Power Transition in China: 1.5/2℃ Scenario, Pathways and Challenges

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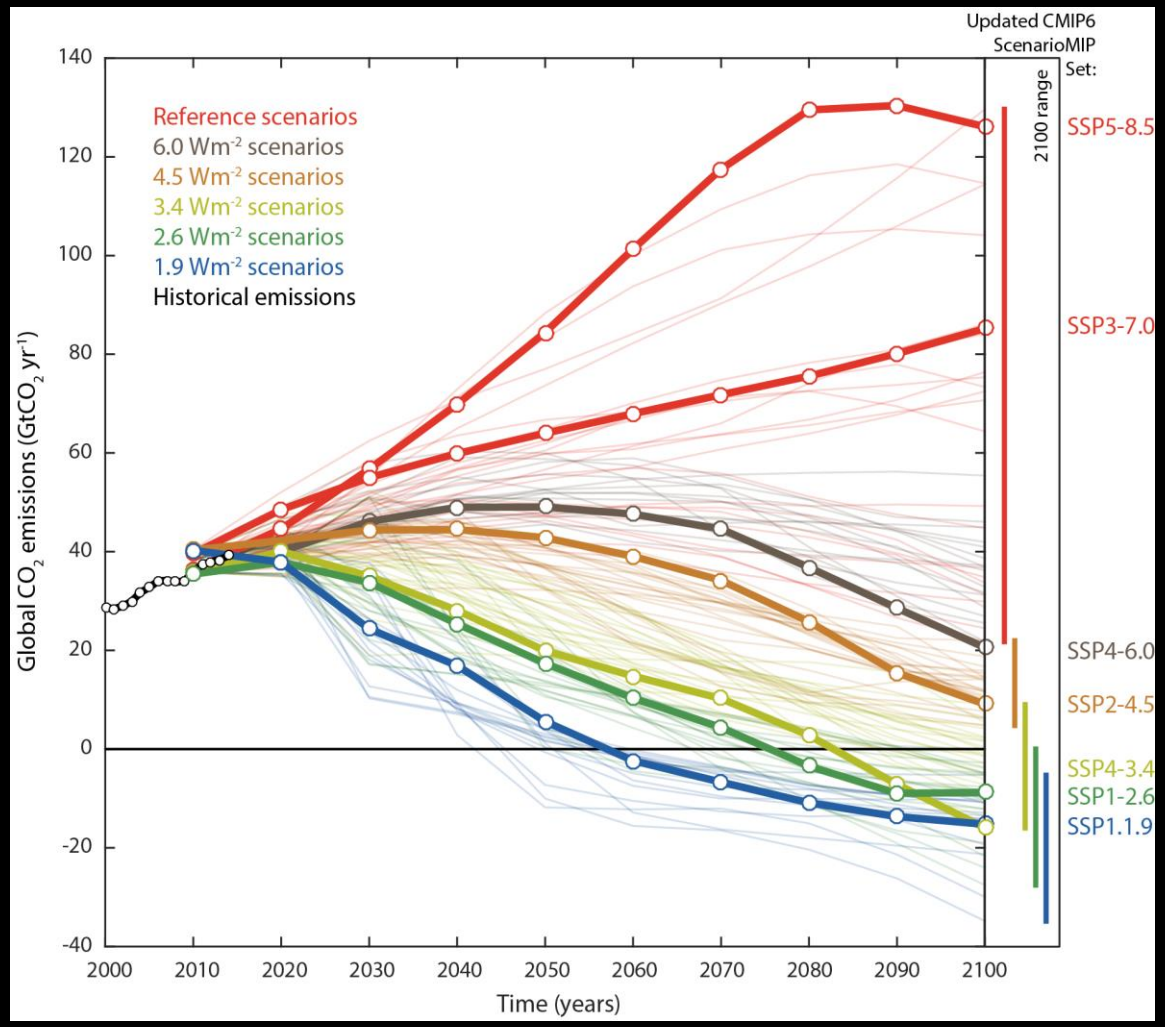
2019.06

Scenarios

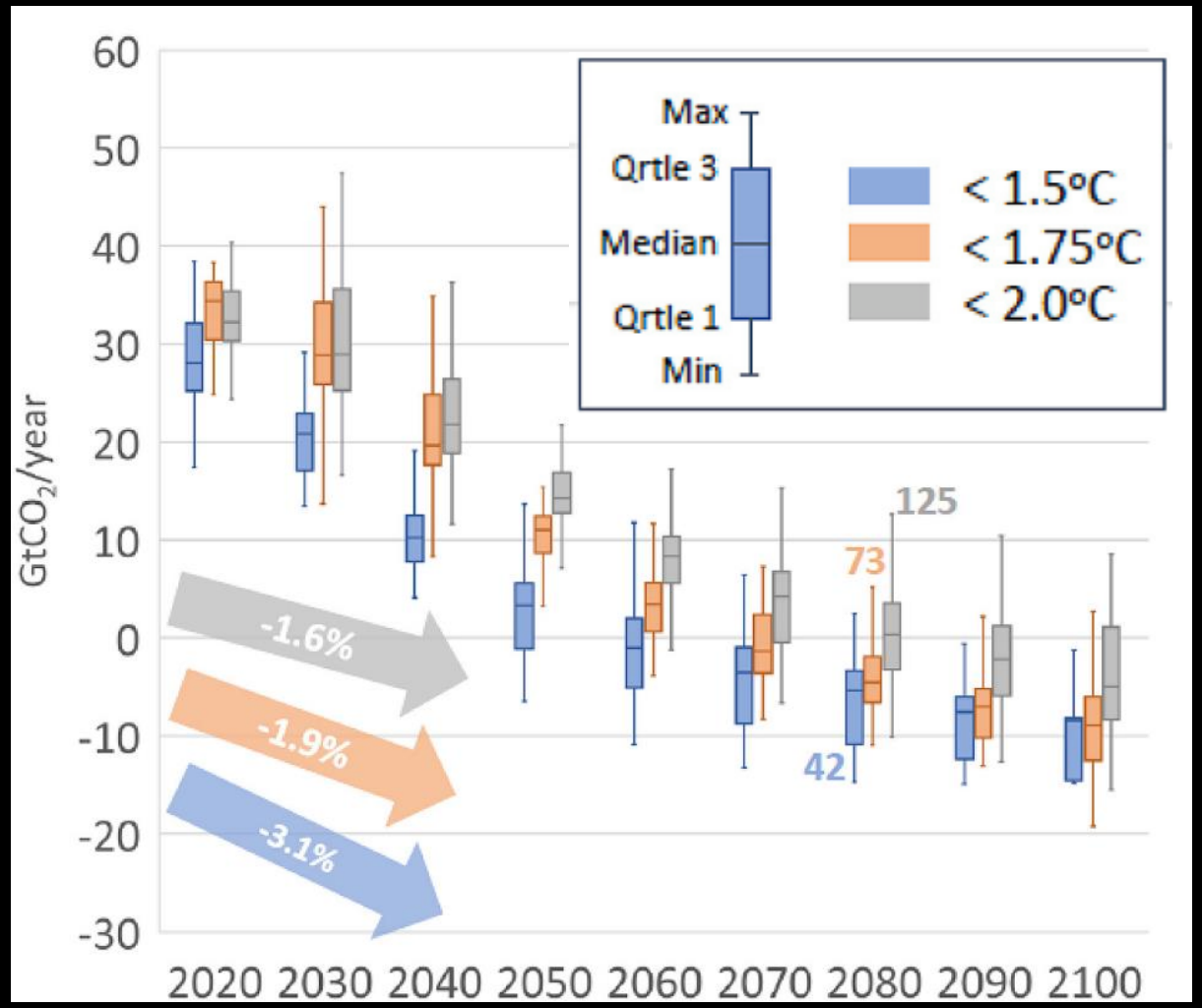
Global carbon budget for 1.5/2℃ scenario

✓ **Global power/energy sector must decarbonize under the frame of carbon emission cap in 1.5/2 ℃ scenario.**

Global carbon emissions in various scenarios



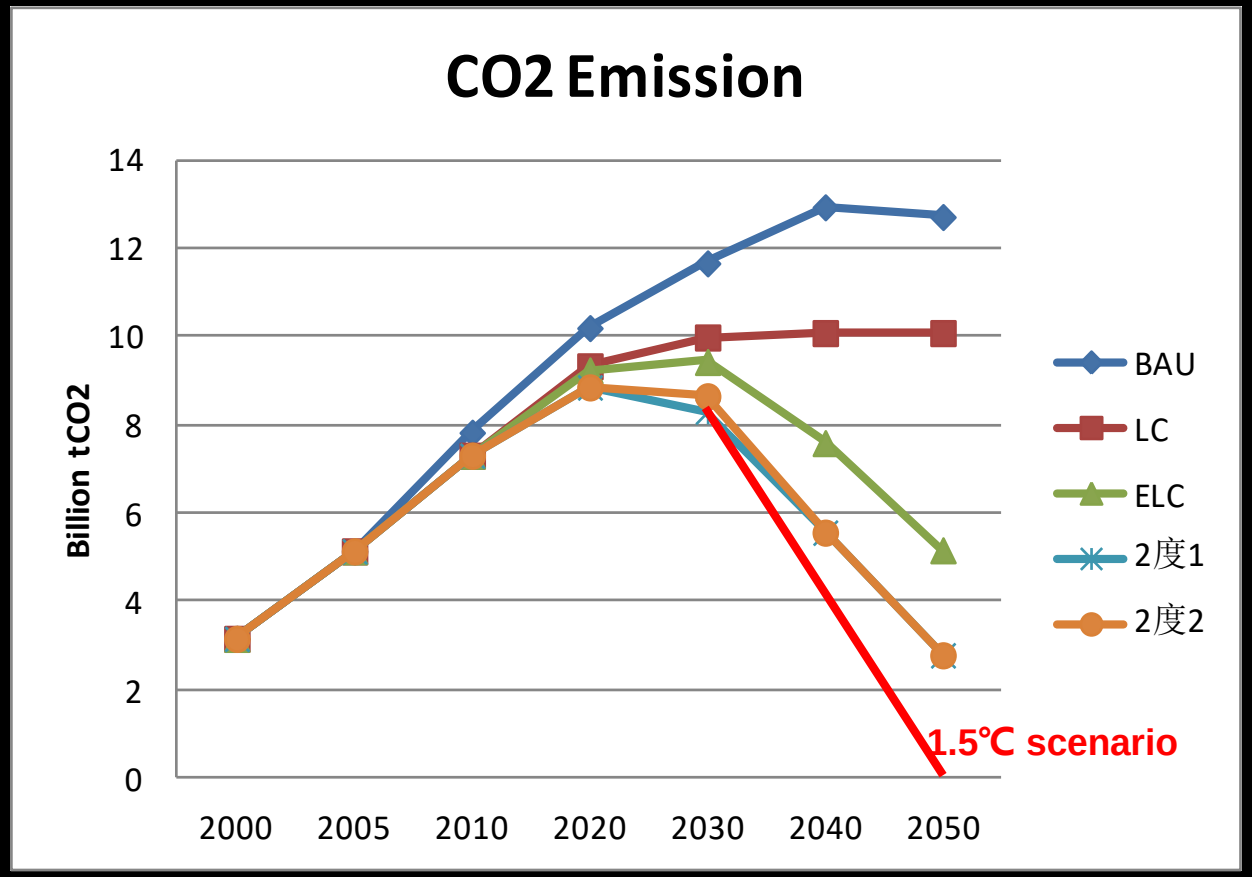
Annual fossil fuel and industrial process CO_2 emissions

