrative Rules on Wind Power Forecast – by NEA

Notice on the Requirement of Wind Power Integration in 2013– by NEA

Feed in Tariff



Priority Dispatch of RE



Wind

2009

全国风力发电标杆上网电价表

资源区	标杆上网电价 (元/kWh)	各资源区所包括的地区
I类资源区	0.51	内蒙古自治区除赤峰市、通辽市、兴安盟、呼伦贝尔市以外其他地区；新疆维吾尔自治区乌鲁木齐市、伊犁哈萨克族自治州、昌吉回族自治州、克拉玛依市、石河子市
II类资源区	0.54	河北省张家口市、承德市；内蒙古自治区赤峰市、通辽市、兴安盟、呼伦贝尔市；甘肃省张掖市、嘉峪关市、酒泉市
III类资源区	0.58	吉林省白城市、松原市；黑龙江省鸡西市、双鸭山市、七台河市、绥化市、伊春市，大兴安岭地区；甘肃省除张掖市、嘉峪关市、酒泉市以外其他地区；新疆维吾尔自治区除乌鲁木齐市、伊犁哈萨克族自治州、昌吉回族自治州、克拉玛依市、石河子市以外其他地区；宁夏回族自治区
IV类资源区	0.61	除I类、II类、III类资源区以外的其他地区

Solar

2013

单位：元/千瓦时（含税）

资源区	光伏电站 标杆上网电价	各资源区所包括的地区
I类资源区	0.90	宁夏、青海海西，甘肃嘉峪关、武威、张掖、酒泉、敦煌、金昌，新疆哈密、塔城、阿勒泰、克拉玛依，内蒙古除赤峰、通辽、兴安盟、呼伦贝尔以外地区
II类资源区	0.95	北京、天津，黑龙江，吉林，辽宁，四川，云南，内蒙古赤峰、通辽、兴安盟、呼伦贝尔，河北承德、张家口、唐山、秦皇岛，山西大同、朔州、忻州，陕西榆林、延安，青海、甘肃、新疆除I类外其他地区
III类资源区	1.0	除I类、II类资源区以外的其他地区

注：西藏自治区光伏电站标杆电价另行制定。

2016

附件2

全国陆上风力发电标杆上网电价表

单位：元/千瓦时（含税）

资源区	2018年新建陆上风电 标杆上网电价	各资源区所包括的地区
I类资源区	0.40	内蒙古自治区除赤峰市、通辽市、兴安盟、呼伦贝尔市以外其他地区；新疆维吾尔自治区乌鲁木齐市、伊犁哈萨克族自治州、克拉玛依市、石河子市
II类资源区	0.45	河北省张家口市、承德市；内蒙古自治区赤峰市、通辽市、兴安盟、呼伦贝尔市；甘肃省嘉峪关市、酒泉市；云南省
III类资源区	0.49	吉林省白城市、松原市；黑龙江省鸡西市、双鸭山市、七台河市、绥化市、伊春市，大兴安岭地区；甘肃省除嘉峪关市、酒泉市以外其他地区；新疆维吾尔自治区除乌鲁木齐市、伊犁哈萨克族自治州、克拉玛依市、石河子市以外其他地区；宁夏回族自治区
IV类资源区	0.57	除I类、II类、III类资源区以外的其他地区

2016

附件1

全国光伏发电标杆上网电价表

单位：元/千瓦时（含税）

资源区	2017年新建光伏电站 标杆上网电价	各资源区所包括的地区
I类资源区	0.65	宁夏，青海海西，甘肃嘉峪关、武威、张掖、酒泉、敦煌、金昌，新疆哈密、塔城、阿勒泰、克拉玛依，内蒙古除赤峰、通辽、兴安盟、呼伦贝尔以外地区
II类资源区	0.75	北京、天津，黑龙江，吉林，辽宁，四川，云南，内蒙古赤峰、通辽、兴安盟、呼伦贝尔，河北承德、张家口、唐山、秦皇岛，山西大同、朔州、忻州，陕西榆林、延安，青海、甘肃、新疆除I类外其他地区
III类资源区	0.85	除I类、II类资源区以外的其他地区



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2006: Section 4 in Renewable Energy Law

Power Grid companies must sign grid connection contracts with renewable energy generation enterprises who get administrative permission, **fully purchase electricity generated by renewable power plants** that is connected to their power grids, and provides grid integration services for the renewable generation.

2009: Section 4-14 in Renewable Energy Law(Revised)

14 Renewable energy is given guaranteed purchase status in China.

The Energy department of the State Council in conjunction with the State Electricity Regulatory agencies and financial departments of the State Council, according to the national renewable energy development and utilization plan, determine the proportion of renewable energy in total electricity generation during the planning period, and formulate the specific measures for grid companies to **fulfill the priority scheduling and guaranteed purchase of renewables.**



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2012: Opinions on Strengthening the security of wind farm operation

