



China's Power, Renewable, Grid Policies and Outlook

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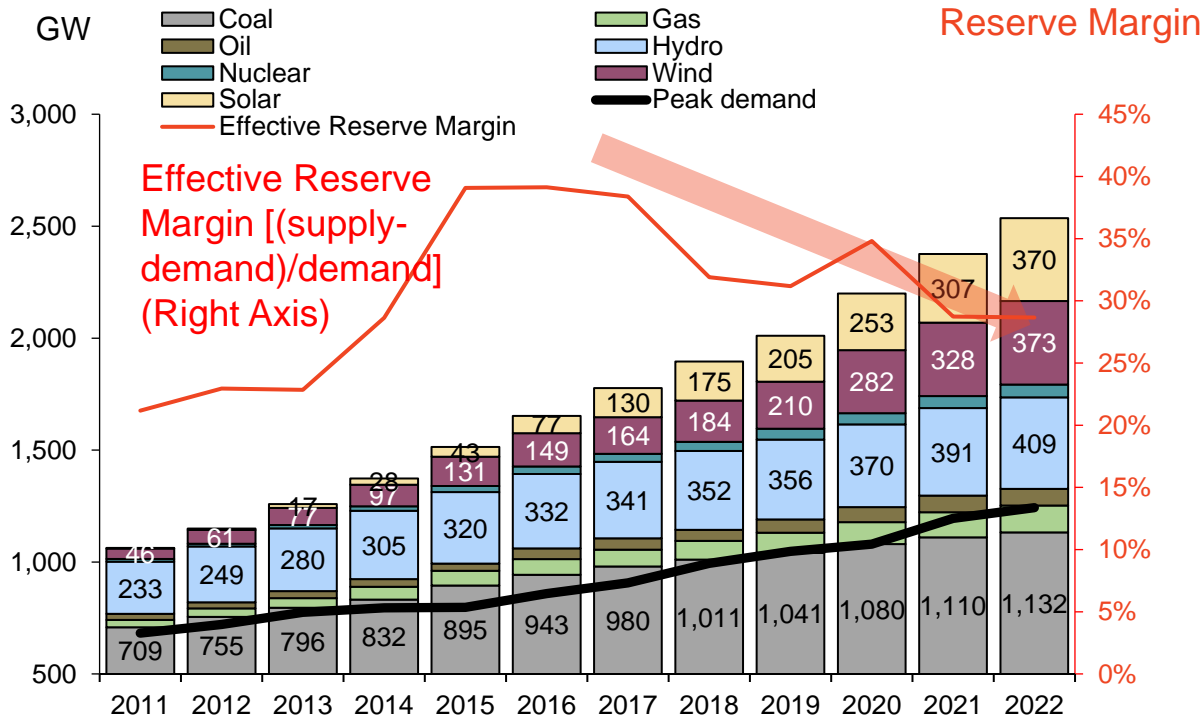
Agenda

- 1 Recent Development in China's Power Sector**
- 2 Market Reform and Its Impact on Grid-parity Solar and Wind Projects
- 3 Long-term Trend: Decarbonizing the Chinese Power Sector
- 4 Summary

Market Fundamental

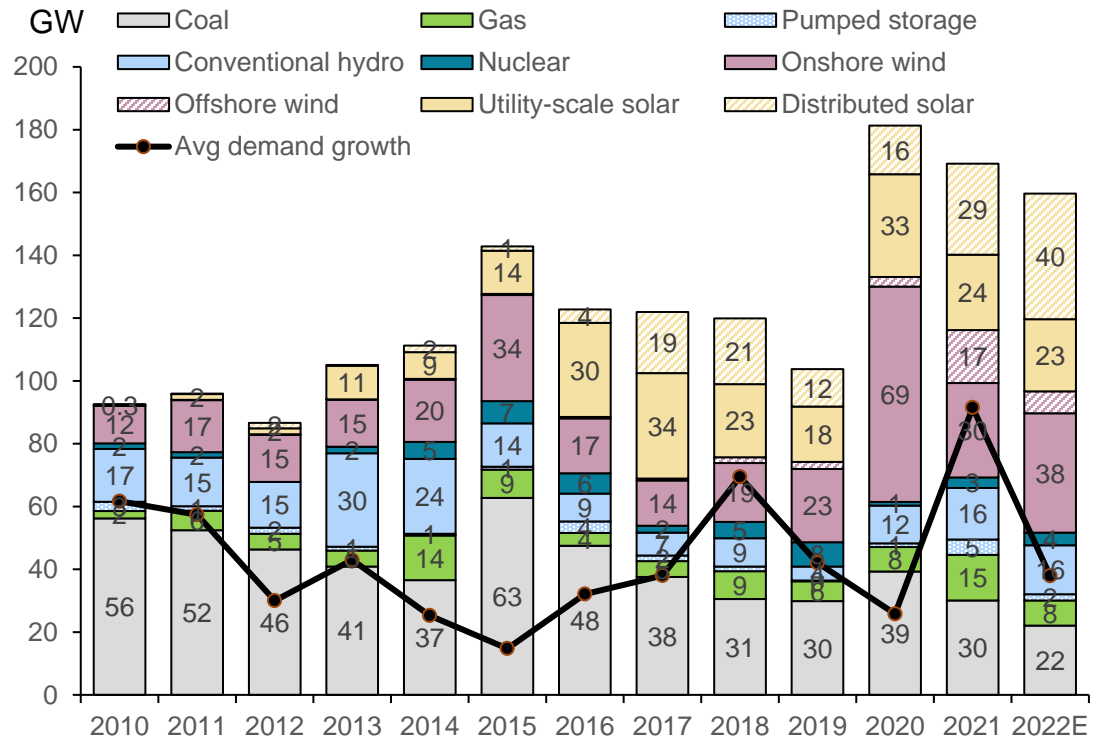
The overall market fundamental has largely re-balanced; and new capacity expansion has shifted more to renewable capacity

Power Supply and Demand Fundamental in China



- Market was over-supplied in 2015-2017, but it has re-balanced with strong load growth and slower expansion of coal capacity since 2018.
- There is no lack of total physical generation capacity in China, but it lacks flexible capacity.

Incremental Annual Supply and Demand



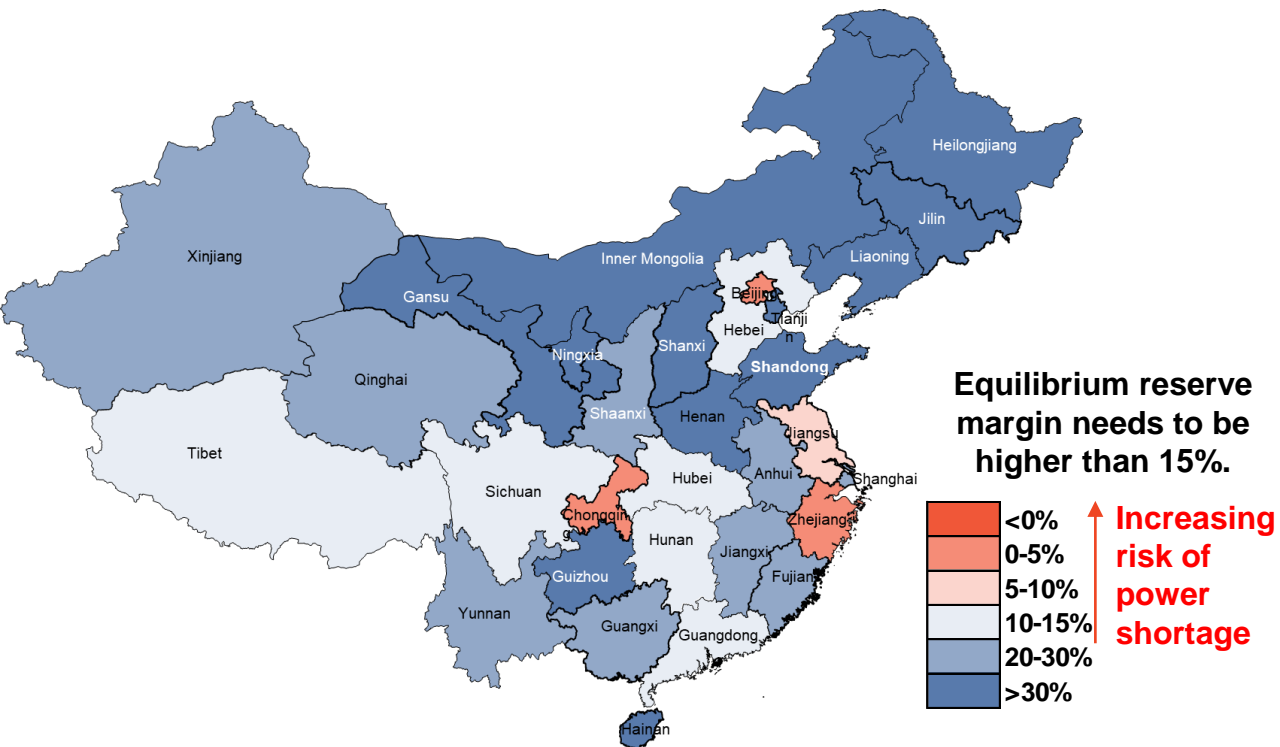
- In 2016-2021, average annual wind capacity expansion was 34 GW and average annual solar capacity expansion was 44 GW.
- Annual coal capacity expansion was reduced from 40-60 GW seen before 2017 to 20-30 GW in recent years.