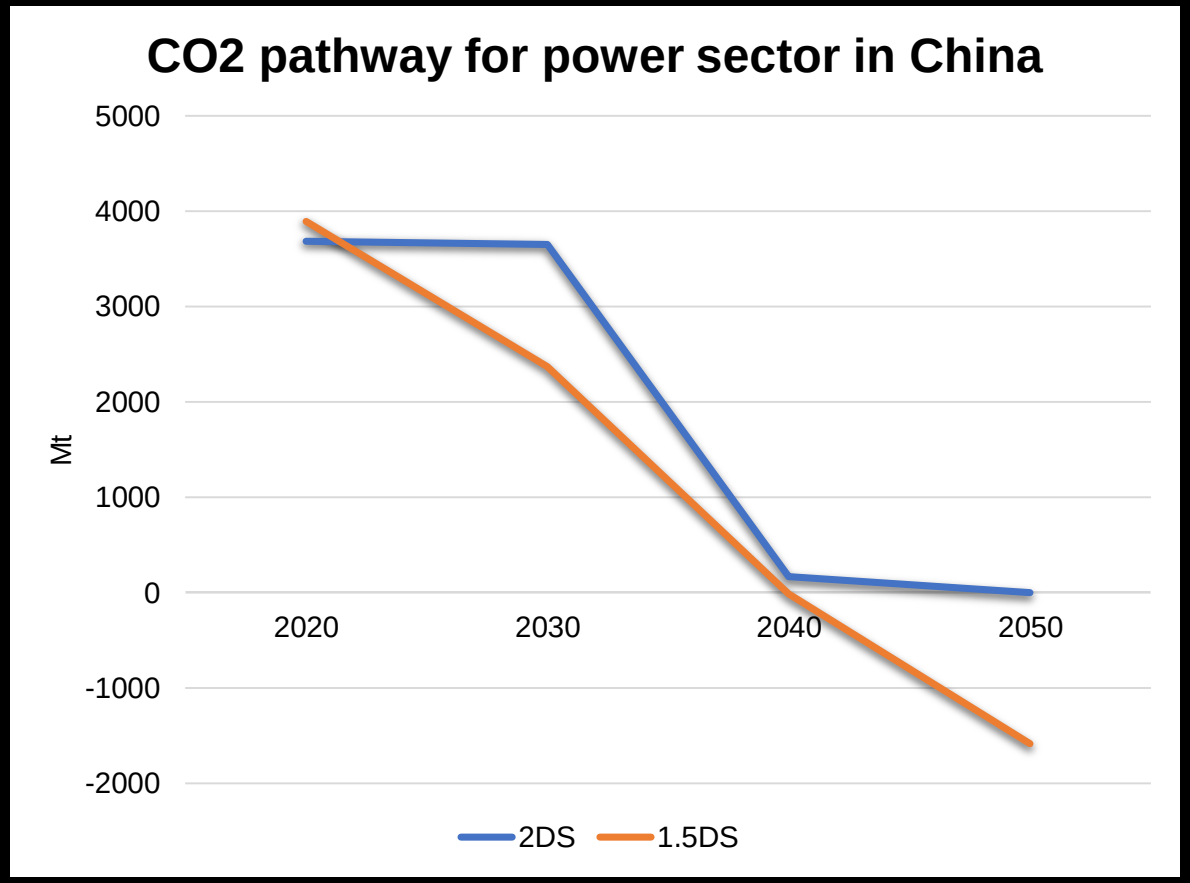


Source: IPCC; Gambhir (2019)

Carbon budget for 1.5/2℃ scenario in China

- ✓ Power sector accounts for **50%** of total CO2 emissions in China.
- ✓ 1.5/2℃ scenario necessitates the zero-emissions and even negative-emissions for power sector by 2050.

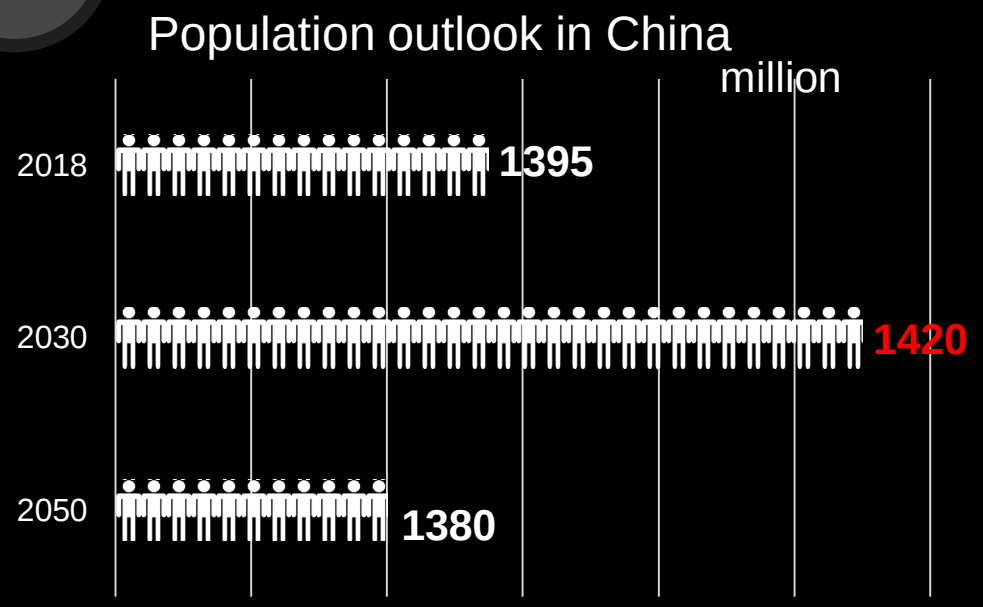


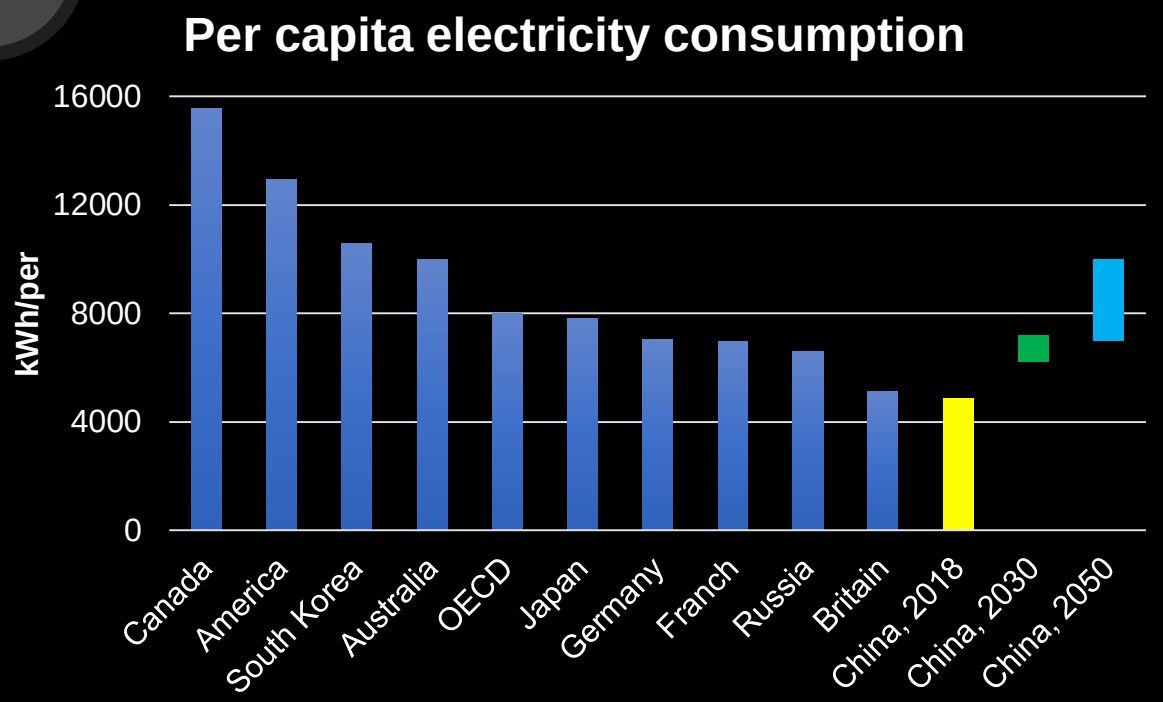


Source: 1.5℃ report - NCEPU

Hypothesis for 1.5/2℃ scenario in China

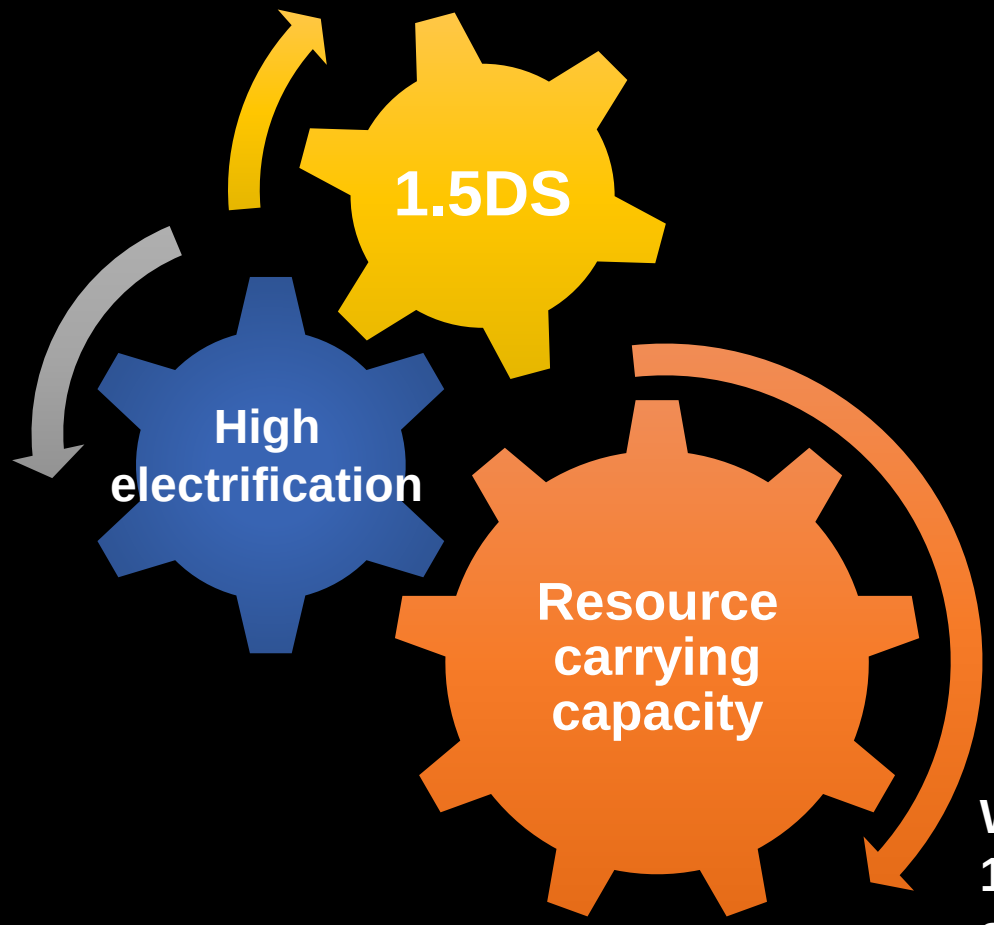
- ✓ **Total population in China will peak around 1420 million by 2030.**
- ✓ **Per capita electricity consumption is expected to be 6200-7200kWh/p in 2030 and 7000-10000kWh/p .**
- ✓ **It is a must for China to rely on ultra-high energy efficiency to effectively curb the growth of electricity consumption.**





Source: 1.5℃ report - NCEPU

Hypothesis for 1.5/2℃ scenario in China



1.5DS

- 1.5DS asks for very high electrification ratio (>70%).