5. Management on Priority Dispatch

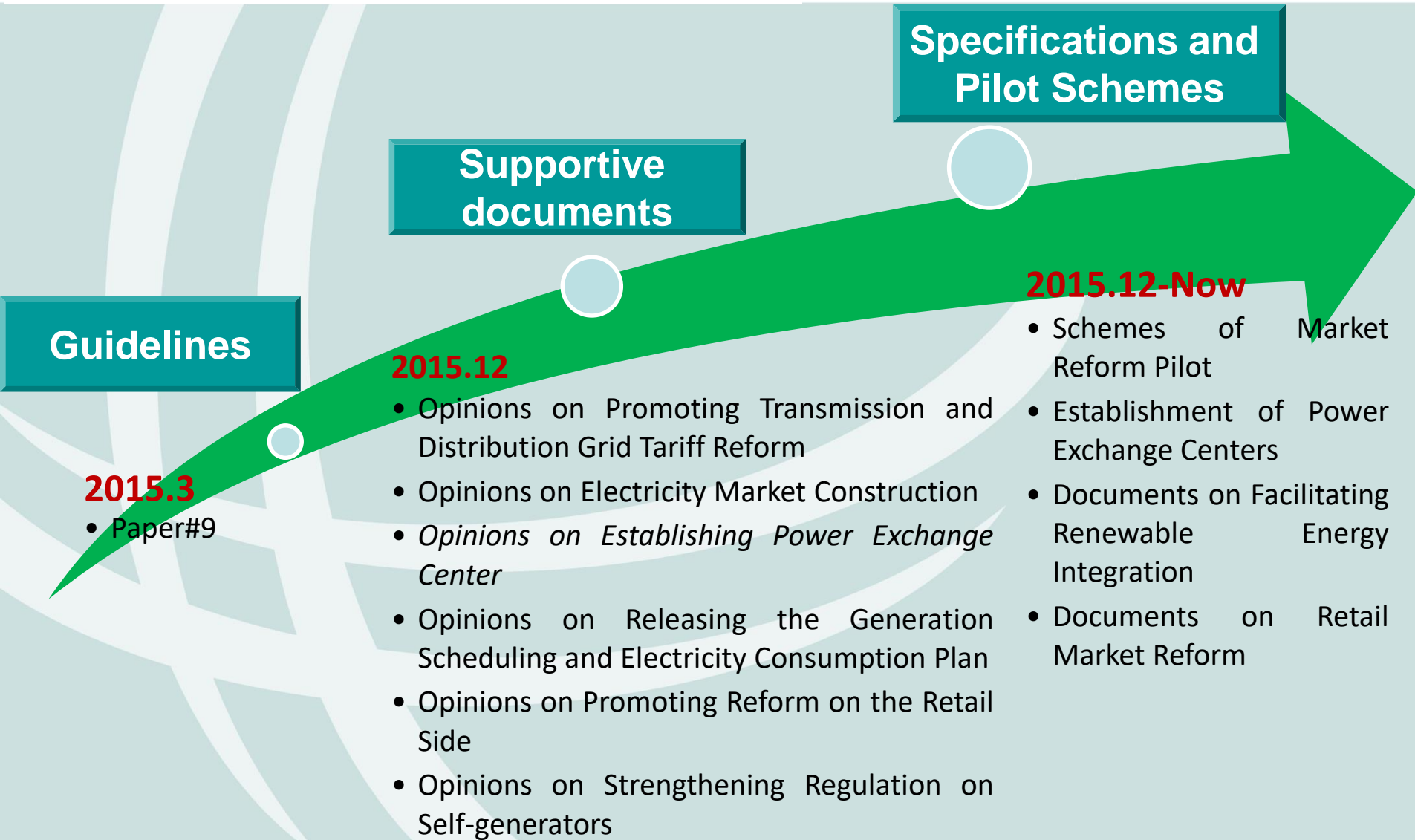
The dispatch centers should strengthen wind power dispatch management and ***ensure the priority dispatch of wind power under the premise that power system is operating safely.***

2012: the 12th five year plan for wind development

Wind power forecast-based generation scheduling mechanism should be established, and the generation schedules of various types of power generation should be coordinated. ***The dispatch centers are responsible for establishing dispatch mechanism for wind power priority dispatch.*** The operation management of distributed wind power in the distribution power grid should be facilitated as well.

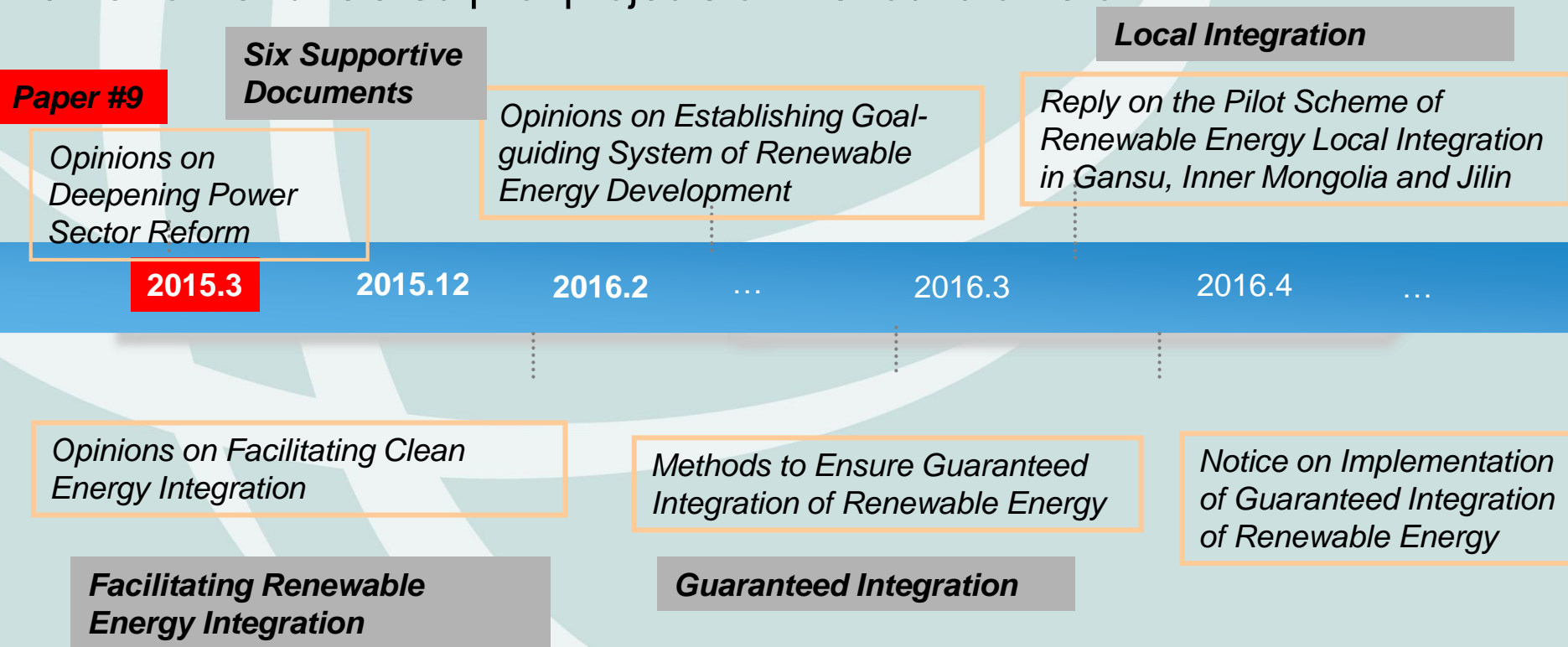


RE Policies (2015+)





To raise the proportion of power generation of renewable energy and distributed energy system in the power supply” is one of the basic principles of deepening the reformation of electric power system. Facilitating the integration of renewable generation is an important part included in the general framework and related pilot projects of this round of reform.