Note: Effective reserve margin calculation takes into consideration of availability factor of different types of capacity (Thermal – 90%, nuclear – 95%, Hydro, wind and solar – actual capacity factor). Effective reserve margin = [available supply – peak load – net export]/peak load. As a rule of thumb, at a national level, a market is in balance with an effective reserve margin of 20-30%. If its reserve margin is higher than 30%, it is over-supplied; if it is less than 15%, it is a tight market with seasonal shortage.
 Source: China Electric Council (CEC), National Energy Administration (NEA) and WaterRock Energy Research and Analysis

Provincial Balance and Power Shortage

We expect that seasonal power shortage will likely continue to happen in coastal and central provinces in the coming years

Effective Reserve Margin at Provincial Level in 2021 [After accounting for imports/exports], Mainland China



Key provinces with potential power shortage risk include those in North China (Hebei-Tianjin-Beijing), East China (Zhejiang and Jiangsu), Central China (Chongqing and Hunan) and South China (Guangdong)

Key drivers for the power shortage :

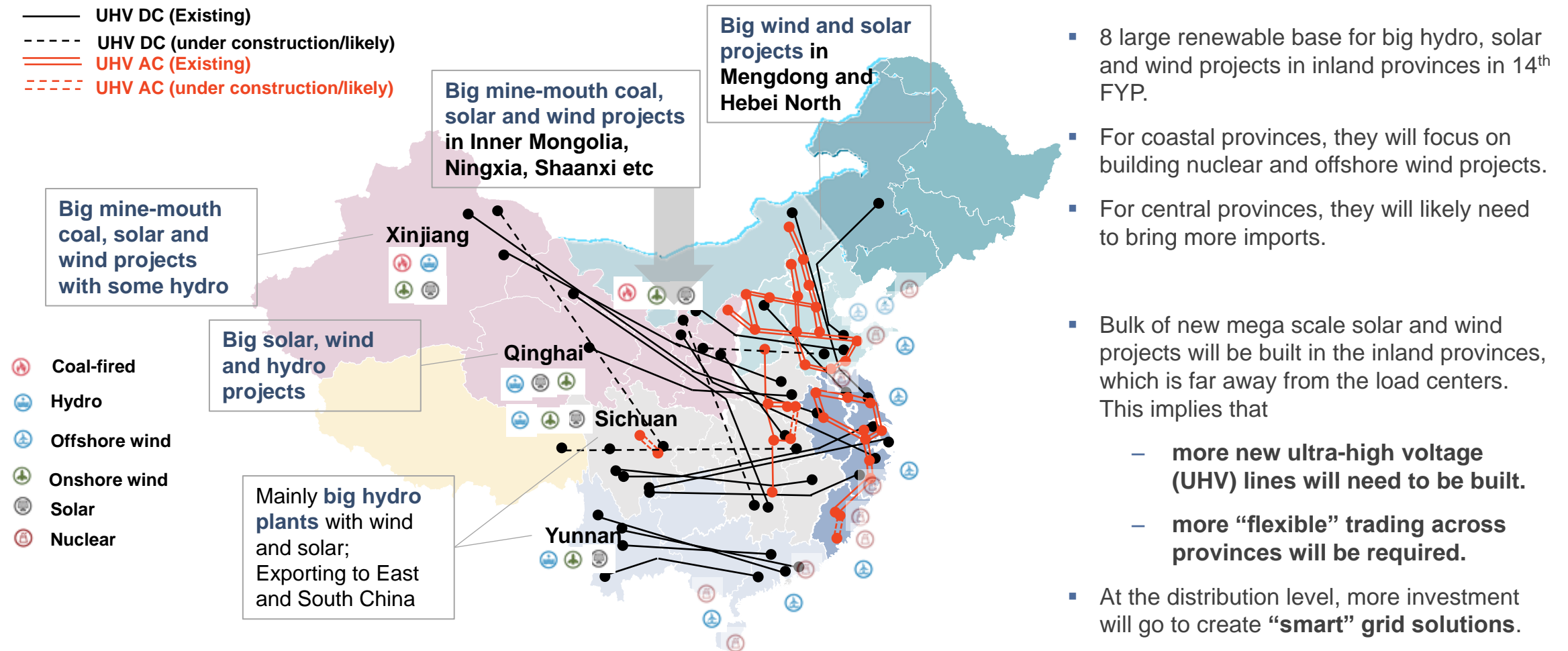
- Tightening overall market fundamental but there is no shortage of physical capacity at national level.
- **Provincial imbalance and the “rigid” trading across provinces**
 - Slow progress on the reform for cross-provincial trading
- **Peakier load profile but lack of flexible capacity**
 - Some progress to encourage investment of battery energy storage and hydro pumped storage, but still insufficient.
- **Mis-alignment of coal tariff and coal price**, dis-incentivizing coal capacity to generate to help meet demand
- Specific factors in a particular year
 - In 2022, weather conditions (drought and high temperature) contribute to the power shortage in Sichuan.

As it will take time to resolve the structural issues on provincial imbalance and lack of flexible capacity in the grid system, seasonal power shortage will likely continue to happen in the next few years.

14th Five Year Plan and UHV Grid Expansion

Key new supply sources would be big hydro, solar, wind and mine-mouth coal projects in inland areas, nuclear and offshore wind in coastal areas

Ultra-high Voltage (UHV) Lines and Resource Distribution in Mainland China



- 8 large renewable base for big hydro, solar and wind projects in inland provinces in 14th FYP.
- For coastal provinces, they will focus on building nuclear and offshore wind projects.
- For central provinces, they will likely need to bring more imports.
- Bulk of new mega scale solar and wind projects will be built in the inland provinces, which is far away from the load centers. This implies that
 - more new ultra-high voltage (UHV) lines will need to be built.
 - more “flexible” trading across provinces will be required.
- At the distribution level, more investment will go to create “smart” grid solutions.

UHV projects commissioned in 2022: UHV DC: Shaanxi North-Wuhan, Yazhong-Jiangxi, Yunnan-Guangdong.

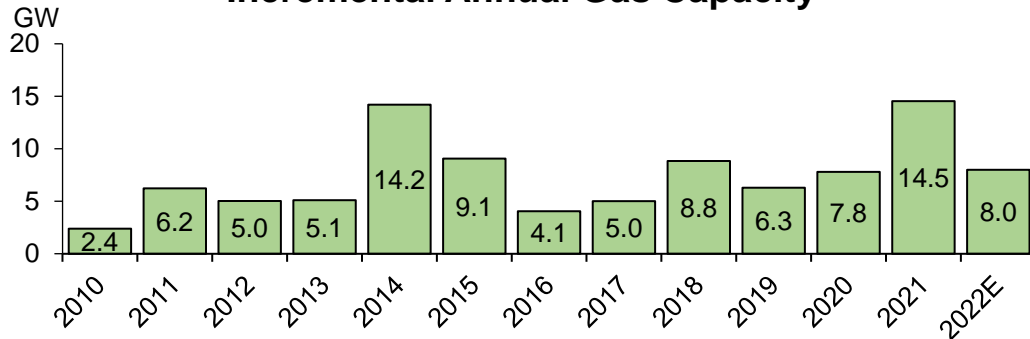
UHV projects under construction/advanced planning: UHV DC lines (Gansu-Shandong, Hami North-Chongqing, Tibet/Sichuan-Hubei, Ningxia – Hunan, Haxi-Central/East China; UHV AC lines: Zhumadian-Wuhan, Fuzhou-Xiamen)

Source: 14th FYP from State Council, State Grid, Southern China Grid, Various news clips, WaterRock Energy Research and analysis

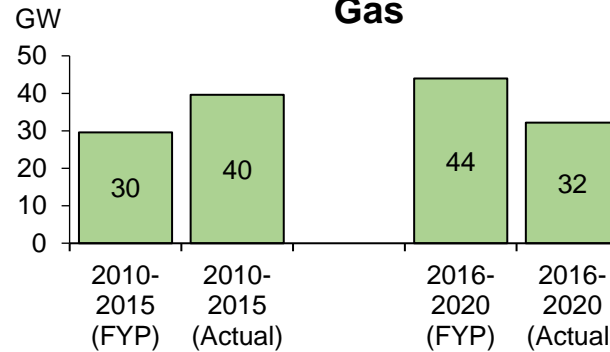
Flexible capacity Investment

There was under-investment in flexible capacity in 2010-2020, but expansion of hydro pumped storage and BESS has picked up

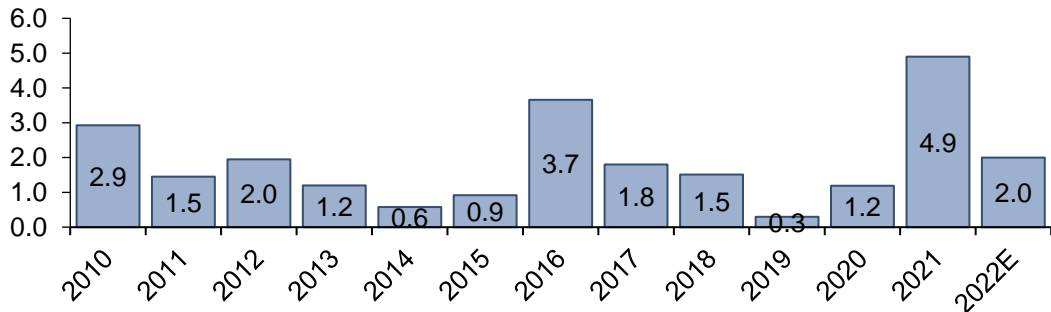
Incremental Annual Gas Capacity



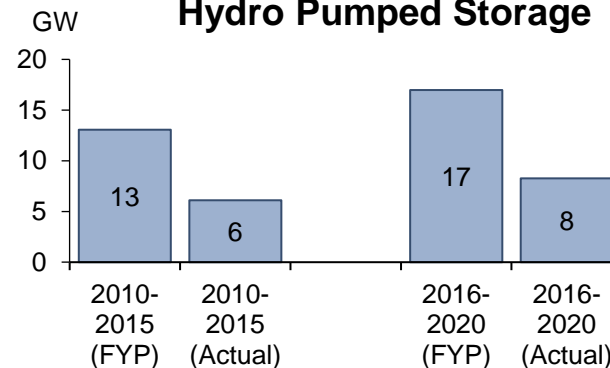
Gas



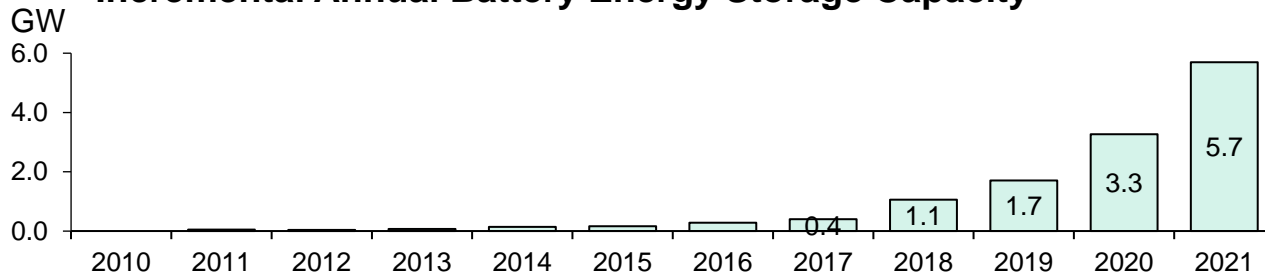
Incremental Annual Hydro Pumped Storage Capacity



Hydro Pumped Storage



Incremental Annual Battery Energy Storage Capacity



- Gas capacity can operate much more flexibly than coal.
- However, gas capacity expansion is lower than government's plan due to rigid on-grid gas tariff and issue on availability of gas.
- Expansion of hydro pumped storage was much slower than government's plan in 2010-20.
- Government revised revenue model and provided capacity payment to pumped storage capacity in 2021. The grid firms has been building pumped storage capacity since 2021.**
- BESS capacity expansion rate has picked up since 2020, mainly due to the mandatory requirement to bundle BESS capacity with new grid-parity solar and wind capacity.