High electrification

- The high electrification pushes up power demand and even exceeds resource carrying capacity.

Resource carrying capacity

Determines that China cannot follow a way that industrialized nations like the USA or Canada have pursued.

Analysis

We assume that ultra-high energy efficiency can reconcile 1.5DS demands with economy-energy-environment (3E) system.

Thus, we hypothesize the per capita electricity consumption in 2050 is 7000kWh/p and 10000kWh/p in the 2℃ and 1.5℃ scenario, respectively.

Source: 1.5℃ report - NCEPU

Hypothesis for 1.5/2℃ scenario in China

- ✓ **Low-carbon transition requires a package of options.**
- ✓ **High-share renewable energy is crucial， but not enough to achieve negative emissions in the 1.5℃ scenario.**

2℃ scenario

- **High efficiency**
- **Low-level of per capita electricity consumption (7000kWh/per in 2050)**
- **No more newly-built coal-fired plants**
- **Non-fossil power capacity approaching resource cap**

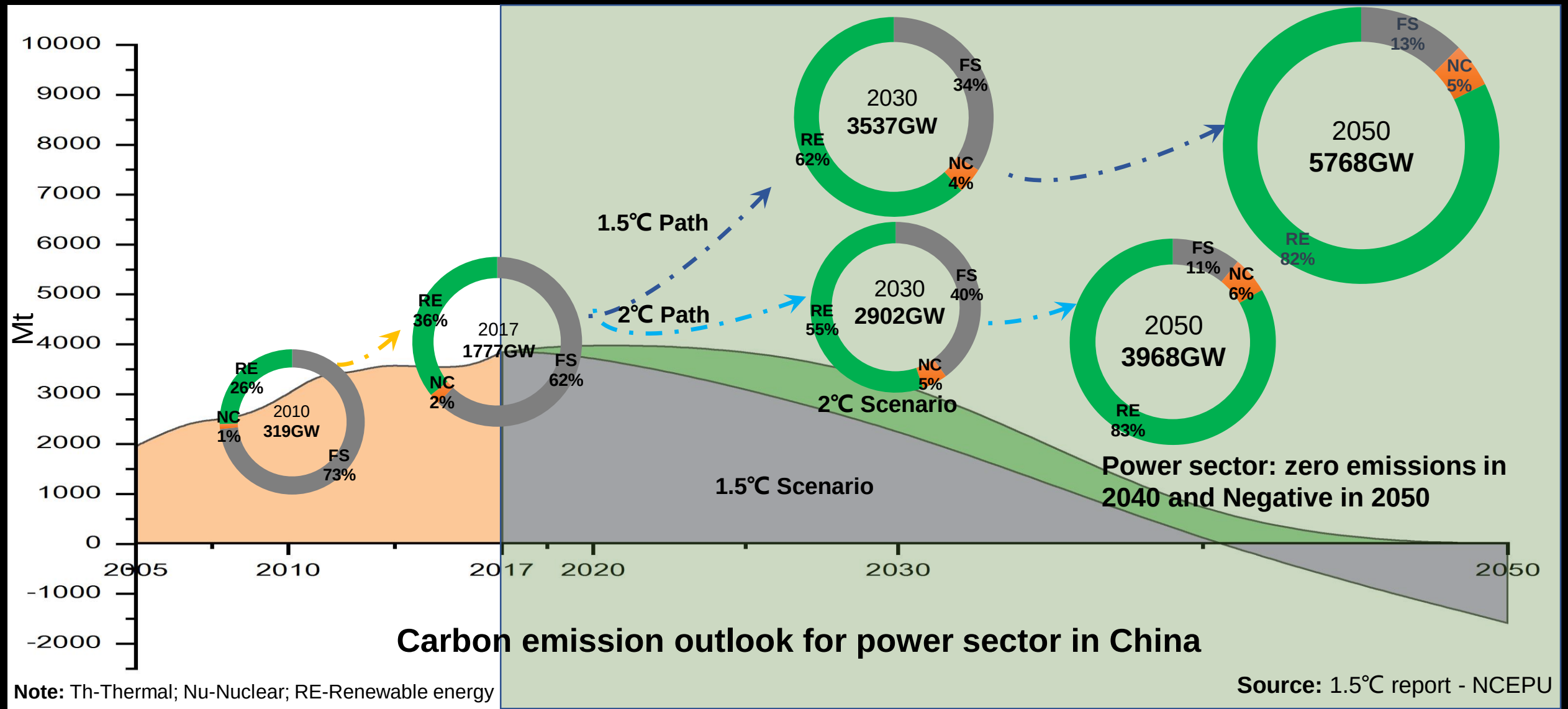
1.5℃ scenario

- **High-level of per capita electricity consumption (10000kWh/per in 2050)**
- **Decarbonization of conventional energy**
- **Non-fossil power approaching resource cap**
- **Zero-emission in 2040 and negative-emission in 2050**

Source: 1.5℃ report - NCEPU

Installation capacity outlook in 1.5/2℃ scenario, China

✓ **The power system for 1.5/2℃ scenario in China features carbon-emitting thermal power generating technologies phase-out and high-share renewables.**

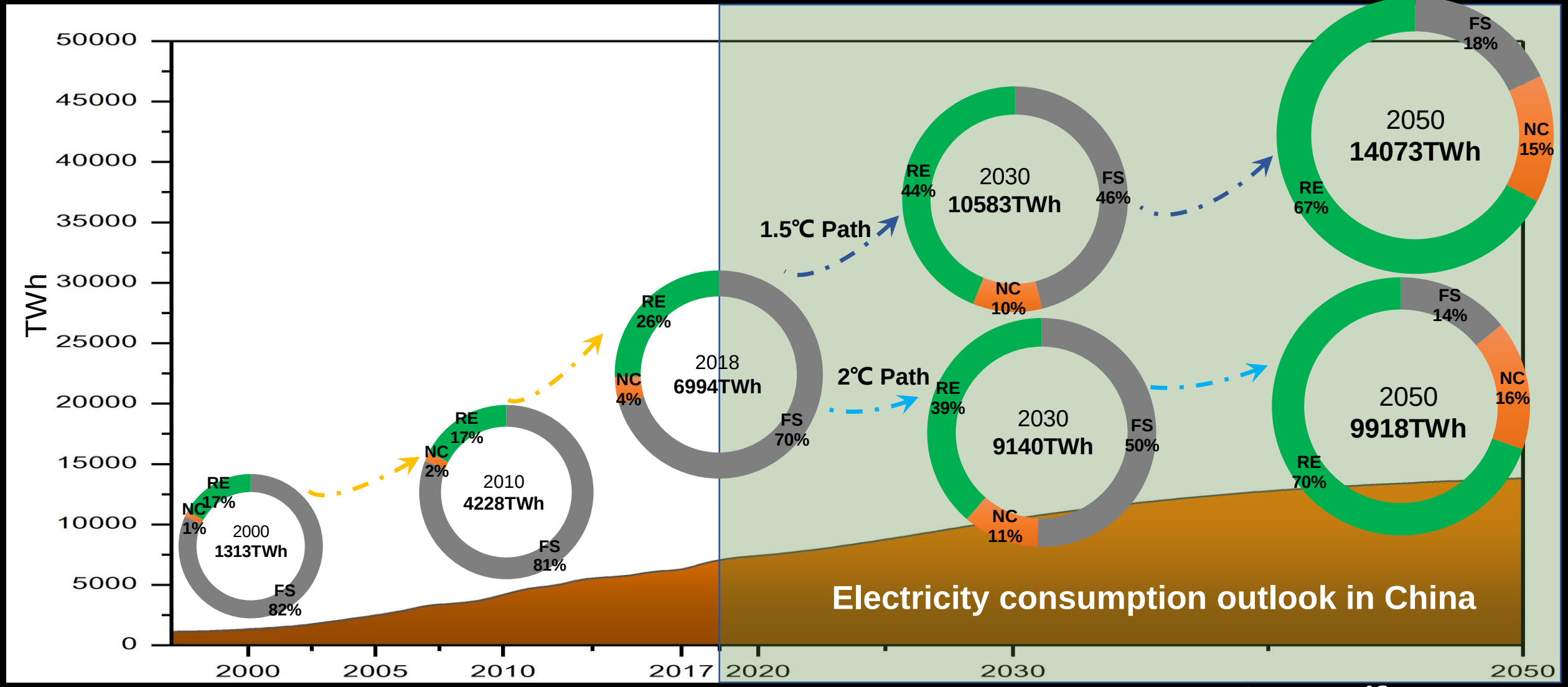


Note: Th-Thermal; Nu-Nuclear; RE-Renewable energy

Source: 1.5℃ report - NCEPU

Power generation outlook in 1.5/2℃ scenario, China

✓ **Renewables will become the dominate power guaranteeing the main power supply through the flexibility of various power plants.**



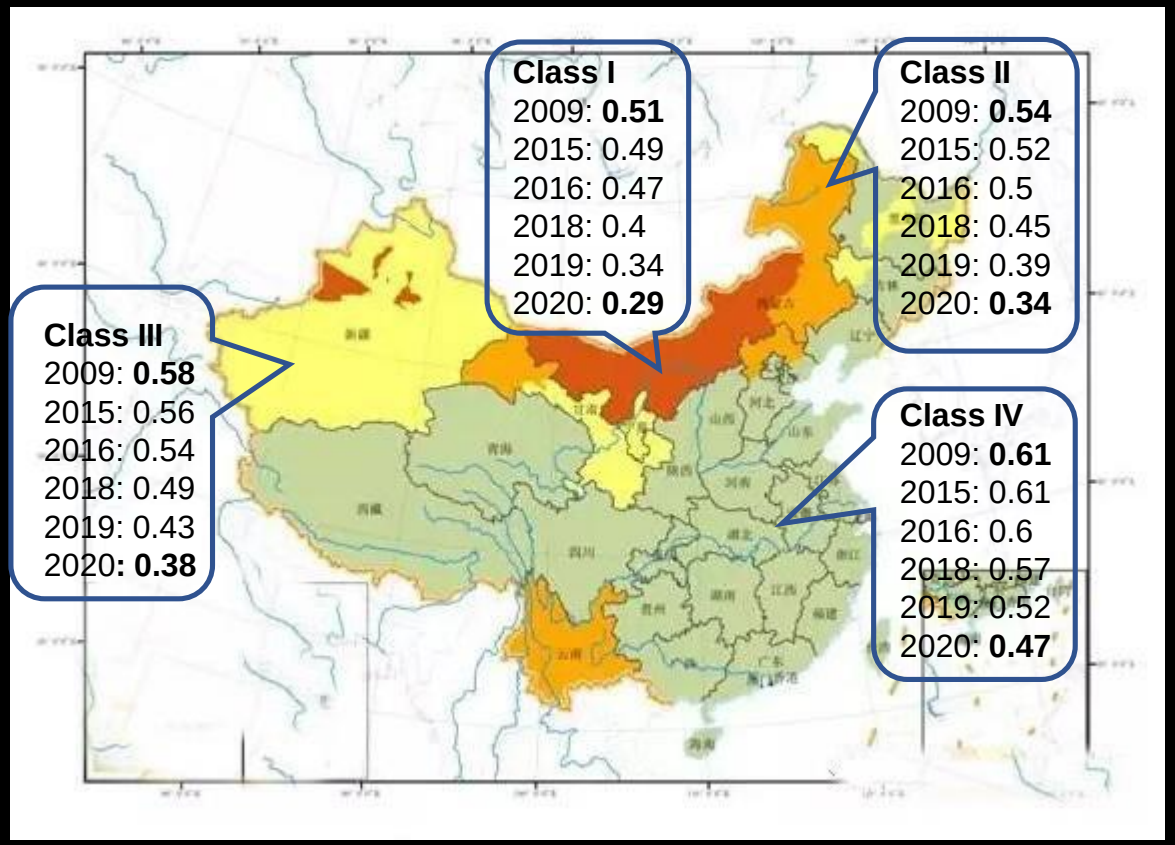
Note: Th-Thermal; Nu-Nuclear; RE-Renewable energy