(1) Paper #9 and its supportive documents

- ❑ Six supportive documents of Paper #9
- ❑ Renewable energy related :
 - *Opinions on release the generation scheduling and electricity consumption plan* - Non pilot areas
 - Generation for public welfare and for regulation and load following purposes is given priority which are seen as annual energy exchange and will be written into contracts. All parties sign long term contracts based on the priority generation status and agreements on bilateral trading
 - *Opinions on electricity market construction* – Pilot areas
 - Priority generation right: Eligible generators have priority to sell their generation with administratively determined price. Eligible generators do not participate in the electricity market at the beginning and their generation is fully arranged in system generation scheduling



(2) Methods to Ensure Guaranteed Purchase of Renewable Energy

Methods to Ensure Guaranteed Purchase of Renewable Energy , March 2016

- Guaranteed Integration of Renewable Energy
 - ✓ Annual generation contract between generators and power grid companies; priority dispatch
- Market Trade of Renewable Energy

Notice on Implementation of Guaranteed Purchase of Renewable Energy , May 2016

- Guaranteed full load hours of wind and solar in some areas are released based on cost and allowed profit.
- Compensation is needed from coal-fired generation if they take up the generation space of the guaranteed wind and solar energy
- Trading of guaranteed renewable energy is prohibited.



(3) Initiating Renewable Energy Local Integration Pilots

In October 2015, NDRC published *Notice on Conducting Renewable Energy Local Integration Pilot Projects*. Gansu and Inner Mongolia are determined to be the two pilot areas. It is expected that lessons learnt from the two areas can be generalized to other provinces.

Pilot content specified include:

- Integration of renewables in the local power grid (renewables and conventional generation, conventional generation providing load-following and regulation)
- Bilateral trading (heating by renewable energy, electricity substitution)
- Priority generation rights (trading of priority generation rights, compensation mechanism for conventional generation)
- Other mechanisms (Retrofit of coal-fired generation that increases its flexibility, demand side response)



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In April 2016, the General Office of the National Development and Reform Commission printed and released the *Reply Letter on Approving the Local Integration Pilot Program of Renewable Energy in Gansu Province, the Inner Mongolia Autonomous Region and Jilin Province*, **approving that Gansu Province, the Inner Mongolia Autonomous Region and Jilin Province conduct the local integration pilot program of renewable energy and requiring the pilot areas to implement the revised pilot program.** The programs in different areas have common characteristics, which also embodies the specific integration features of renewable energy in different areas.



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RE Targets

Non-fossil fuel consumption in primary energy consumption:

$\geq 15\%$ by 2020

$\geq 20\%$ by 2030

RE planning in the 13th FYP

Wind Capacity: 210GW+

Solar Capacity: 110GW+

Share of Non fossil fuel generation in the Generation Structure:

$\geq 31\%$ by 2020

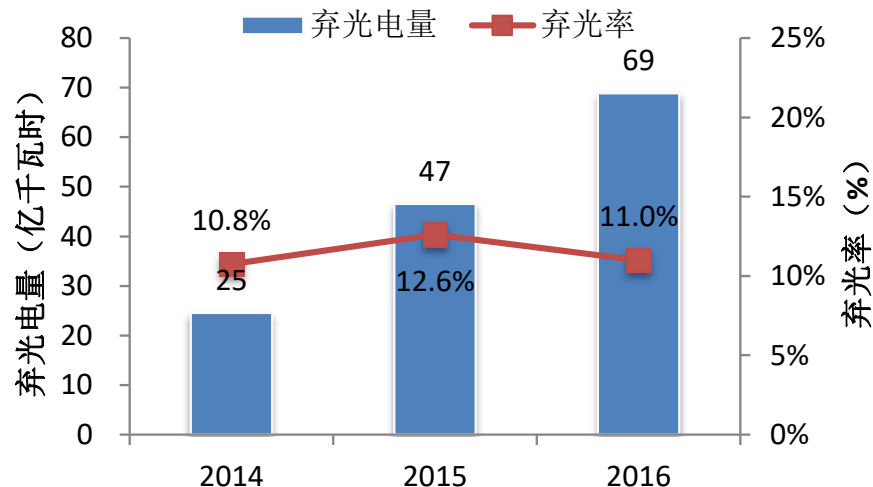
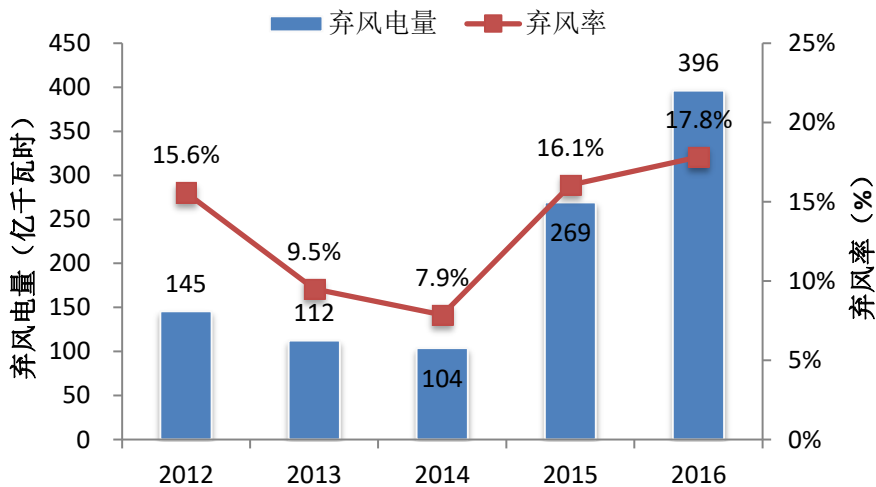