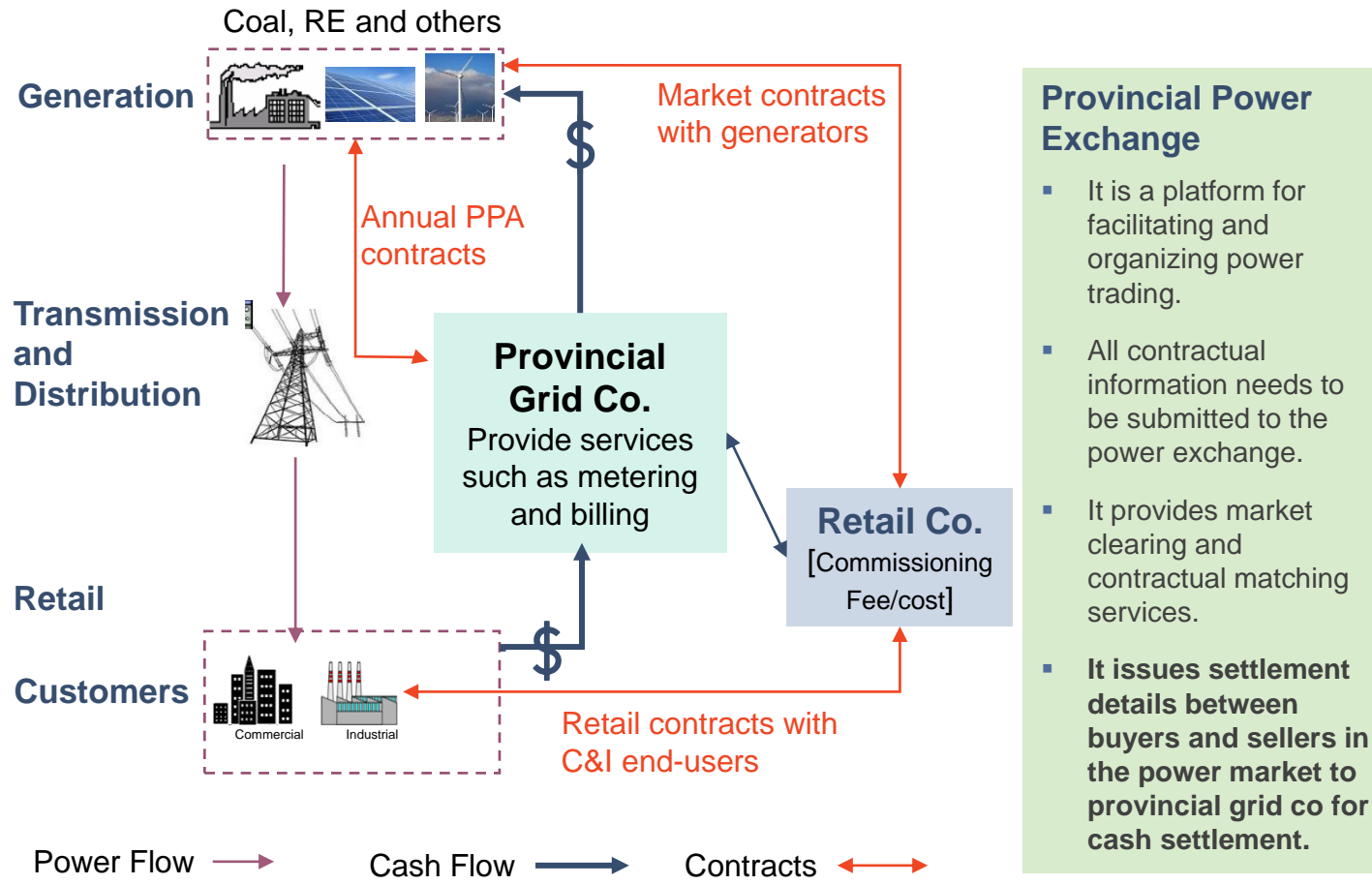
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Market Reform

Grid-parity wind and solar capacity needs to participate in the “market” although the exact regulation differs by province

Market Structure of the Chinese Power Sector



Within the provinces

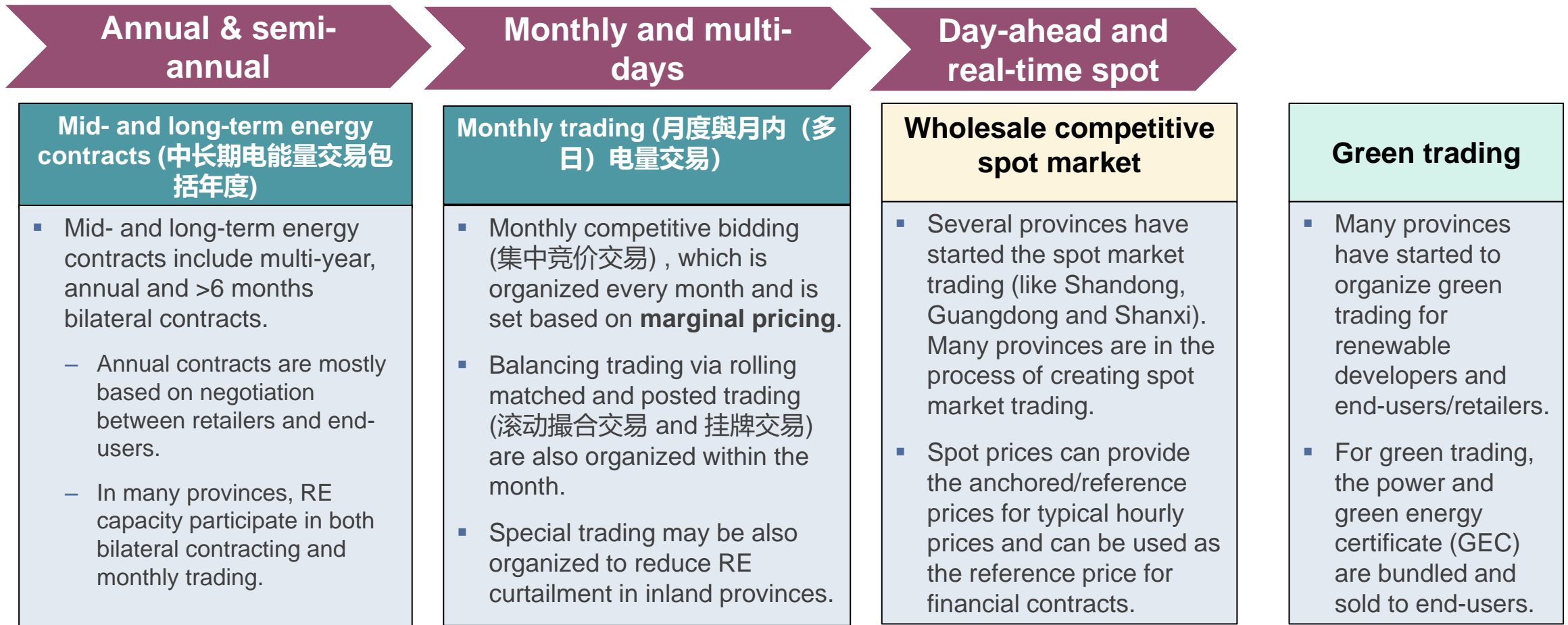
- **Generation:** All coal capacity needs to participate in the markets. Participation of wind and solar projects in the “market” varies by province. **The overall trend is that new grid parity wind and solar capacity will need to participate in market trading.**
- **Retail:** all C&I customers above 10 kV needs to enter the market from October 15, 2021 onwards in principle. The provincial grid company can help C&I customers purchase power from the market at the “third-party grid purchased tariff”.
- **Provincial power exchange** is a platform that organizes and facilitates power trading.

Across provinces:

- Largely based on government-to-government negotiation, but this will be also evolved to be more market based.

Form of Power Market Trading

There are several types of the market trading for coal and RE capacity in the Hunan power exchange

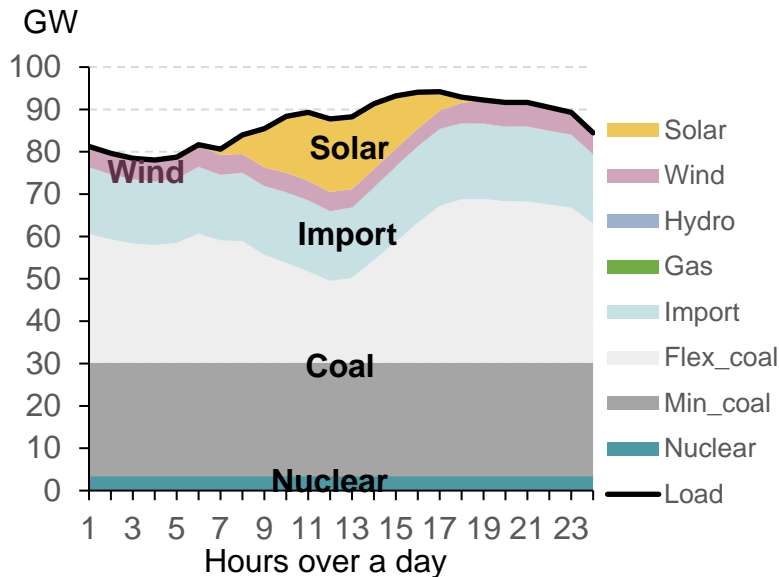


China is also rolling out cross-provincial trading in the regional grid and eventually in the national grid.