Source: 1.5℃ report - NCEPU

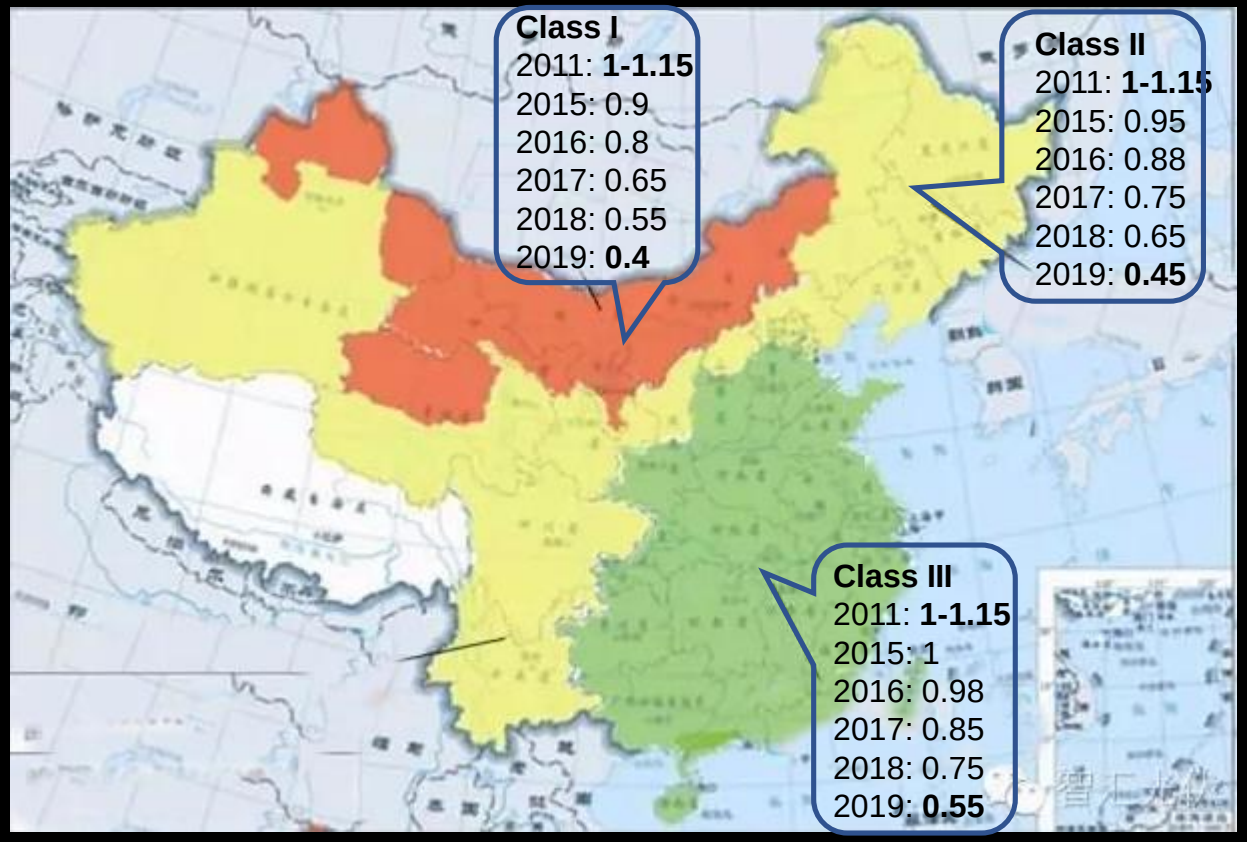
Pathways

Pathway 1: mass deployment of renewables

- ✓ **Grid parity will be achieved in the near & short term.**
- ✓ **A sun-set mechanism in FiT and then integration with the market are the solution for large-scale development of renewables.**



Wind power resource districts and its tariff in China

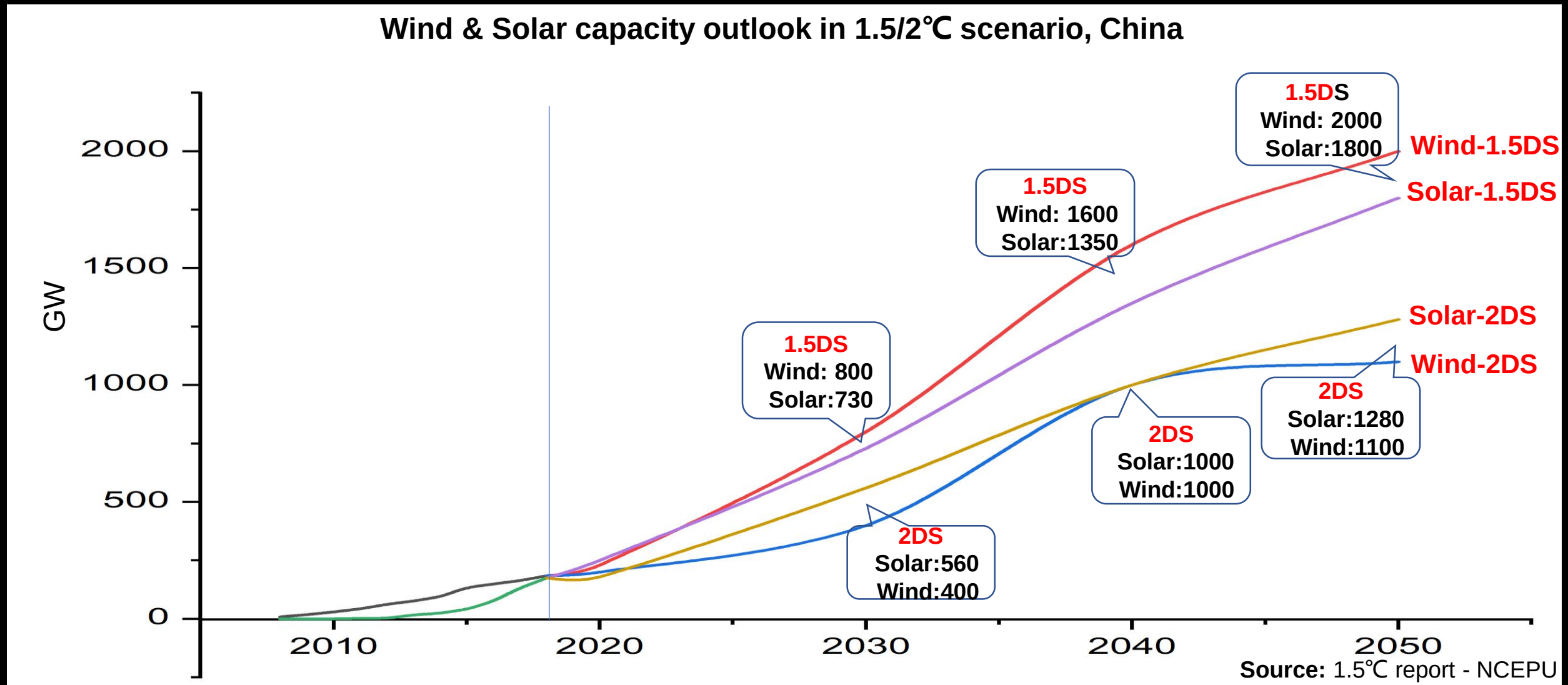


Solar power resource districts and its tariff in China

Source: NDRC

Wind & solar outlook in 1.5/2℃ scenario, China

✓ **The large-scale deployment of wind & solar power is the pillar of energy supply revolution, replacing coal power.**

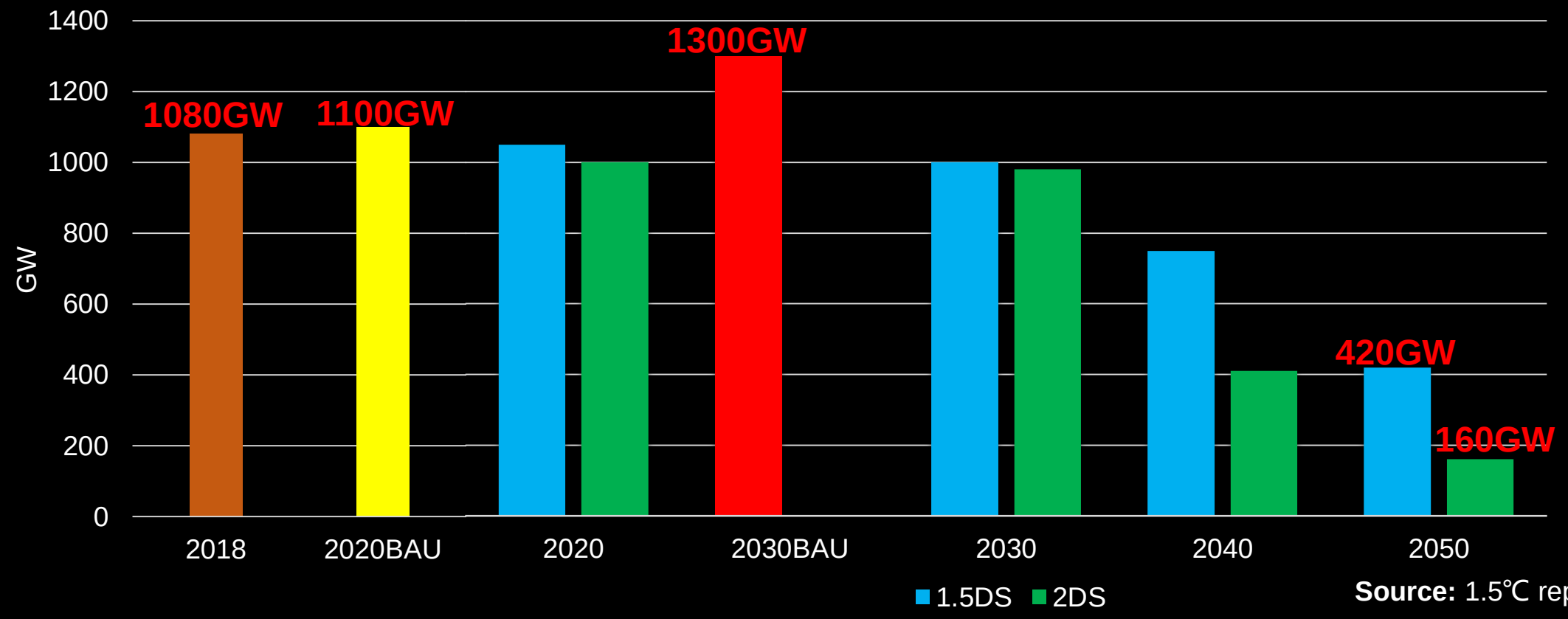


Source: 1.5℃ report - NCEPU

Pathway 2: coal power phase-out

- ✓ **Both scenarios will require the coal capacity stabilizing around 1000GW during 2020-2030 and then quick phase out afterwards.**
- ✓ **The pressure of phase-out in the 1.5 DS is smaller than that in 2DS, due to more CCS deployment.**
- ✓ **BUT, Coal power phase-out is not on track with China's existing policy**