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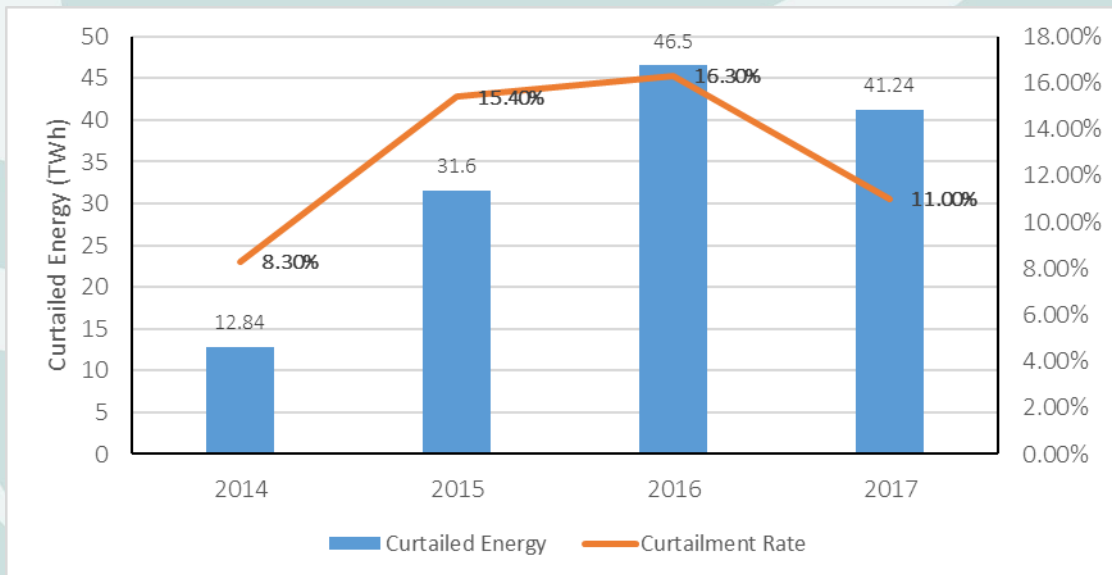
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2017 Amount of Wind+Solar curtailment : 41.2 TWh (curtailment rate 11%).





RE Curtailment

Amount of wind curtailment: 34.5 TWh (curtailment rate 12.9%).

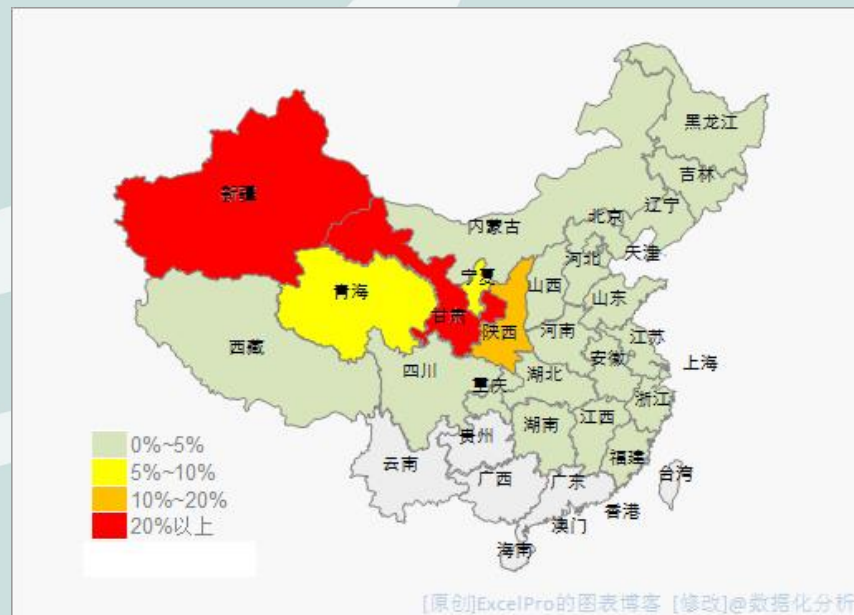
Distribution: Gansu, Xinjiang, Jilin and Inner Mongolia are over 20%.

Amount of solar curtailment: 6.74 TWh (curtailment rate 6.3%).

Distribution: Northwest China, i.e. Gansu, Xinjiang, Qinghai.



Distribution of Wind Curtailment in China



Distribution of Solar Curtailment in China



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Barriers to RE Integration in China

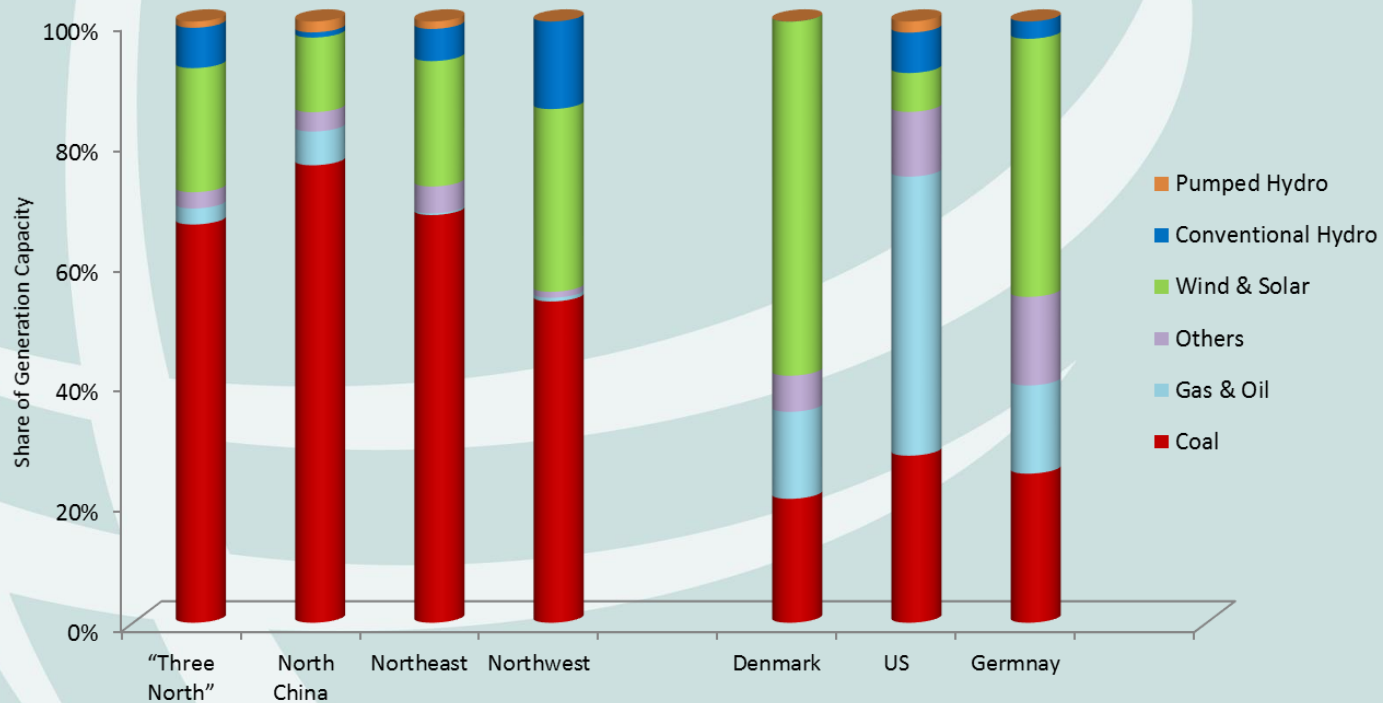
- Limited trans-regional and trans-provincial interconnection
- Lack of flexibility from conventional generation
 - CHP
 - Self generation
 - Nuclear
- Institutional barriers
 - Lack of ancillary service market
 - Inflexible price mechanism
 - Lack of demand side participation in renewable energy integration
 - ...