Market Tariffs in Shandong (Example)

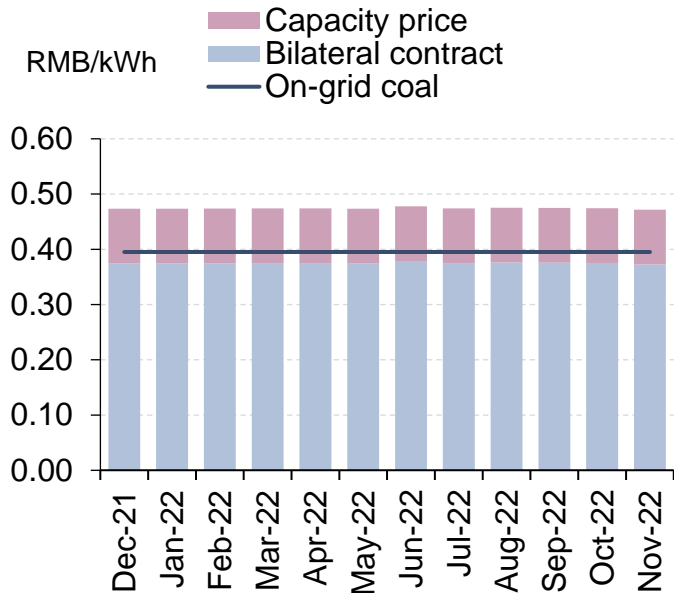
Grid-parity solar and wind projects get bulk of their “market” revenues from bilateral contracts, which has been traded at a premium in most provinces

Avg Hourly Gen Mix in Shandong (2022)



- Shandong has a “mini” duck curve shape due to the relatively high solar penetration in the local fuel mix.
- There is limited flexible capacity in the energy mix.

Bilateral Contractual Prices [80-90%]

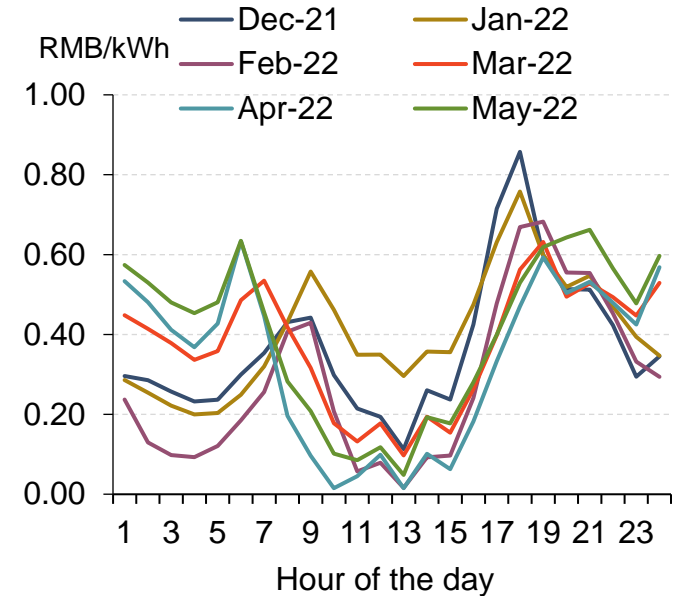


1

- The bilateral contractual prices reflect:
 - Local market fundamental
 - Cost of generation and
 - Non-hydro renewable portfolio standard (RPS)



Avg Real-time Hourly Spot Prices [10-20% of total volume]



2

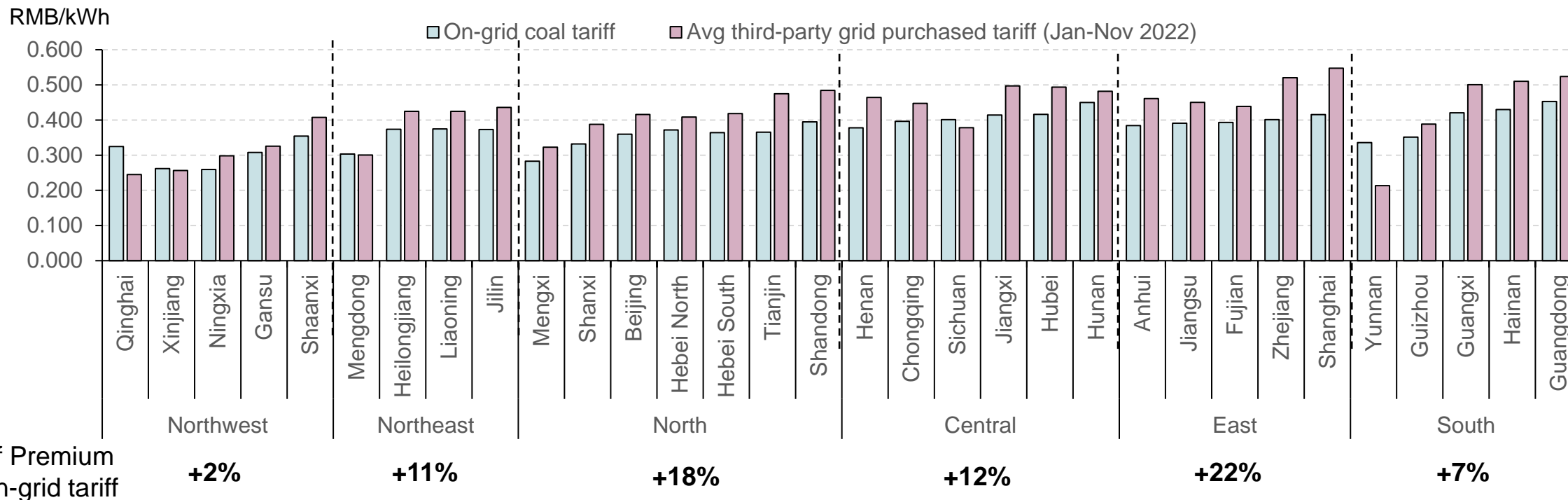
- The avg spot hrly prices in 11am – 3pm are the lowest, drive by high solar generation and rigid coal plant operation in Shandong.
- 10-20% of the volumes participate in spot market.

Note: *The capacity of utility-scale and distributed solar capacity has increased exponentially in Shandong, from around 1 GW in 2015 to 33 GW in end 2021. Such rapid solar penetration has led to the appearance of a duck curve shape for net load, making spot prices very low at 11 am – 3 pm when solar generation is high.
Source: Shandong Power Exchange, WaterRock Energy Research and Analysis

Proxy Market Tariff for bilateral contracts

Market tariff in most provinces is higher than the on-grid coal tariff, mainly driven by high coal prices and tightening market fundamental

Comparison of On-grid Coal Tariff and “Proxy” Market Tariff, including value-added tax (VAT)



- The higher market tariff largely reflects higher market trading prices of coal-fired power plants in the local provinces.
- Nonetheless, based on our detailed analysis and forecast of renewable tariff for >10 provinces, the market trading tariff for grid-parity solar and wind projects in most provinces are higher than local on-grid coal tariff in 2022.

Market Trend – Market Power

Three out of the four key tariff drivers are on the upward trend, so it is likely that tariff will be up in the near- and medium-term

Key Drivers

Latest Market Development

1

Supply and Demand Market Fundamental



- Tighter market fundamental driven by high demand growth but slow-down in coal capacity addition in 2017-2021.
- Gas is becoming a more important fuel as a flexible fuel in coastal provinces.
- Ongoing market reform means that market tariff will increasingly reflect the tightening market fundamental across China.

2

Coal and gas prices



- **Both coal and gas prices will be higher than the level seen in 2017-2020 :**
 - Cost of producing coal will increase because of (much) stricter regulation on safety and environmental emission.
 - Share of gas import will likely continue to increase, and the Asian gas prices are moving upwards.
- Labor, water and material costs will increase in nominal term in the future.

3

Carbon prices/taxes



- The amount of free carbon allowances will be reduced over time, so a positive carbon price/tax will likely be imposed on thermal producers.

4

Technological improvement

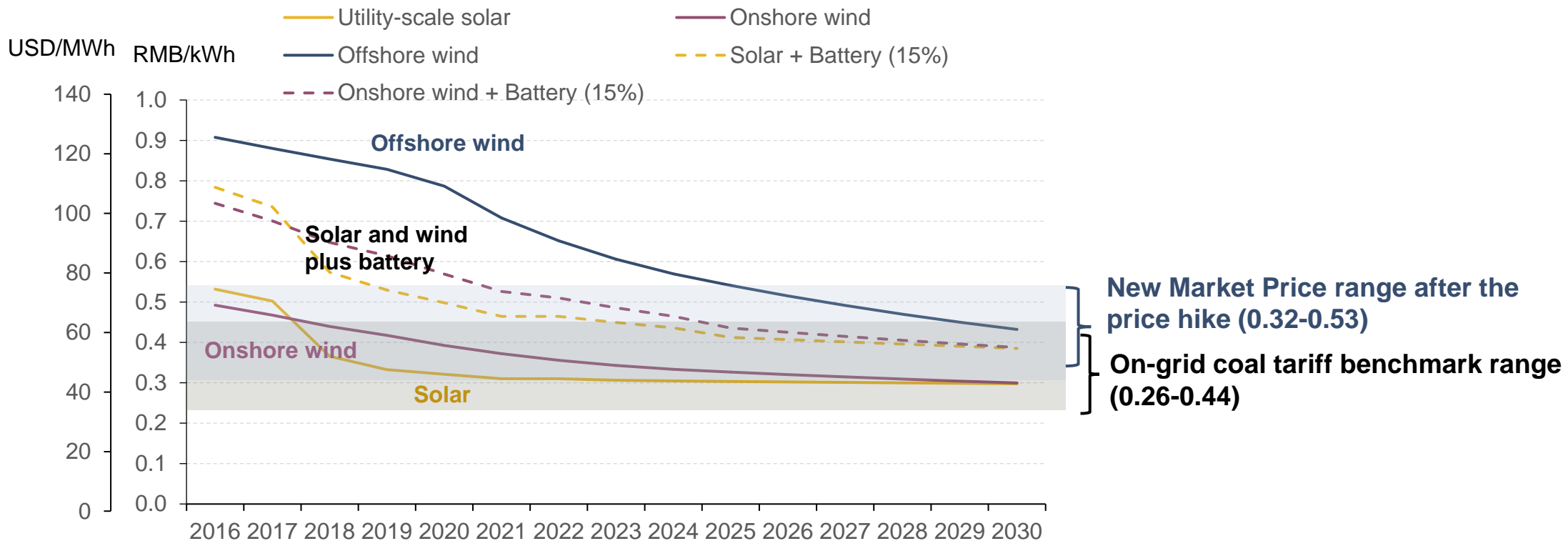


- Cost of building new solar, wind and battery energy storage capacity will continue to drop, mitigating tariff increase.
- Cost for non-technological components (like land and labor costs) will increase over time.