Coal power phase-out pathways in line with 2/1.5DS in China



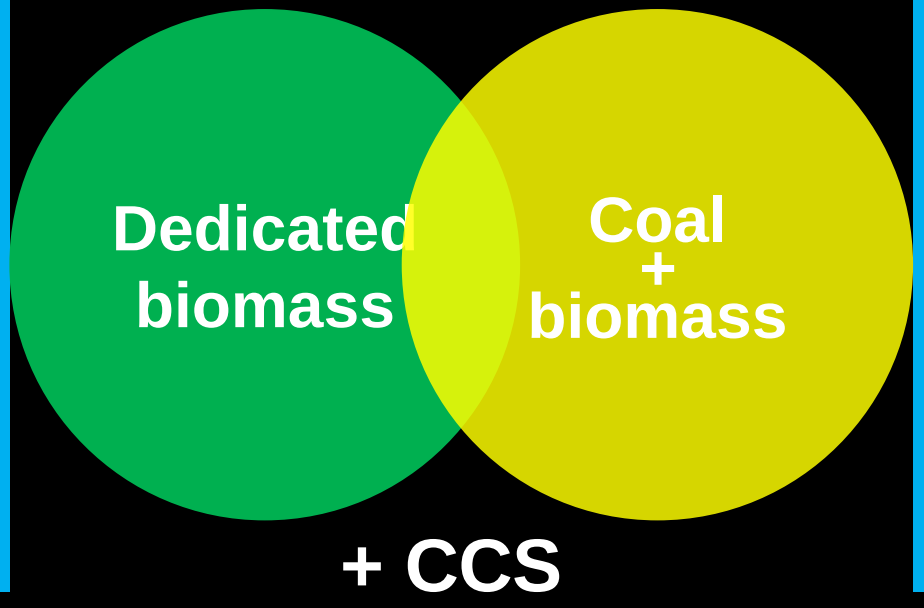
Source: 1.5℃ report - NCEPU

Pathway 3: massive biomass deployment

✓ **Large-scale development of coal coupled biomass is essential for negative-emissions of power sector.**

Characteristic

- Capacity: **1-50MW**
- Efficiency: **≤30%**
- Initial investment: **High**
- Economics: **Poor (limited by biomass resource)**



Characteristic

- Capacity: **100-1000MW**
- Efficiency: **≥40%**
- Initial investment: **Only retrofit cost**
- Economics: **High**

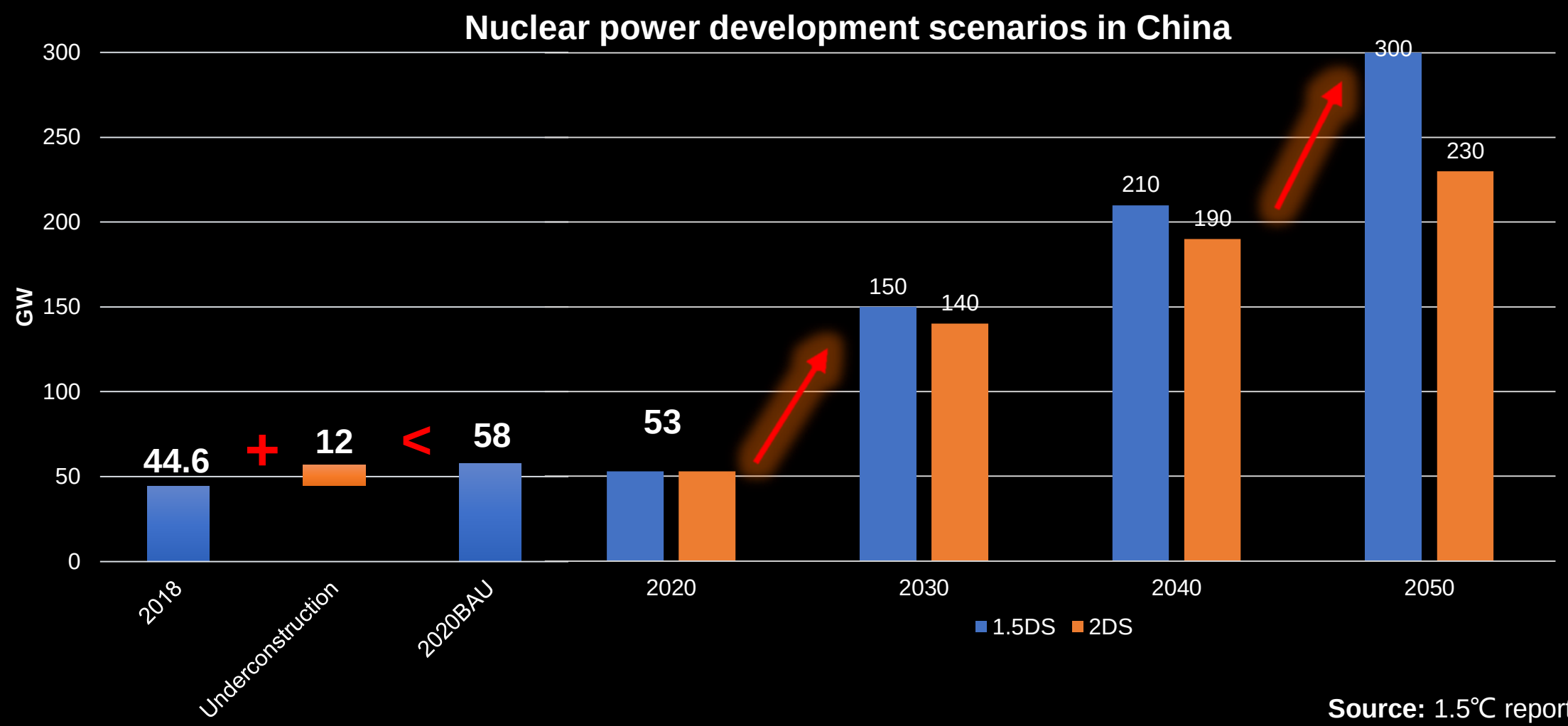
Tip

The expansion of biomass power is decided by the unconventional biomass resources.

Source: 1.5℃ report - NCEPU

Pathway 4: nuclear power development

- ✓ Nuclear capacity under construction in China ranks the first place in the world.
- ✓ There is still a fraction of gap between reality and target of nuclear power during 13th FYP.
- ✓ For the long-term transition, the capacity gap is even large in China.



Source: 1.5℃ report - NCEPU

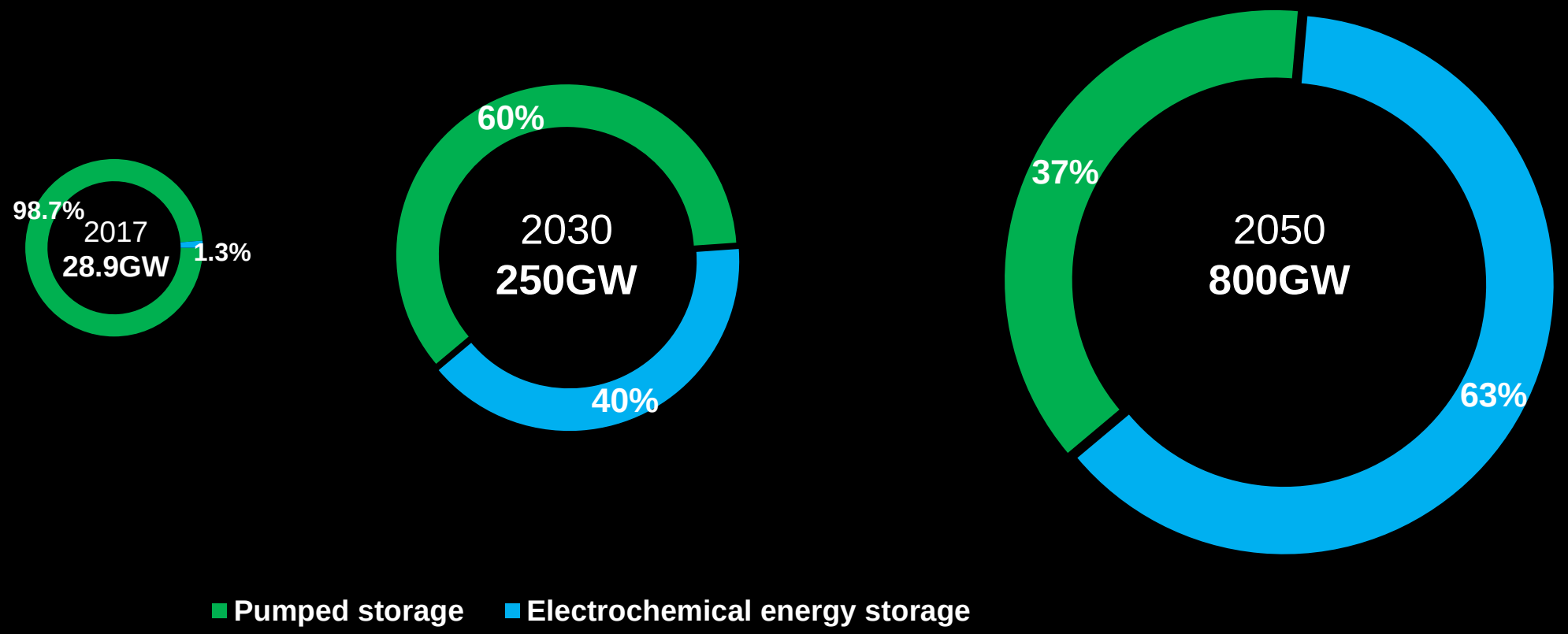
Pathway 5: energy storage deployment

- ✓ China's energy storage development are seriously inadequate.
- ✓ Proper pumped storage resources are rather limited.
- ✓ To be on track, new energy storage must develop quickly in China.