(1) Inflexible Generation Structure

In general, there is a high share of coal-fired generation in China.

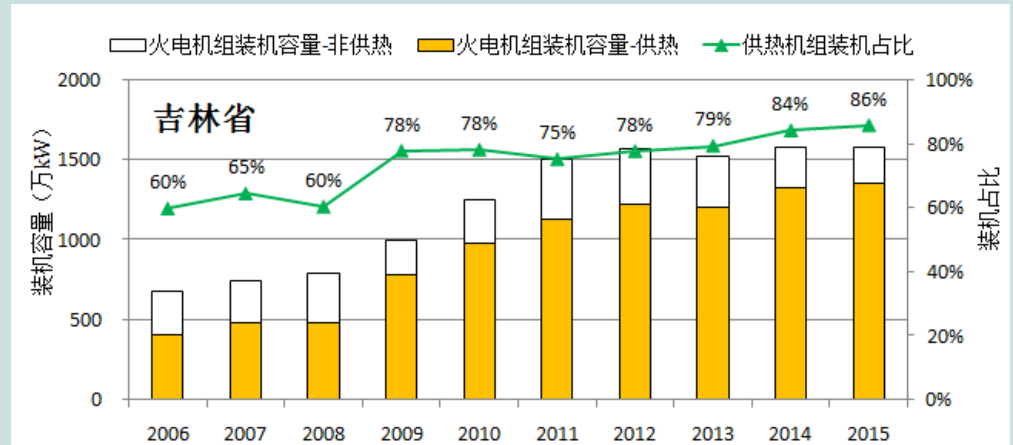
The share of coal-fired generation in the Three Norths Areas is ~70%.



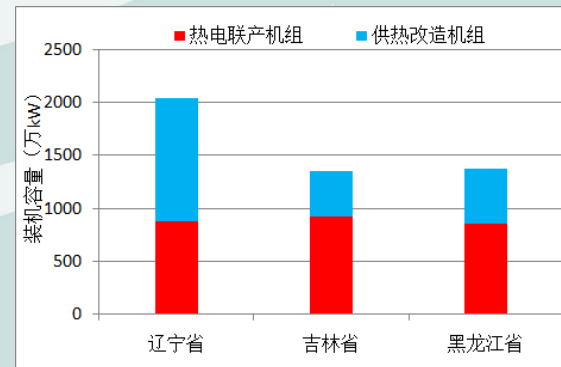


Of all the coal-fired generation, there is a high proportion of CHP generators.

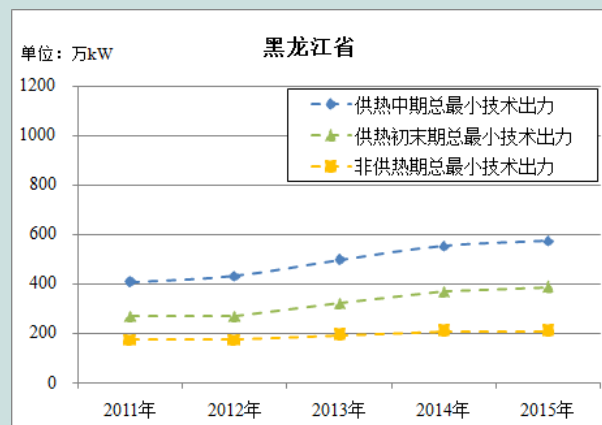
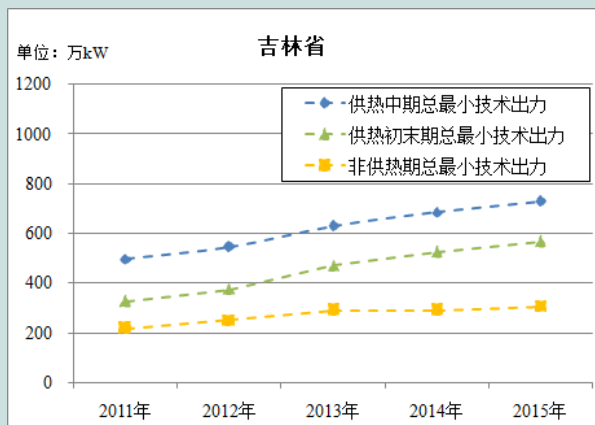
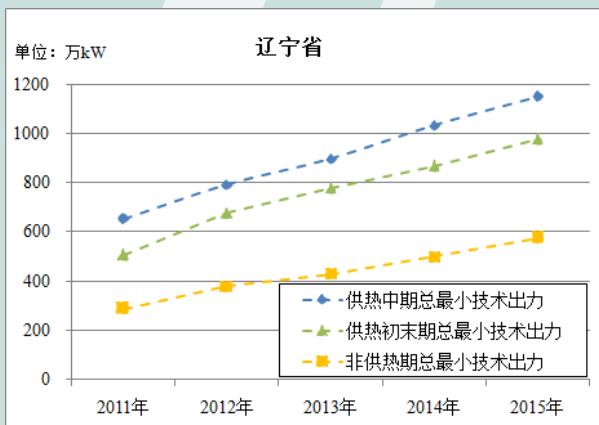
- Motivation: More generation opportunity
 - More energy quota
 - Higher minimum output
- Retrofit CHP from non-CHP units.