Economics of New Solar and Wind

The recent increase in market tariff can help to incentivize more wind and solar capacity expansion

Levelized Cost of Energy (LCOE) of Different Technology (Ex-tax)



- Future onshore solar and wind capacity expansion will be mainly driven by economics as they are more cost competitive than new coal projects.
- New offshore wind projects may need local subsidies or “special” tariff, but they are largely more competitive than local gas plants.

Special Initiatives for RE

Grid-parity solar and wind projects have potential revenue upside by selling carbon credits or green energy certificates

Carbon Market

Trading started in the power sector but limited impact

- The national carbon market has started trading since early July 2021, and the **market prices have been 40-60 RMB/tonne-CO2 (i.e. USD 6-10/tonne)**. Trading of China Certified Emission Reductions (CCERs) has also started. Prices have been below 40 RMB/tonne.
- Large state-owned power companies largely do their internal balancing to meet their carbon emission target, so trading volume has been relatively small.
- Over time, as the national carbon market is open to more sectors, there will be likely more liquid trading on carbon credit.

Green Trading and GEC Trading

Positive development

- Each province has an obligation to meet its non-hydro renewable portfolio standard (RPS), which has been increasing 1-2 percentage point each year.
 - Local governments need to come out with local renewable policies to incentivize investment and local consumption of renewables to help meet local RPS. For example, Xinjiang government issues a local policy to provide a floor price for solar and wind capacity, which is set at a price higher than the on-grid coal tariff.
- Since September 2021, China has started **green trading (bundled generation volume and green energy certificate)**, allowing corporates to directly purchase green power from wind and solar capacity.
- The green premium is typically **0.01-0.04 RMB/kWh**.
- Green energy certificates (GECs) can be also traded separately, but its trading is not liquid.

Agenda

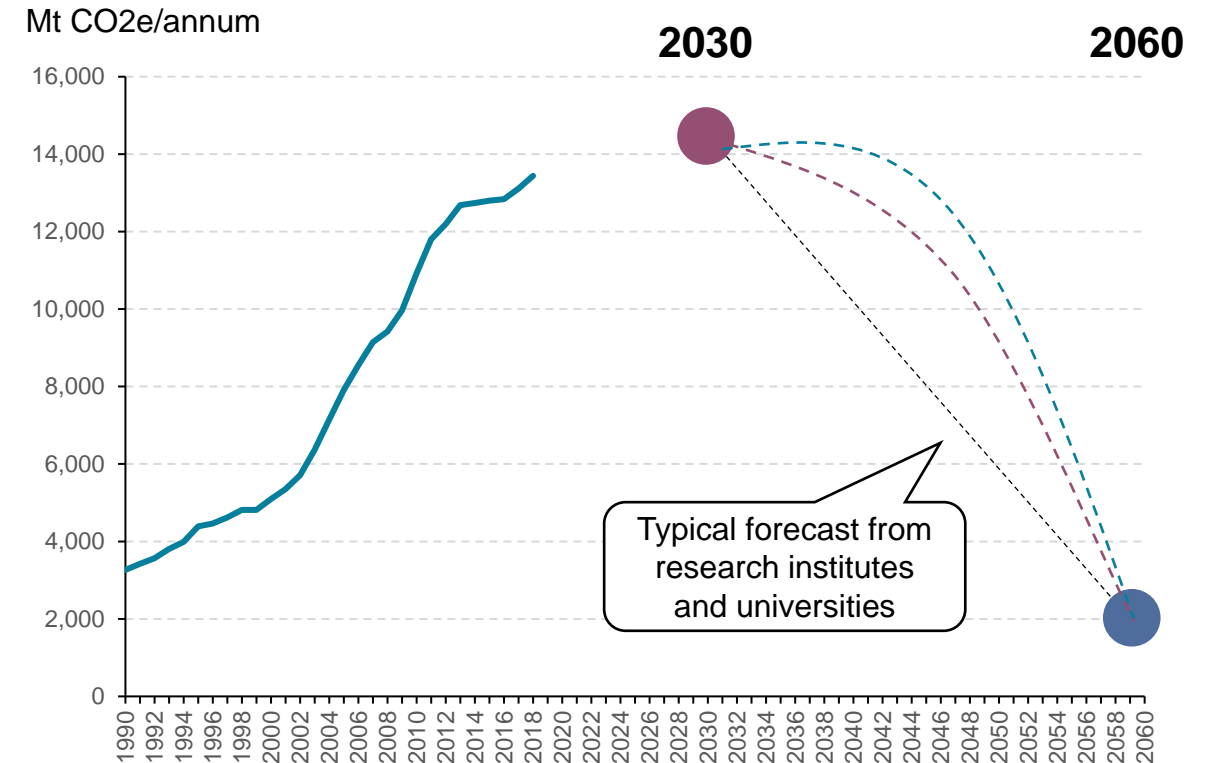
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Carbon Neutrality Target

The 2060 carbon neutrality target sets the direction for de-carbonization in the long term

- President Xi Jinping UN Address on Sep 22, 2020
 - CO2 emissions **peak before 2030** and **achieve carbon neutrality before 2060**
 - “..... achieve a green recovery of the world economy in the post-COVID era....”
- **Non-fossil fuel mix** targets in primary energy consumption in 2014 under COP 21 Paris Agreement
 - **2020: 15%** [Actual non-fossil fuel mix is 9.4% in 2010 and 15.3% in 2019]
 - **2030: 20%**.
 - Propose to **peak CO2 emission around 2030** and make efforts to peak earlier if possible.
- Statements in the 20th National Congress in Oct 2022
 - **The 2030 carbon peaking and 2060 carbon neutrality targets are not changed.**

CO2 Emission in China

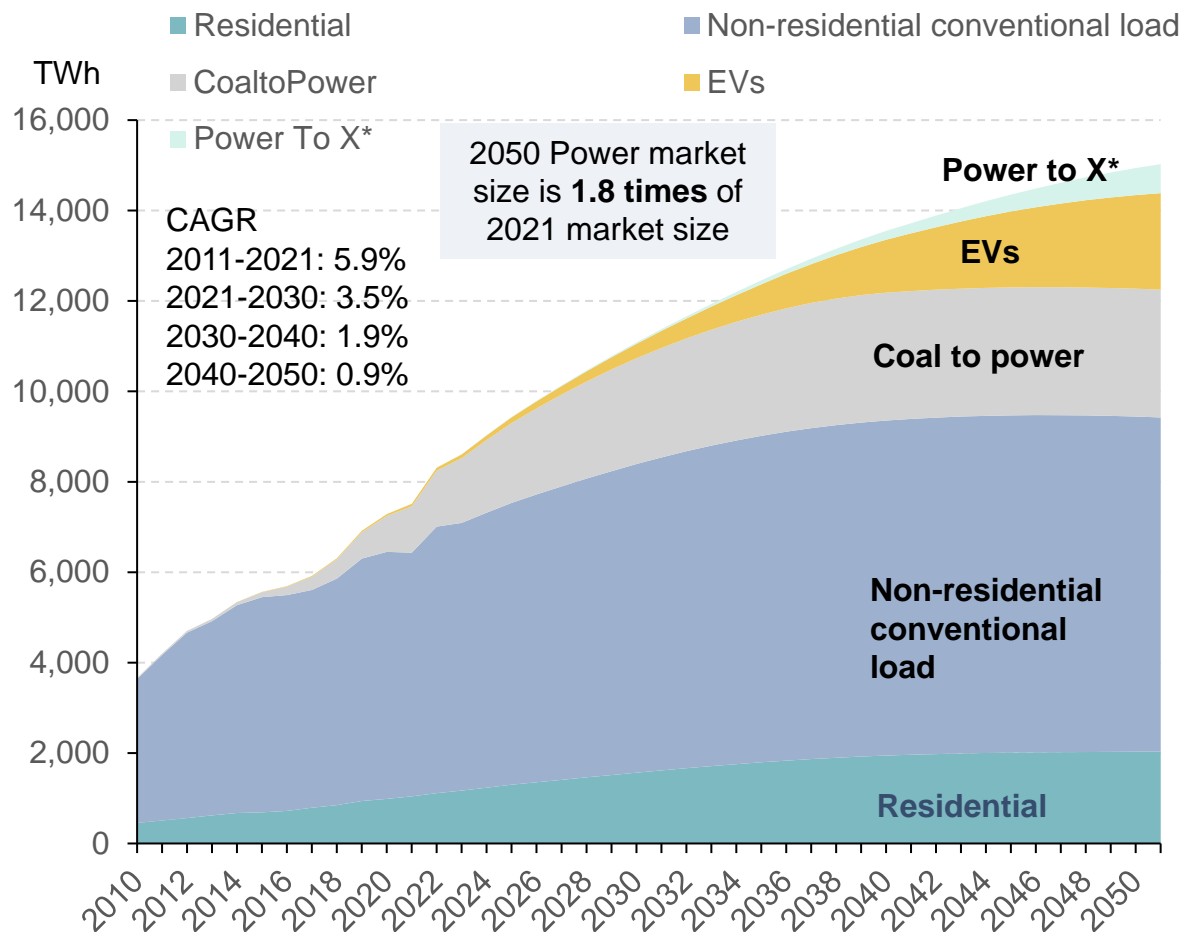


Source: Climate Action Tracker, WaterRock Energy Research and Analysis

Energy mix: Demand

Load growth will slow down but still at modest rate in the long-term, so tariff needs to at least reflect cost with reasonable profit to incentivize investment