1.6%

The share of ES in total generation capacity, 2017

Energy storage development in China

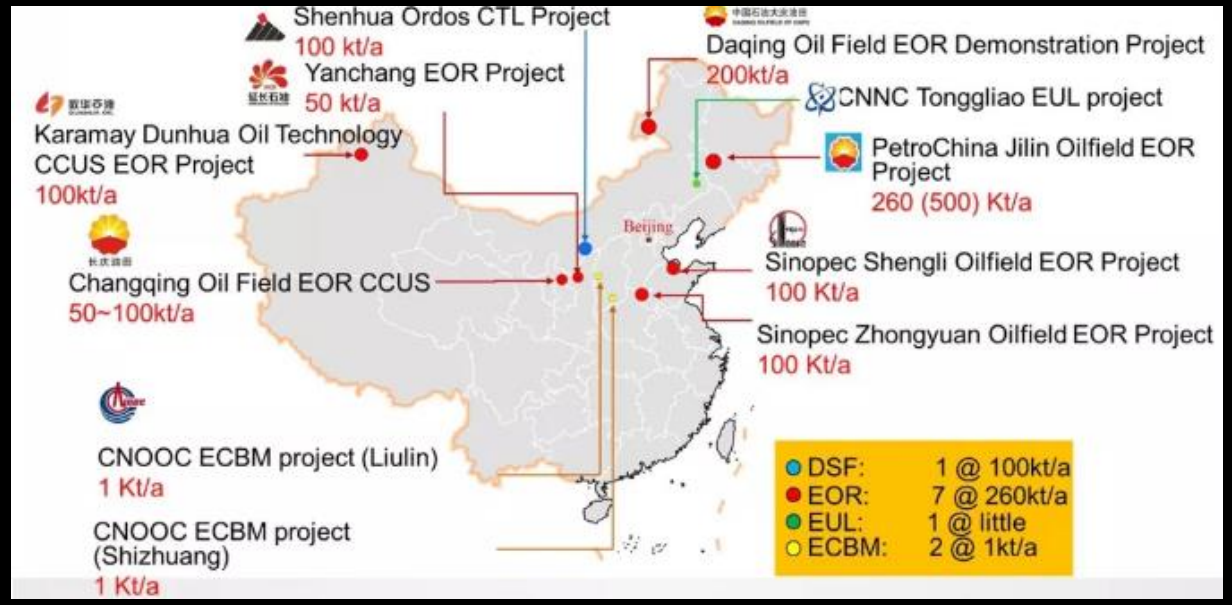


Source: 1.5℃ report - NCEPU

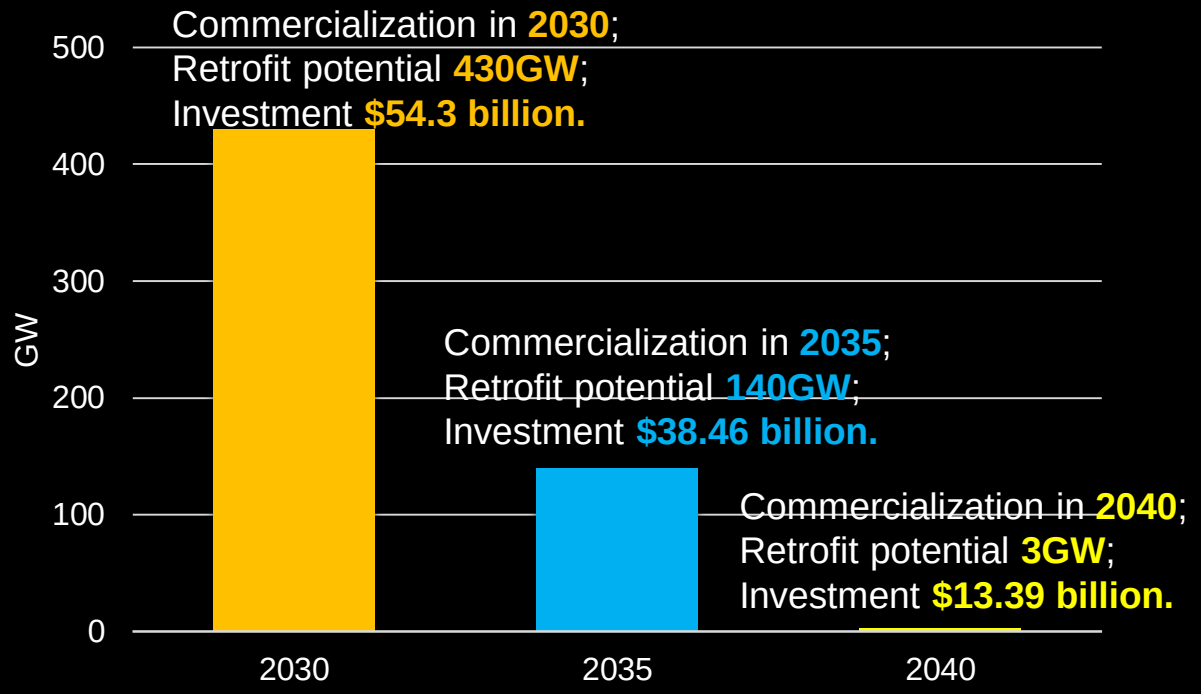
Pathway 6: CCS deployment

- ✓ **CCS technology is essential to global carbon emissions abatement.**
- ✓ **China has the largest fleet of coal units that should be considered attractive for CCS retrofit.**
- ✓ **The below 2℃ target necessitates 182 GW coal power with CCS retrofit, while 2030-2035 is the best deployment time for China.**

Existing CCS project map in China



CCS retrofit outlook in China



Source: IEA; Yang (2019)- CCUS map

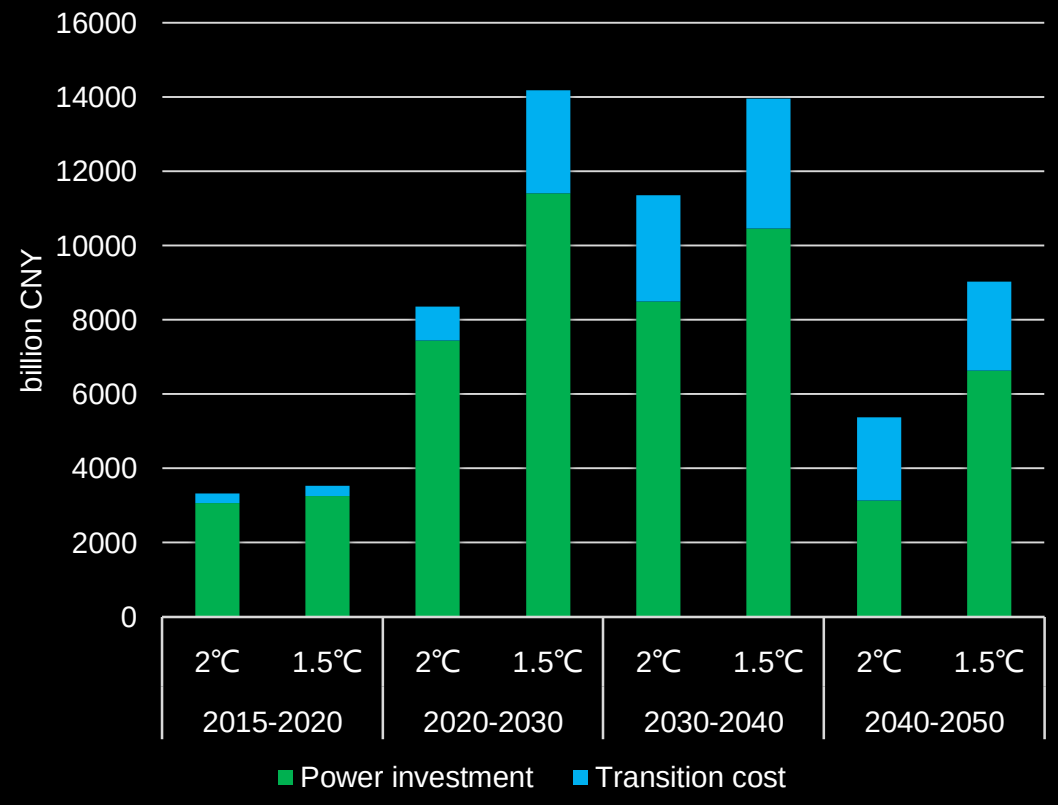
Transition costs in 1.5℃ scenario, China

- ✓ **Renewable investment will peak during 2030-2040.**
- ✓ **The additional transition investment from 2DS to 1.5DS will be ¥8960 billion during 2015-2050, including decarbonization cost of traditional power, renewables grid-integration cost and new energy storage cost, etc.**

LCOE outlook for decarbonization power technology in China

Category (CNY/kWh)	2020	2030	2040	2050
USC	0.39	0.37	0.36	0.35
USC+CCS	0.68	0.66	0.65	0.64
CFBC	0.48	0.46	0.45	0.44
CFBC+CCS	0.86	0.83	0.82	0.80
IGCC+CCS	0.74	0.70	0.67	0.65
NGCC	0.72	0.66	0.6	0.53
NGCC+CCS	0.8	0.74	0.67	0.6
Distributed gas power	0.7	0.64	0.58	0.5

Total investment for 1.5/2℃ transition in China

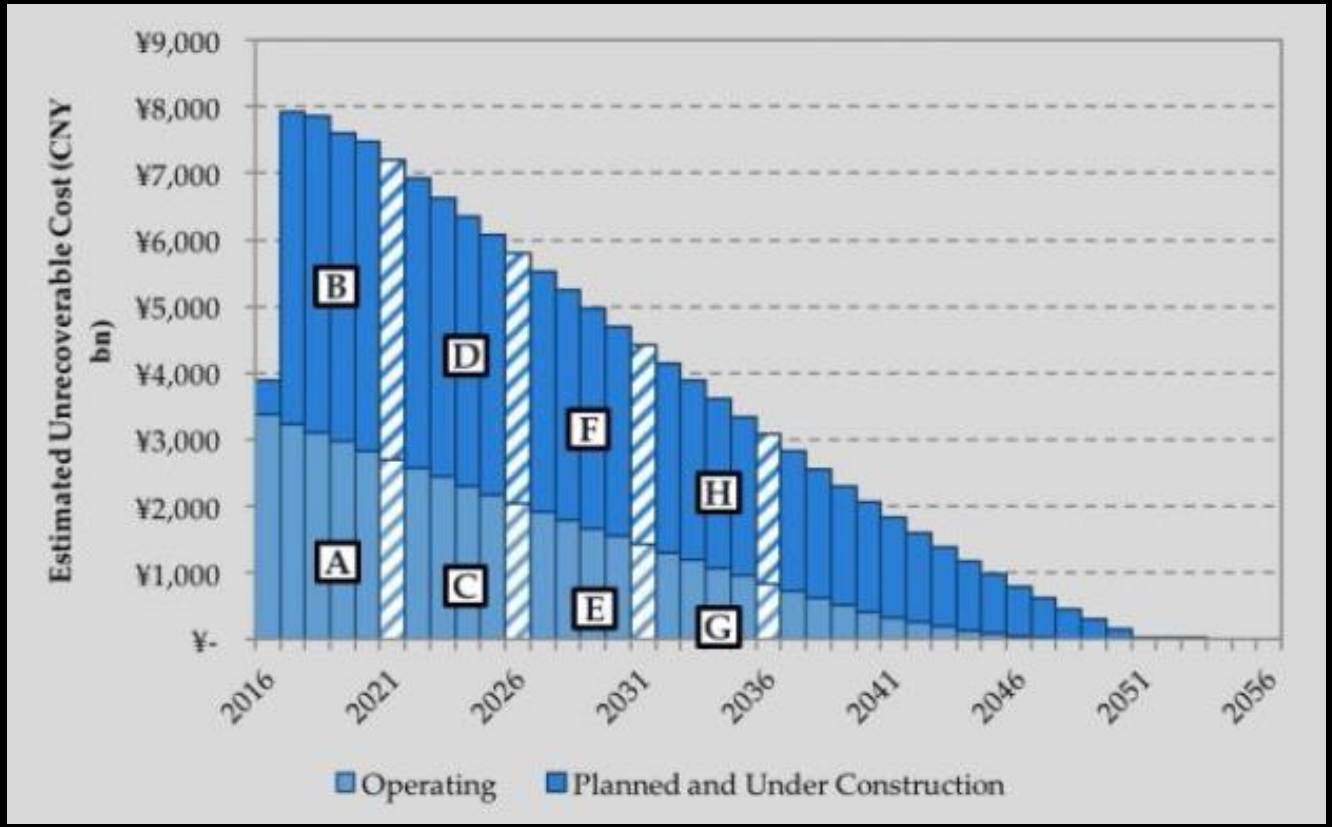


Source: 1.5℃ report - NCEPU

Transition costs in 1.5℃ scenario, China

✓ **However, if the stranded assets value of earlier coal phase-out/low efficiency operation are taken into consideration, the transition costs will double!**