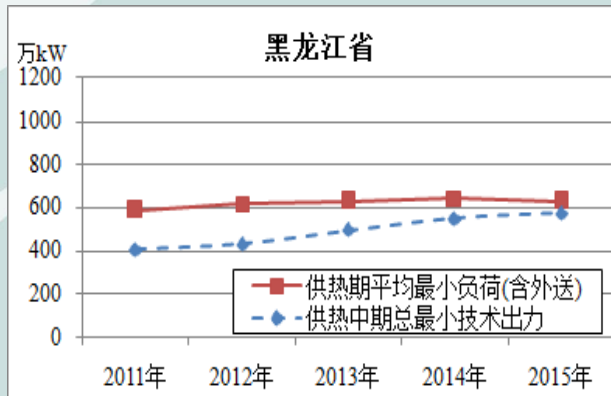
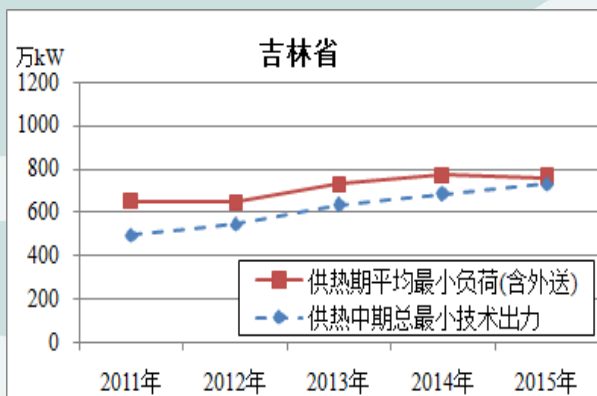
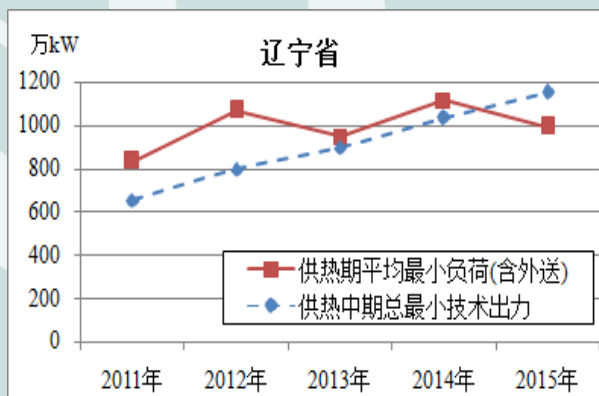
The capacity and share of CHP generators in Jilin Province 2006~2015



The capacity of CHP and retrofitted CHP generators in Northeast China in 2015



Minimum output of all the CHP generators in Northeast China during 2011~2015



Comparison of average minimum output of generators and average minimum load during mid term heating season in Northeast China during 2011~2015



In some provinces, there are high shares of self-generators, who do not contribute to system flexibility.

- By the end of 2016, the capacity of self-generation in the Three North Areas is 82GW, 19% of the coal-fired generation.
- 7 provinces have self generation more than 10% of their of thermal generation.
- Do not contribute to the load following and regulation capability of the system.

Example: Xinjiang

- Share of self-generation in thermal generation is 43%.
- Full load hours of self-generators **6161 VS. 3007** (public generators)



(2) Insufficient Transmission Capacity

Insufficient capacity of trans-regional transmission channels restricts the trans-provincial and trans-regional integration of renewable energy

Existing trans-regional transmission capacity of China accounts for only 20% of the installed capacity of new energy. However, the transmission capacity of outgoing channels in Denmark is 1.1 times the installed capacity of new energy.



(3) Inadequate Supporting Policies and Mechanisms

Supporting Policies and Mechanisms are not adequately established to facilitate renewable energy integration

- Due to a lack of compensation mechanism for conventional generators that provide ancillary services to wind and solar, the incentive for conventional generators to help integrate more renewables into the system is weak.
- Energy only price mechanism that does not reflect the technical advantage, environmental value, capacity value for different types of generation. Revenue of coal-fired generation largely comes from the amount of energy they generated.



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- A flexible pricing mechanism on the consumption side that promotes new energy utilization remains in blank. Most regions have issued the consumption side peak-valley price policy for specific users; however, it does not help change of system operation characteristic after large-scale new energy is introduced.



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- 3. RE Integration Issues in China**
- 4. RE Future and Practices to Facilitate RE Integration in China**



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Targets

Non-fossil fuel consumption in primary energy consumption:

$\geq 15\%$ by 2020

$\geq 20\%$ by 2030

RE planning in the 13th FYP

Wind Capacity: 210GW+

Solar Capacity: 110GW+

Share of Non fossil fuel generation in the Generation Structure:

$\geq 31\%$ by 2020

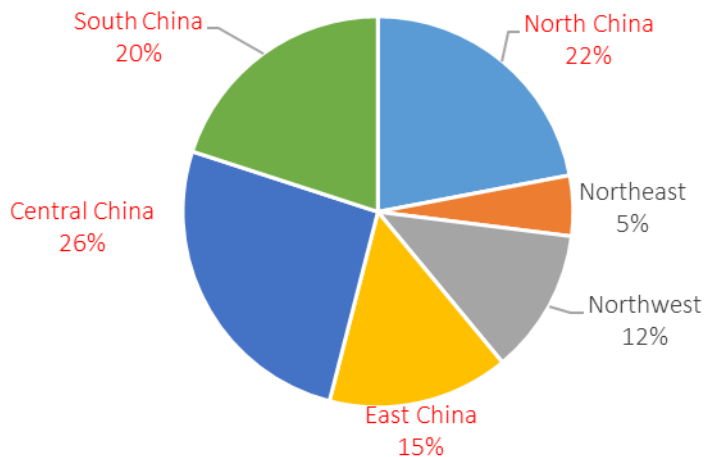
Reduce the RE curtailment rate:

$< 5\%$

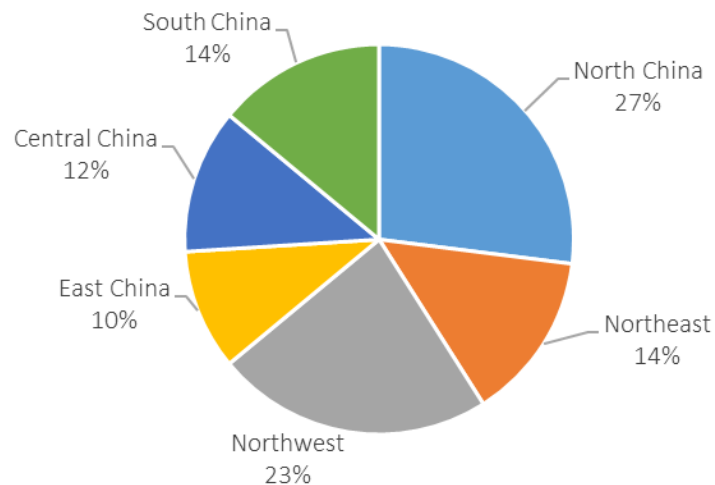


Wind: more newly installed capacity in Central China, East China and South China. Newly installed Wind 42GW in Central China, East China and South China. Newly installed Wind 35GW in the Three Norths Areas.