Power Consumption (WaterRock)



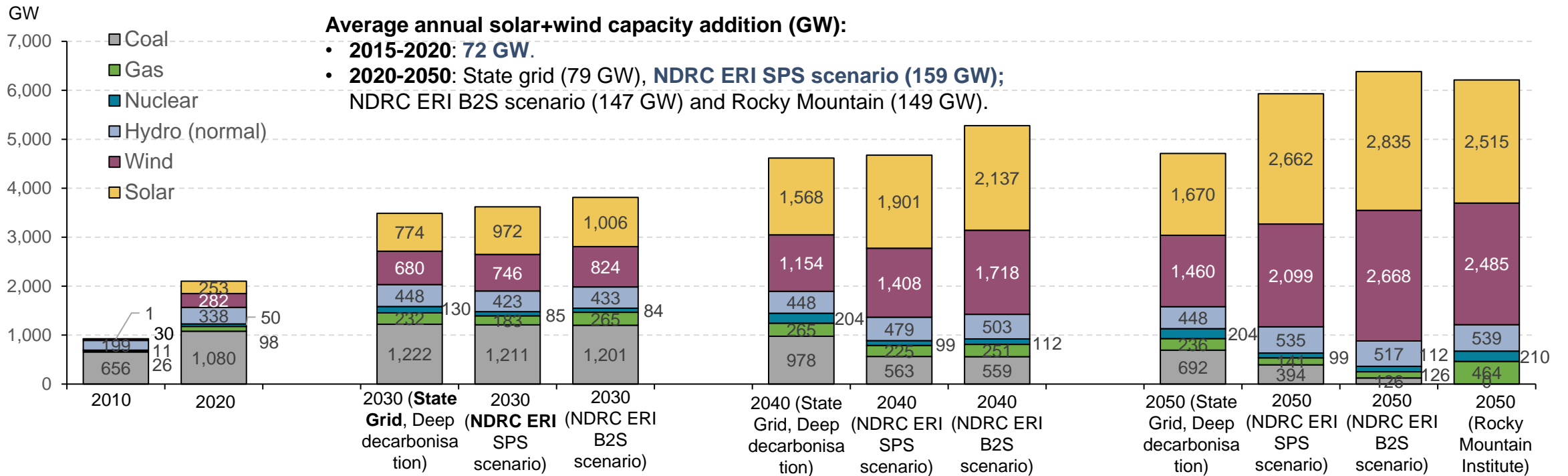
- Power demand is expected to continue to grow, partly driven by the electrification of the economy.
 - 2014-2030:** Ambitious effort to switch the decentralized use of coal to electricity in residential, commercial and industrial sectors have become one of the key drivers, leading to high power demand growth for the period.
 - Post 2030:** Increasing penetration of electric vehicles (EVs) will be one of the key drivers for demand growth from 2025 onwards; hydrogen production (i.e. power-to-H2) will likely become a new driver for power consumption growth after 2040.
- However, the power consumption growth rate will still decline over time as
 - Increasing focus on energy efficiency and efficiency gains from replacing old equipment with new will lower the energy consumption in the different sectors, particularly in the industry sector.
 - Economic activity will shift from heavy industry towards high tech industry and services.

Note: *Power-to-X is power to hydrogen or power to other chemicals, which can be used to replace fuels in the non-power sectors. Source: Historical Data (CEC), forecast is based on WaterRock Energy internal research and analysis.

Forecast from NDRC and State Grid

Total supply capacity can more than double from 2020 level by 2040 and possibly triple by 2050

Forecast of Power Supply from Different Organizations



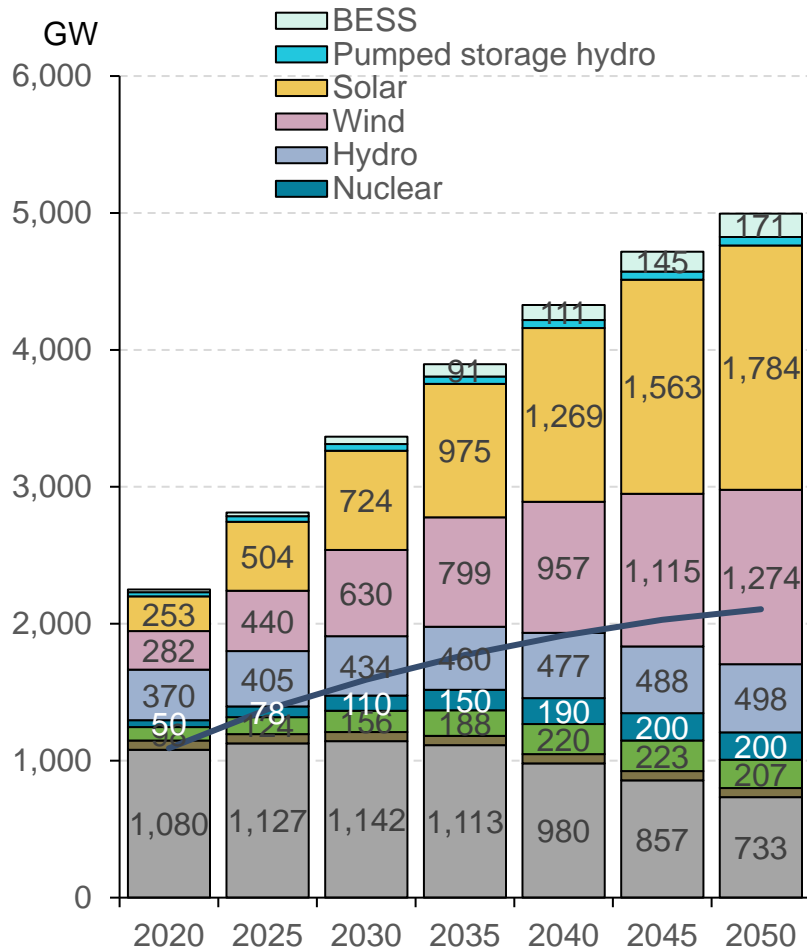
- **Thermal:** Consensus is that 10-20 GW of annual *net* coal capacity will be still added in 2021-2030. Gas addition will be moderate.
- **Nuclear:** Capacity will be expanded, but cap around 200 GW due to site availability in coastal provinces.
- **Hydro:** Capacity is likely capped at 450-540 GW due to hydro resource limitation.
- **Solar and wind:** Forecast varies, but pace of wind and solar expansion is expected to be (much) faster than 2010-2020 period.

Source: Estimates by WaterRock Energy based on State Grid (*China Energy and Electricity Sector Outlook 2020*, 中国能源电力发展展望2020, published in Dec 2020); NDRC Energy Research Institute (*China Renewable Energy Outlook 2020*, published in April 2021); Tsinghua University, Institute of Climate Change and Sustainable Development (*China's Long-term Low-carbon Development Strategy and Pathway*, published in Oct 2020); Rocky Mountain Institute (*China 2050: A Fully Developed Rich Zero-carbon Economy*, published in April 2021).

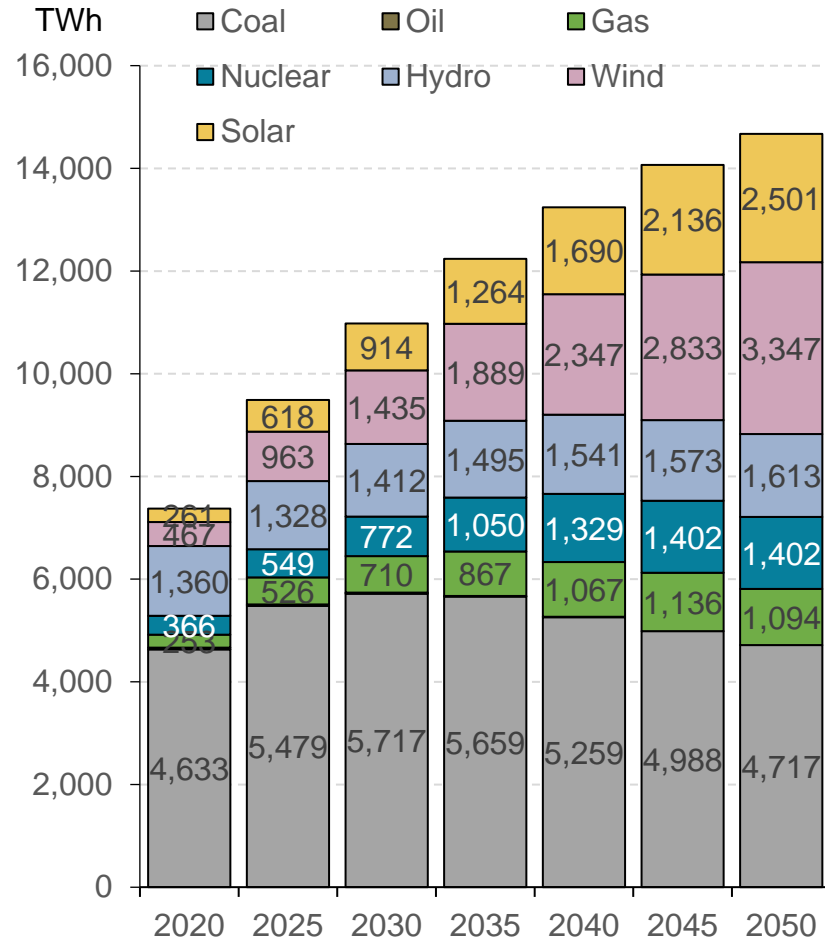
Energy mix: Supply

Wind and solar will be expanded 1.5-2.0 times of the expansion rate seen in 2016-2020, but some thermal capacity will remain