Stranded asset estimation of existing and new coal power beginning in 2016, China



Gross stranded assetS of coal power in China

billion

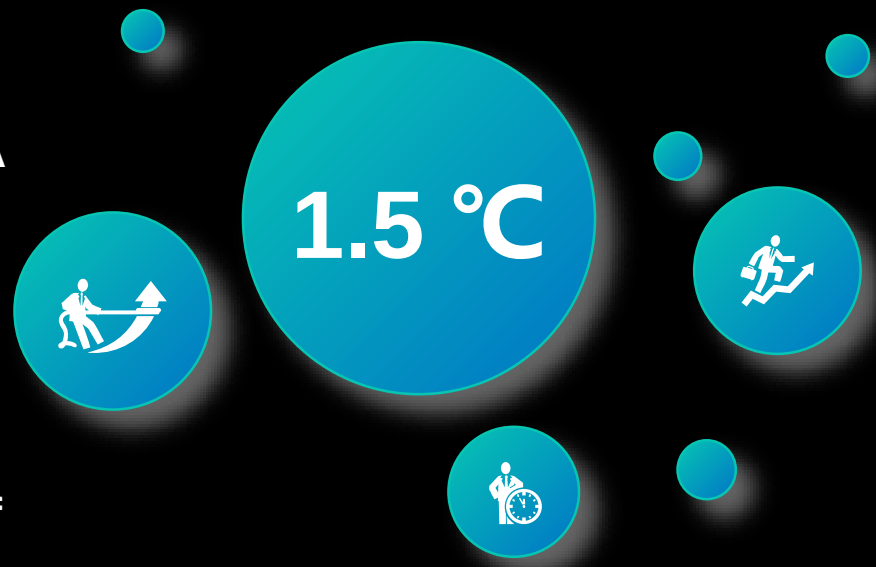
Stranded year	Existing	Newly-built	Total
2021 (5 years)	[A] ¥2703 ($393)	[B] ¥4498 ($654)	[A+B] ¥7201 ($1047)
2026(10 years)	[C] ¥2051 ($298)	[D] ¥3746 ($545)	[C+D] ¥5797 ($843)
2031(15 years)	[E] ¥1426 ($207)	[F] ¥2994 ($435)	[E+F] ¥4420 ($643)
2036(20 years)	[G] ¥843 ($123)	[H] ¥2243 ($326)	[G+H] ¥3086 ($449)

Source: Stranded assets and thermal coal in China- B. Caldecott, et al.- University of OXFORD

Challenges

Transition challenges in China

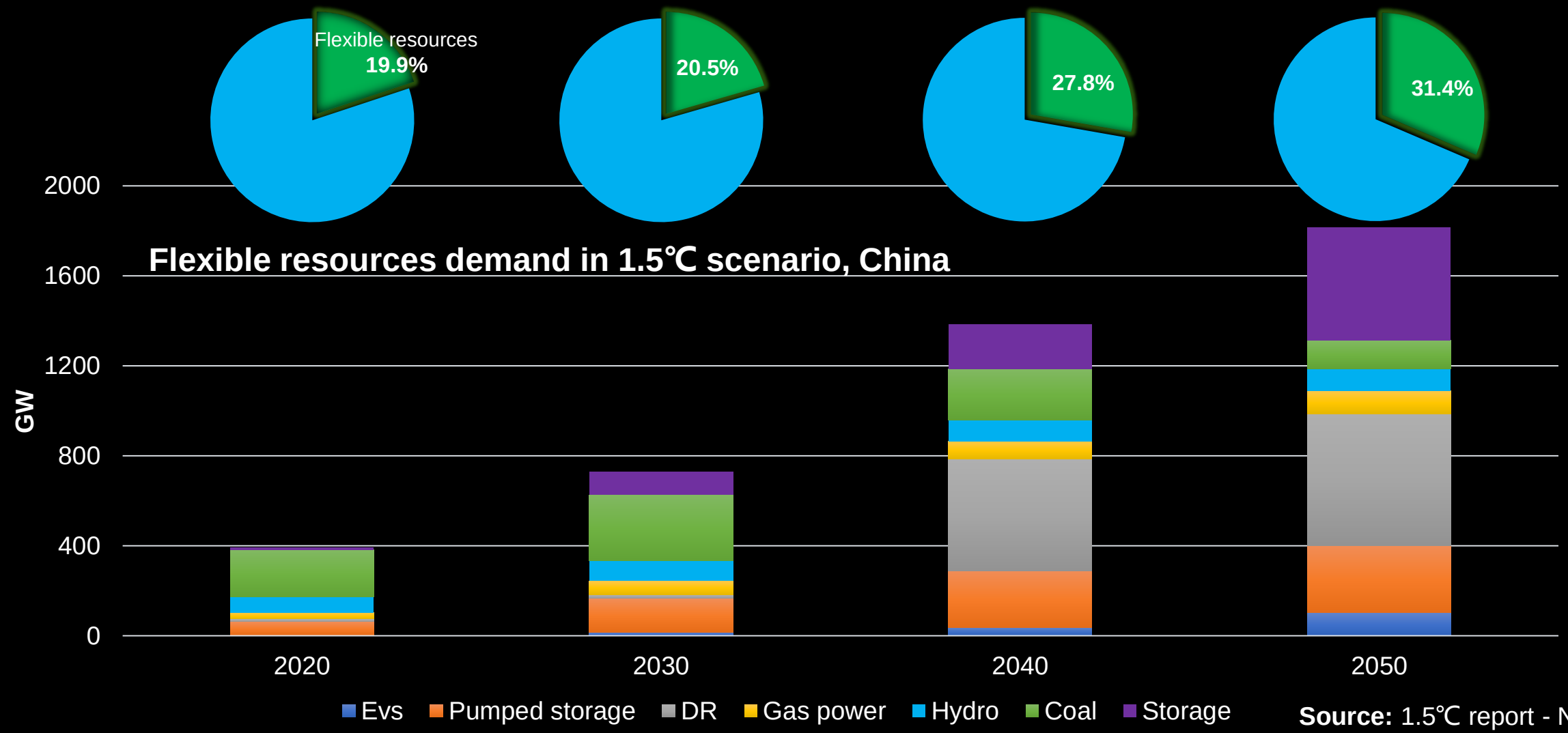
- 1.5DS asks for very high electrification ratio(>70%) and pushes up demand
- The planning and operation of high-share renewables-based power system
- Unconventional biomass resource (LUBE) and its LCA carbon footprint



- The integration of multi-energy systems and energy internet
- Technology breakthrough of CCS/CCUS and its massive deployment
- Commercialization and mass application of Energy storage in power systems
- Technology innovation and prompt commercialization of GⅢ and GⅣ nuclear

Challenge 1: provision of flexibility

✓ **Large-scale commercial energy storage, traditional flexible power (pumped storage, gas and CSP) and new flexible resources (EVs and DR) ensure the reliable operation of renewable power system.**

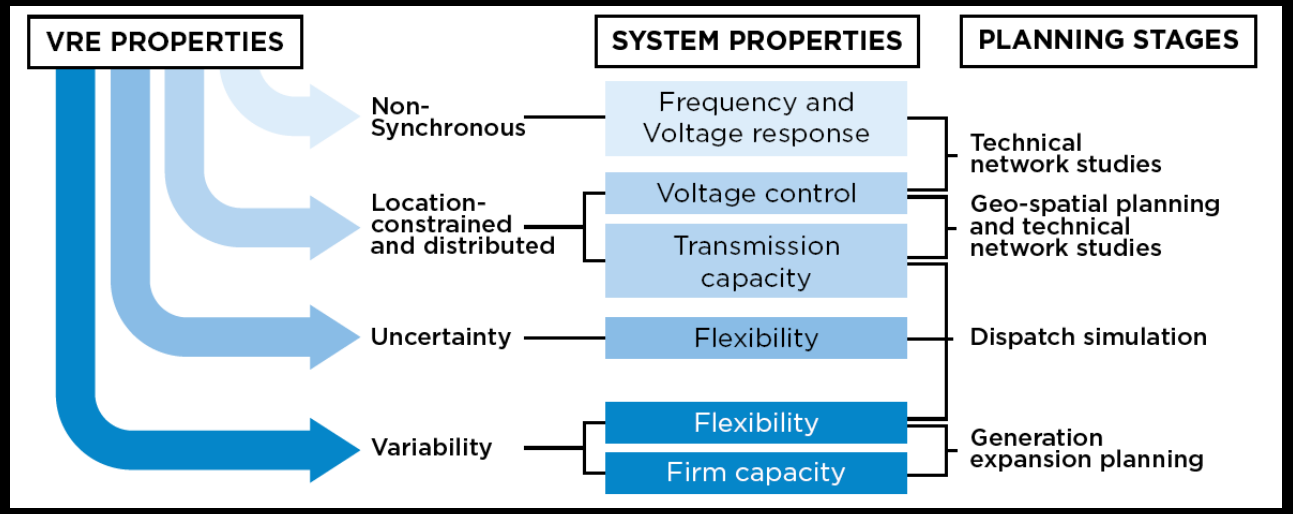


Source: 1.5℃ report - NCEPU

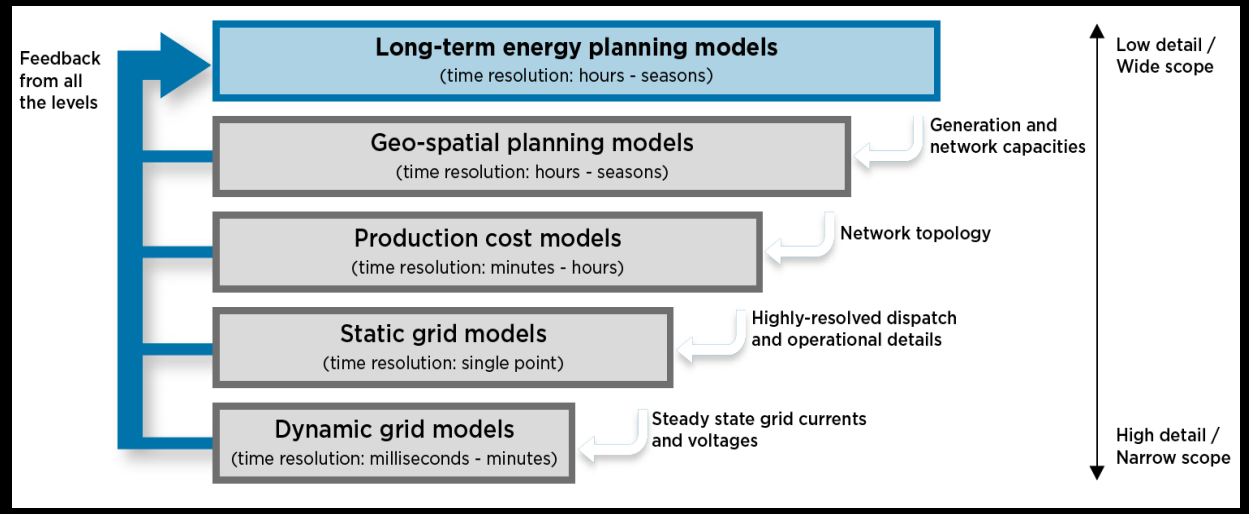
Planning process of power transition in China

- ✓ Four steps of transition planning are defined as: **generation expansion planning** (20-40 years), **geo- spatial planning** (5-20 years), **dispatch simulation** (weeks to a year) and **technical network studies** (current and near-time).
- ✓ From long-term through short-term planning steps, clear and internally consistent **feedback loops** within techno-economic assessments can avoid near-term inefficiencies due to a poorly specified long-term transition plan.
- ✓ The five main properties of VRE generators are: **weather-dependent nature, uncertainty in forecasts, location constrained, non-synchronous and feature as distributed generation**, which influences certain functional properties of the power system (**firm capacity, flexibility, transmission capacity, voltage control, and frequency and voltage response**).