Distribution of Newly Installed Wind during 2016-2020

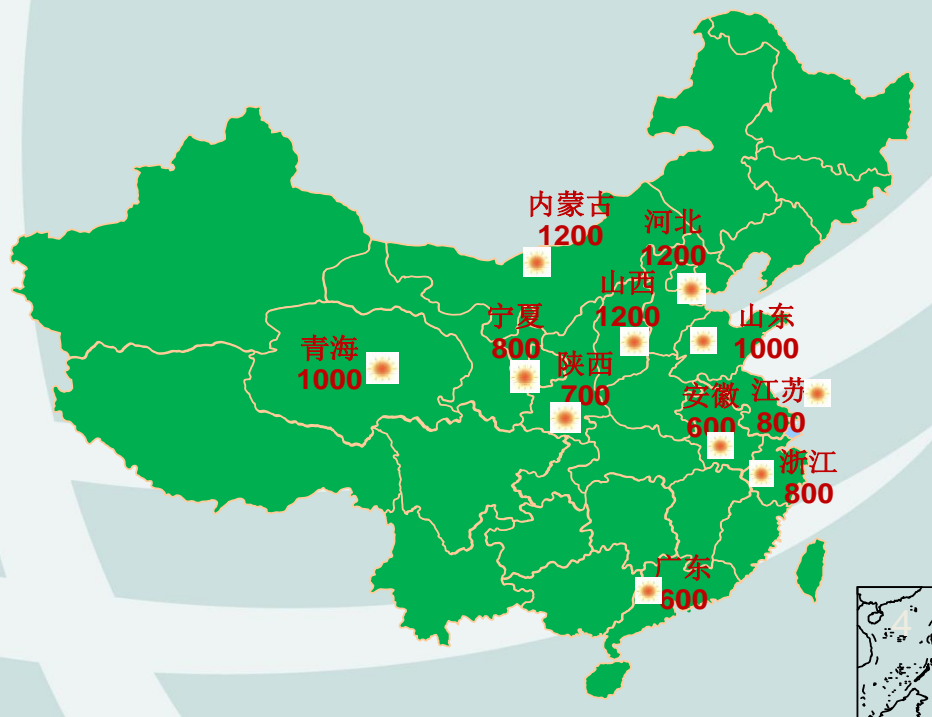


Distribution of Accumulated Wind Capacity in 2020





Solar: concentrated and distributed solar. The capacity of distributed PV reach 60GW by 2020. Focus on Rooftop distributed PV.

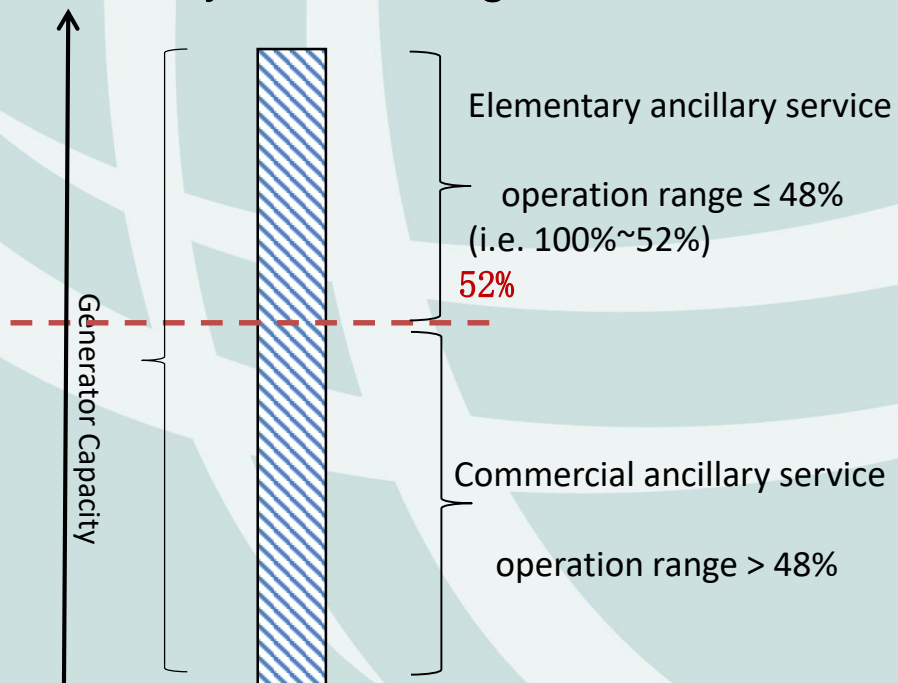


Capacity of PV in key areas in 2020

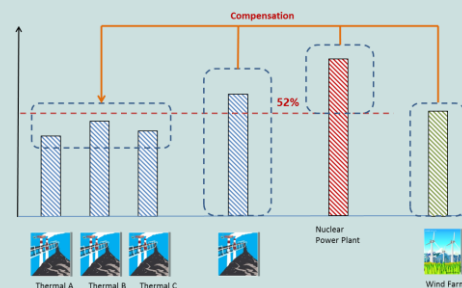
Practices to Facilitate RE Integration

(1) Ancillary service scheme in Northeast China

Basic Idea: The market price mechanism is introduced. Thermal generators can bid for their capabilities to be dispatched down and they will be compensated based on the clearing price. The more they can be dispatched down, the higher compensation rate they will get. The cost initiated will be borne by coal-fired generators, wind, nuclear, etc.