Capacity Fuel Mix



Generation Fuel Mix

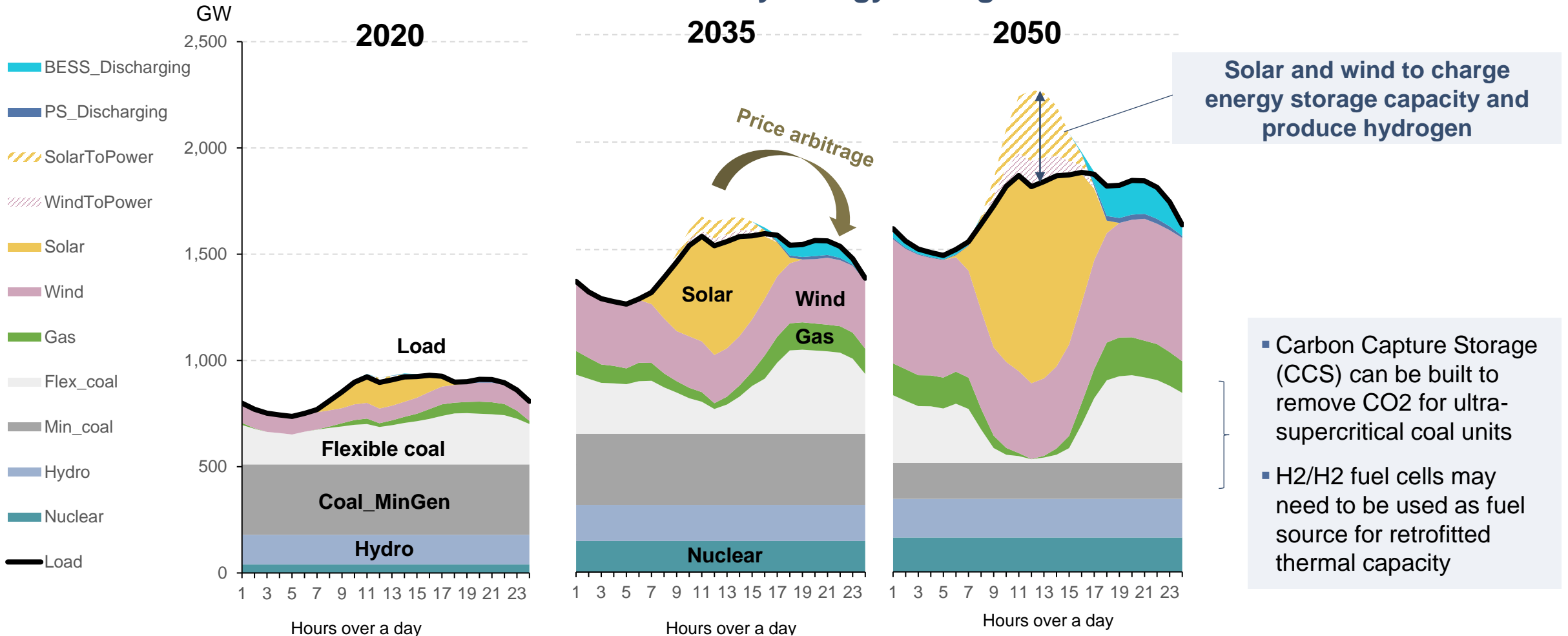


- Zero carbon emission resources will increase their generation share from 33% in 2021 to 65% in 2050.
 - In the medium- and long-term, average annual capacity addition is 45-55 GW for wind and 50-80 GW for solar, 1.5-2.0 times of the solar and wind capacity expansion rate in 2016-2020.
 - Annual capacity expansion of energy storage facilities (pumped storage and battery energy storage) could be 10-20 GW in 2021-25 and then increase to around 30 GW to integrate RE after 2025.
- CCS, H2 and carbon offsets need to be adopted to help reach net carbon zero.

Typical Hourly Load and Generation

Flexible capacity will become increasingly important to help integrate higher renewable penetration in the power system

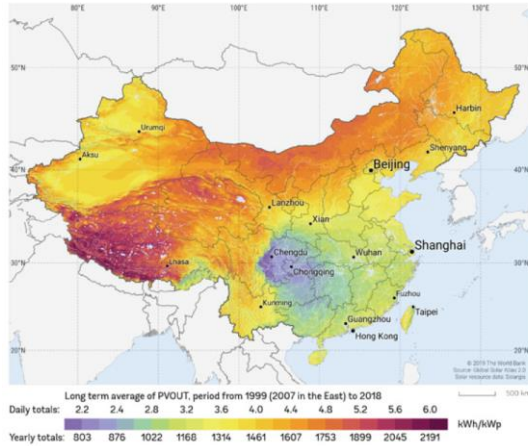
Power Balance Without Consideration of Battery Energy Storage and Power-to-X*



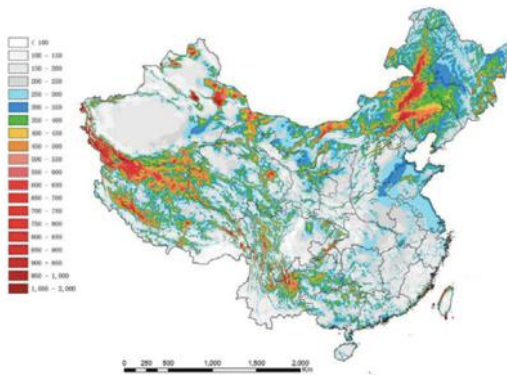
Grid infrastructure

Most of onshore solar and wind resources are concentrated in the inland provinces, so it is expected that more UHV lines need to be build