Period	Type	Loading rate	Bid Floor (RMB/kWh)	Bid Cap (RMB/kWh)
Non-heating	Non-CHP	$40% < R \leq 50%$	0	0.4
	CHP	$40% < R \leq 48%$		
	All	$R < 40%$	0.4	1
Heating	Non-CHP	$40% < R \leq 48%$	0	0.4
	CHP	$40% < R \leq 50%$		
	All	$R < 40%$	0.4	1





(2) Co-operation of CHP generators and electric boilers

Basic idea: Co-operation of CHP generators and electric boilers, heat storage, ... to increase the flexibility of CHP generators, so as to facilitate RE integration

- Pilot projects in Northeast China.
- Incentive: **downward regulation ancillary service market in Northeast China**
- Profit share between CHP generators and electric boiler investors



Example: Dandong Jinshan CHP power plant in Liaoning Province, Northeast China



- 2*300MW CHP generators, 19 million m² heating area
- Pilot of flexibility promotion projects for CHP
- Incentivized by the downward regulation ancillary service market, a solid electric heat storage system was constructed in 2016, owned by a heat storage company.
 - Capacity: 260MW
 - Annual electricity consumption is 300GWh, which is 3% of the curtailed wind energy in Liaoning province.
- Auxiliary power is used for heat generation. The amount of electricity fed into the power grid is reduced, which is seen as a downward regulation service from the system operators' side.
- Pay back period: 3~5 years



(3) Generation rights trading between wind and coal fired generation

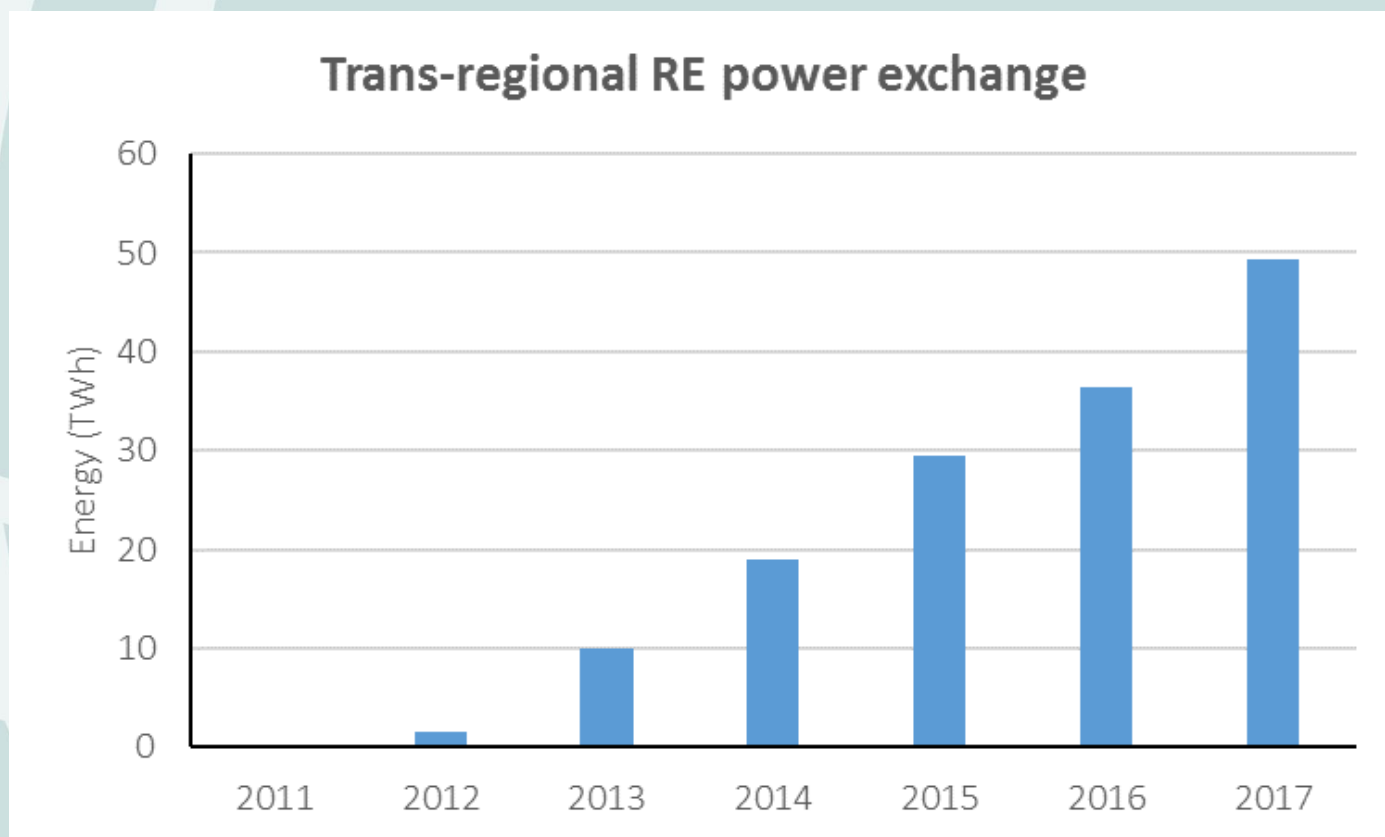
■ Basic idea :

- Wind power buy generation rights from coal-fired generators, so that coal-fired generators back down to make room for wind energy. The trading price is settled between the trading parties.
- Usually between wind power and self-owned coal-fired generators of industrial electricity users

In 2015, Gansu, Xinjiang and Ningxia conducted the generation rights trading between wind and coal fired generation. The the extra amount of wind energy being generated due to the scheme was 2.81 TWh, accounting for 4.6% of total wind energy in the Northwest.



(4) Encouraging trans-regional RE power exchange





(5) Wind Heating

Basic idea: Use the curtailed wind energy for heating.

- 10+ pilot wind-heating projects in China so far, mainly in wind-intensive areas, such as Jilin, Inner Mongolia.
- Two business models
 - Wind power plant owners invest in electric boilers, which buy potentially curtailed wind from the power grid and sell the generated heat to heat companies

Wind power plant

Power grid

Heat company



Residency

Electric boiler

Power flow



Cash flow





- Direct trading between wind and electric users, who uses electric boilers for heat generation
 - ✓ Wind power in Northeast China – Beijing electricity users
 - ✓ Reduced FIT for wind power

Wind power plant



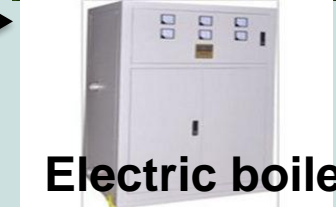
Power grid



Residency



Electric boiler



Power flow
→

Cash flow
→



(6) Electricity Substitution

Basic idea: Substitution of the direct consumption of fossil energy such as coal, oil and natural gas with electricity in energy consumption, and increase the proportion of power energy in the terminal energy consumption, which help RE integration.

- Widely implemented in China since 2016.
- Incentive: Air pollution prevention. Indirectly for RE Integration.





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- SGCC has accumulatively implemented over 90 thousand electricity substitution projects in which fossil fuel consumption equaling to about 280 billion kilowatt-hour of power was substituted.
- Increase the **utilization of electric boilers** for heat generation is a key part of electricity substitution.
 - Subsidies in equipment investment
 - Preferable retail electricity price during valley load hours to for heat generation



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Thank you !

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