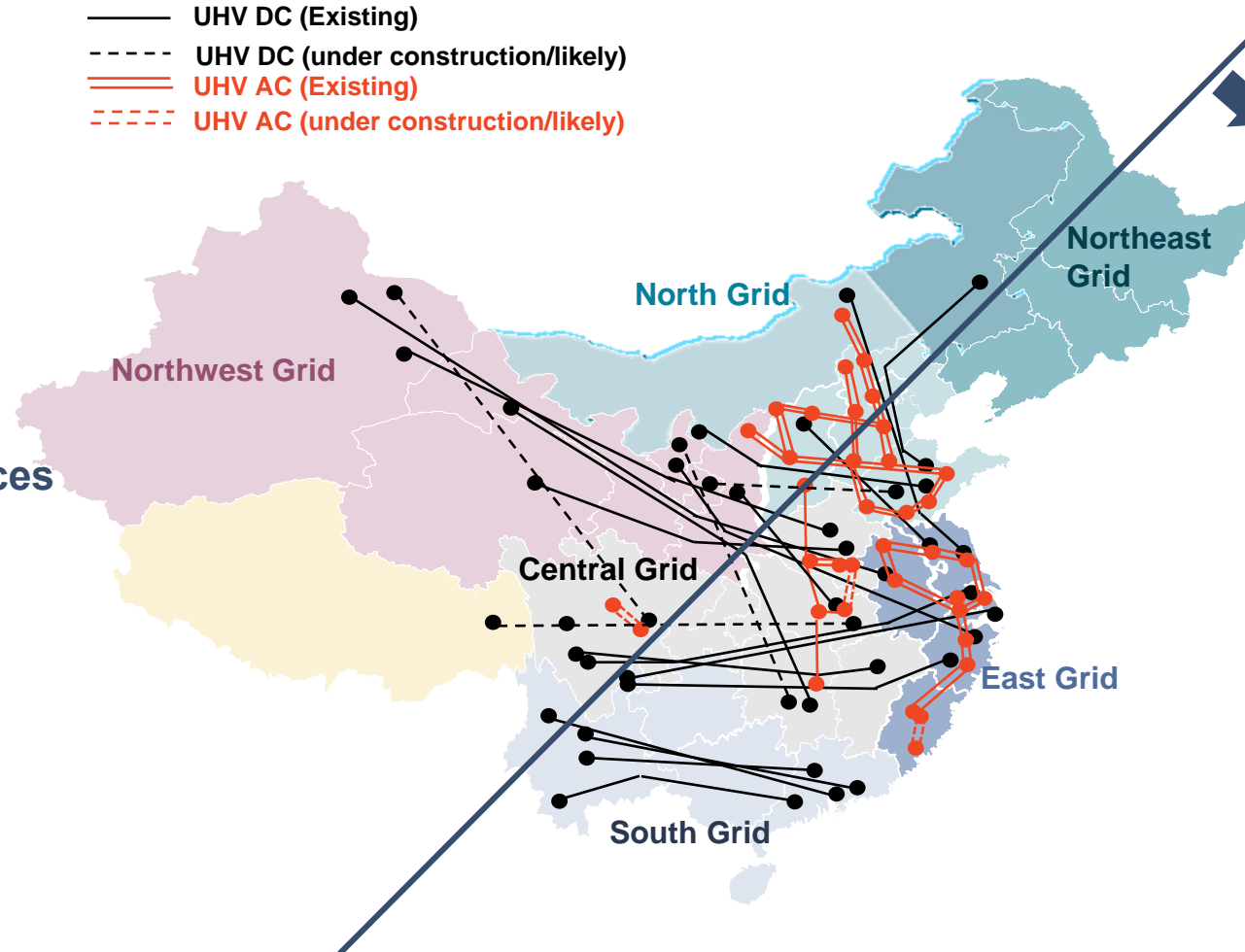
Solar PV power potential



China's onshore wind resources



Six Regional Grids and UHV Lines in Mainland China



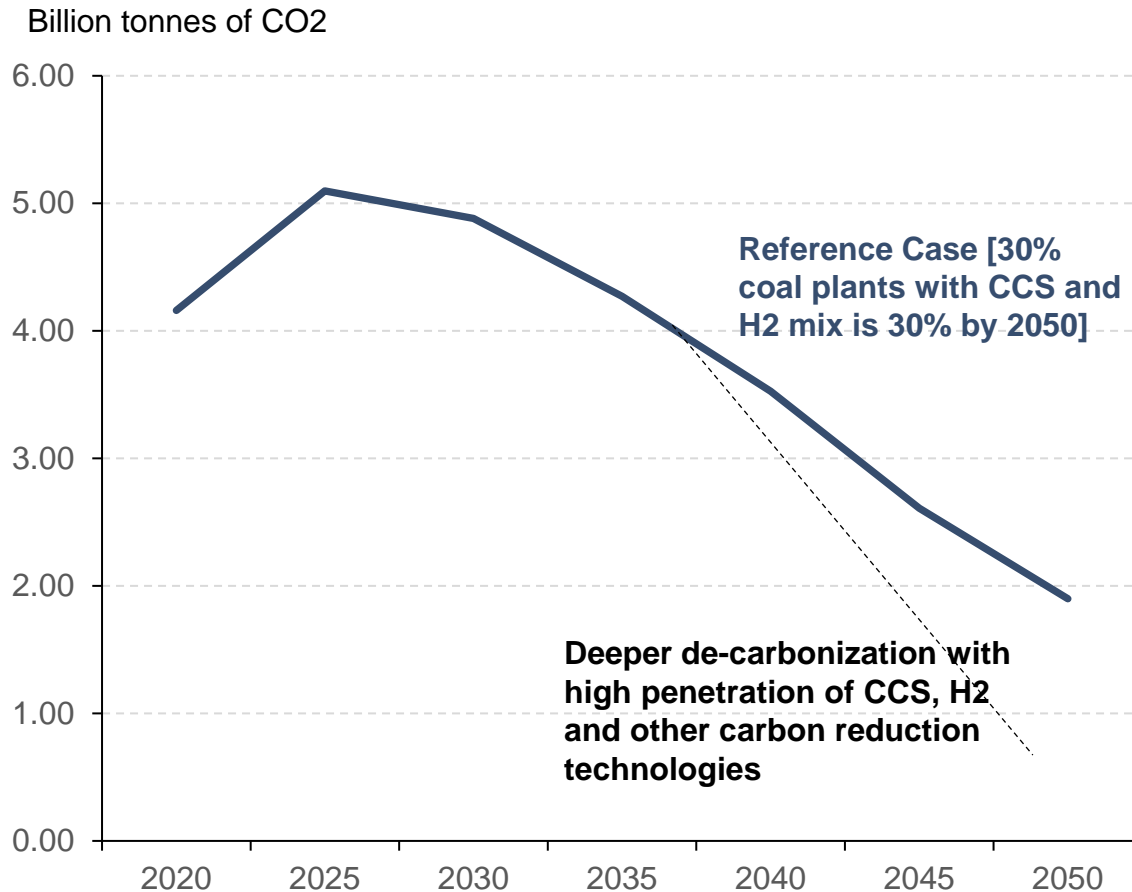
Hu Huanyong Line

Eastern side has 43% of China's land size, 93% of population, 94% of GDP.

Carbon Emission

The new supply capacity will be mostly zero carbon emission technologies, and adoption of CCS and H2 will be also needed to help achieve carbon neutrality

CO2 Emission from the Power Sector in China



To bend the CO2 emission, zero/low carbon emission technologies need to be built to meet the growing demand and replace coal generation.

- **Hydro:** Most of the easy hydro resource is already exploited. Some large hydro power capacity can be further expanded in Sichuan and Yunnan, but the pace will be (much) slower
- **Nuclear:** The technical limitation on nuclear capacity expansion in China is mainly related to site availability. Its capacity **is likely capped around 200 GW in the long term**, if nuclear capacity can only be sited in the coastal provinces.
- **Onshore utility-scale wind and solar:** Due to the resource endowment and the land availability, the bulk of mega projects will be built in the inland provinces (Northwest, Inner Mongolia and Northeast)
- **Offshore wind:** coastal provinces will push further for offshore wind projects.
- **Distributed solar:** Distributed solar will be built across China. The government has been encouraging rural towns to build distributed solar to help meet their local load.

Note: For our reference case, we assume that about 150 GW of remaining coal capacity have Carbon Capture and Storage (CCS) (i.e. about 30% of the total coal capacity in 2050), and blue/green hydrogen makes up 30% (in calorific value) of gas fuel consumption in 200 GW of gas capacity in 2050.

Source: WaterRock Energy Modelling and Analysis

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Summary

Solar and wind capacity expansion rate will continue to be fast, and much more flexible capacity, UHV and “smart” grid infrastructure solutions are required

Power Shortage:

- Seasonal power shortage in central and coastal provinces will likely continue in the near- and medium-term because of the structural shortage of flexible capacity and “rigid” trading regime of power imports/exports across provinces.
- The market reform on cross-provincial trading and regulatory changes to incentivize investment of hydro pumped storage and BESS can help to gradually resolve the power shortage situation.

Market price and market reform:

- Higher “market” prices will likely help to incentivize faster capacity expansion of solar and wind capacity around China. The introduction of green market trading will also provide potential upside for wind and solar capacity.

De-carbonizing the Power Sector and Its Implication

- Electrification of the economy, residential demand growth and expansion of data centers will help to drive demand growth at 3-5% in the medium-term and 1-3% in the long term.
- Solar and wind capacity expansion needs to be 1.5-2.0 times of the expansion rate seen in 2016-2020 to help bend the carbon emission profile from the power sector.
- Much faster expansion of energy storage capacity and grid infrastructure are also required to help integrate increasing capacity and generation share of intermittent renewable sources in the grid system.

Thanks and Contact

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Liutong has over 14 years' experience of providing advisory services on the power and gas market in China and ASEAN electricity markets.

He has in-depth knowledge in greater China region, including forecasting of solar and wind curtailment and power tariffs, asset valuation and evaluation of opportunities/risks of investing in renewables and gas infrastructure in mainland China, Hong Kong and Taiwan.

He has also been extensively involved in the market design of a Forward Capacity Market in Singapore since early 2019. In the Philippines, he was invited to present to the Philippines' Energy Committee of the Senate and Philippines' House of Representatives on the role of natural gas and economics of building new LNG terminals in early 2020.

He holds a Bachelor of Chemical Engineering with first class honours from the National University of Singapore (NUS). He is fluent in English and Mandarin.

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Transaction support, market analysis, regulatory support, Tariff benchmark

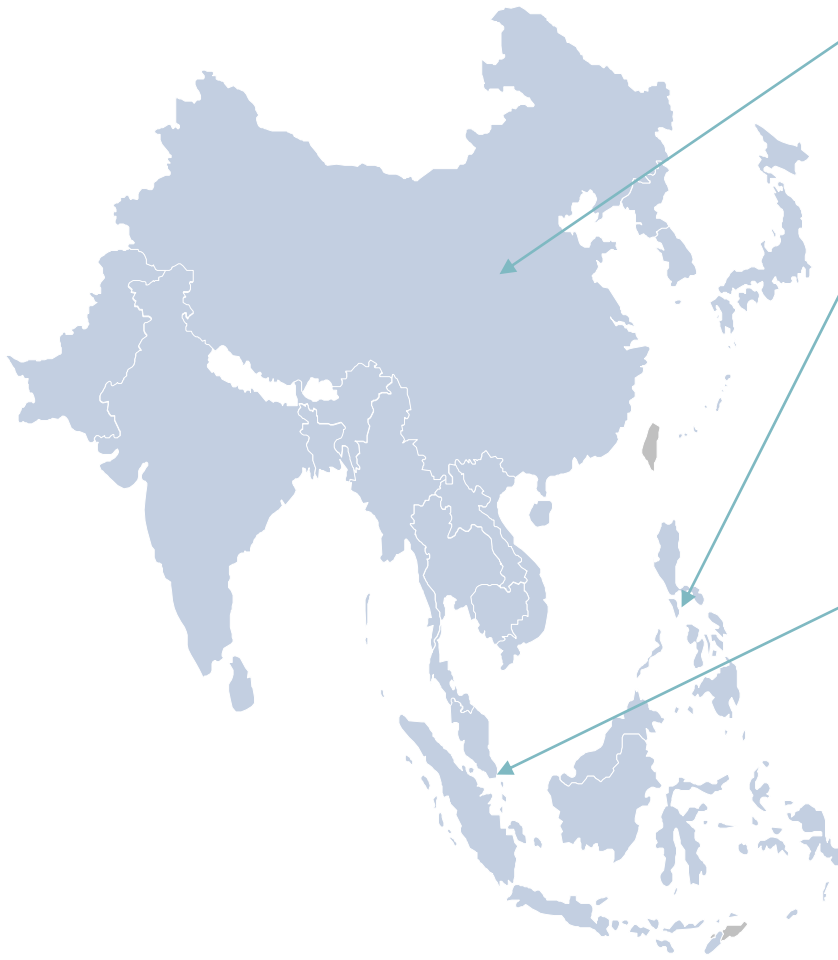
Strong client base

Regulators, grid companies, utilities, PE funds, financial institutions, gas suppliers and importers

Our Key Clients (since July 2018)



Extensive Experience in ASEAN and China Power and Gas Markets



For foreign investors and gas exporters to mainland China, Taiwan and Hong Kong:

- More than 10 GW of due-diligent studies on issues such as regulatory risks, fundamental power supply ad demand, renewables curtailment and tariff forecast
- Multiple detailed provincial level natural gas studies on key drivers of gas demand, economics of gas-to-power and opportunities of selling LNG to greater China region.

For both domestic and international players in the Philippines:

- More than 5 GW of due-diligent studies on thermal and renewables plants.
- Multiple studies on the opportunities and risks of investing in LNG terminals.

For Singapore regulators:

- Energy market design issues such as market power mitigation and resource adequacy studies
- Fuel mix and carbon emission related projects

For existing generators, large consumers and potential investors:

- More than 2 GW of due-diligent studies on wholesale electricity price and end-user tariff forecast; modelling support to existing Gencos
- Over-contracted gas and financial sustainability issues.

Regional studies:

- Multiple studies on investment opportunities in the electricity sector in Asia
- Multiple studies on regional gas market and opportunities of selling LNG to Asia.