Key links between variable renewable energy, power system properties and planning



Tools and analyses for energy system planning with feedback

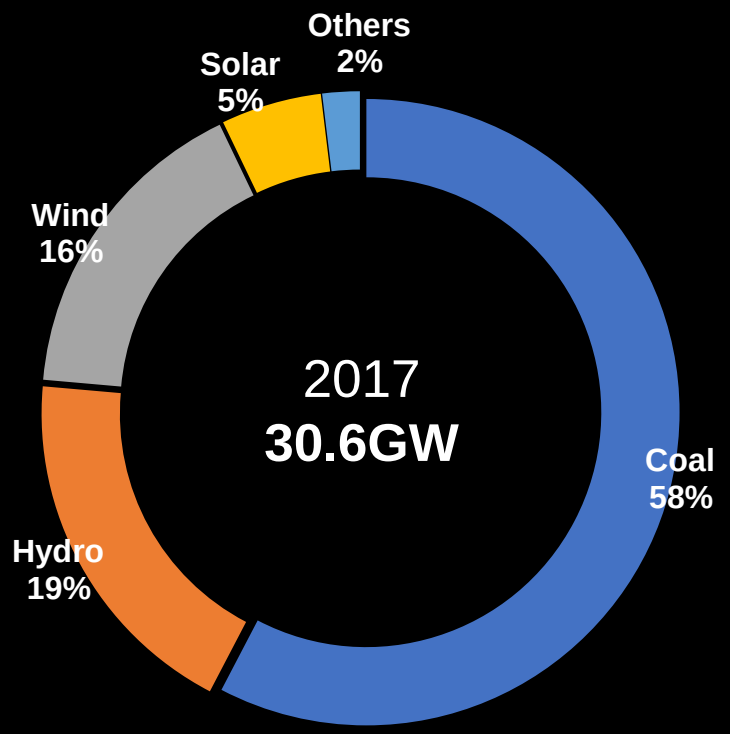


Source: Planning for the renewable future - IRENA

Production simulation case in Jilin province

- ✓ **For reasons specific to Jilin province, wind power curtailment is more pervasive owing to an inflexible power generation system dominated by conventional heating fleet.**
- ✓ **The production simulation case hypothesizes that the minimum technical output of condensing and CHP units could reach 30% and 40% of rated capacity, respectively.**

Power structure in Jilin province



Parameters for production simulation in Jilin, 2030

Parameters	BAU scenario	Low-carbon scenario	Extreme scenario
Maximum load	18.75GW		
Minimum output of **condensing unit**	30%		
Minimum output of **CHP in summer**	30%		
Minimum output of **CHP in winter**	40%		
Coal power capacity	22.75GW	12GW	6GW
REs	22.5GW	29.7GW	34.7GW
Pumped storage	4.1GW		
Gas power	1GW		
Nuclear	2.5GW		
Net export	3.34GW in summer		2.56GW in winter

Source: NDRC, NCEPU

Production simulation case in Jilin province

- ✓ **De-capacity for coal power would not weaken the reliability of power system.**
- ✓ **The loss of load probability is still within reliable range in the low-carbon and extreme scenarios.**

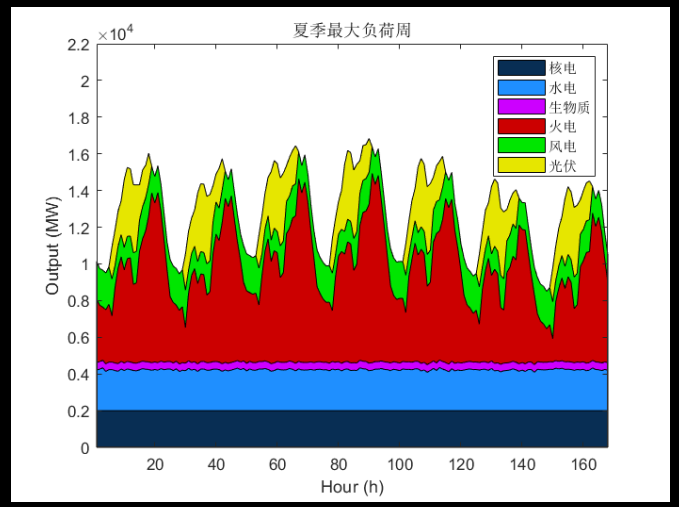
Scenario indicators of production simulation, 2030

		BAU		Low-carbon		1.5DS	
		Summer	Winter	Summer	Winter	Summer	Winter
Loss of load probability (LOLP, %)		**4.95E-22**	**1.54E-11**	**1.01E-06**	**9.61E-06**	**6.48E-06**	**5.01E-05**
Hydro power	Seasonal utilization hours	1027	0	1031	0	1033	0
	Annual utilization hours	2053		2063		2066	
Coal power	Seasonal utilization hours	522	1027	738	1557	938	1912
	Annual utilization hours	3098		4589		5700	
Wind power	Seasonal utilization hours	504	597	499	598	498	595
	Annual utilization hours	2203		2194		2188	
Solar power	Seasonal utilization hours	308	310	310	311	302	312
	Annual utilization hours	1236		1242		1227	
Wind curtailment rate (%)		0.46	0.22	1.21	0.35	1.46	0.59
Solar curtailment rate(%)		0.41	0.31	0.86	0.22	2.92	0.16

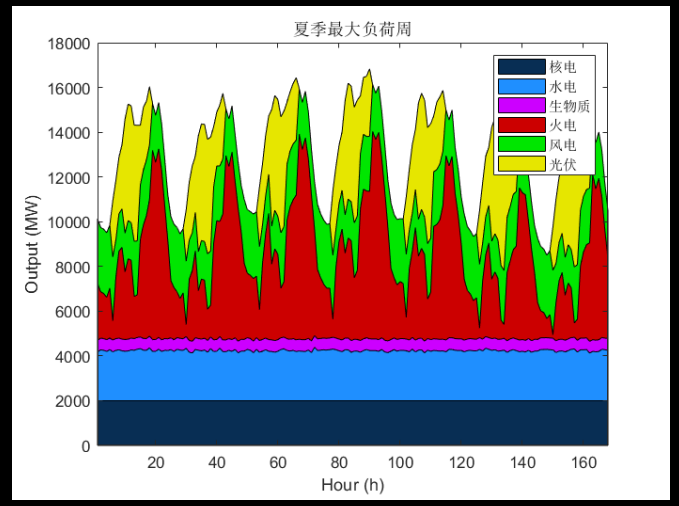
Source: NDRC, NCEPU

Production simulation case in Jilin province

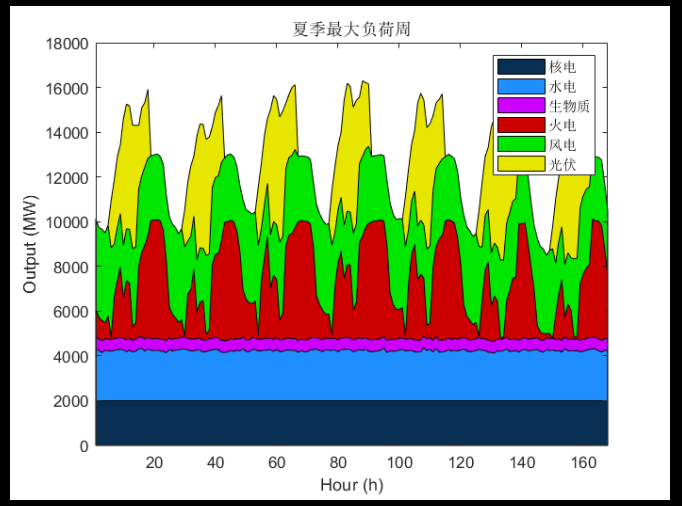
✓ **The flexibility of coal power and adding gas capacity is crucial to gird-integration of wind & solar power.**



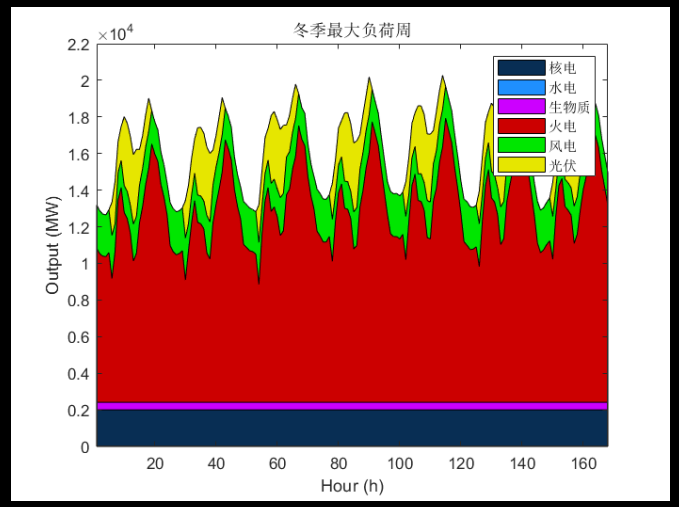
Summer in BAU scenario, 2030



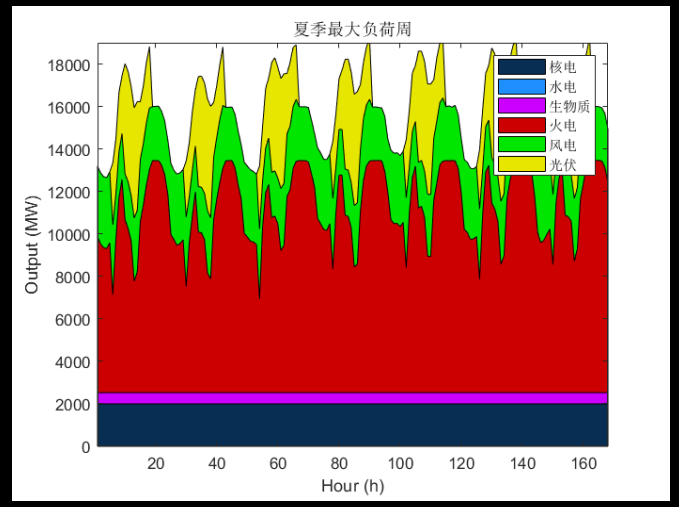
Summer in low-carbon scenario, 2030



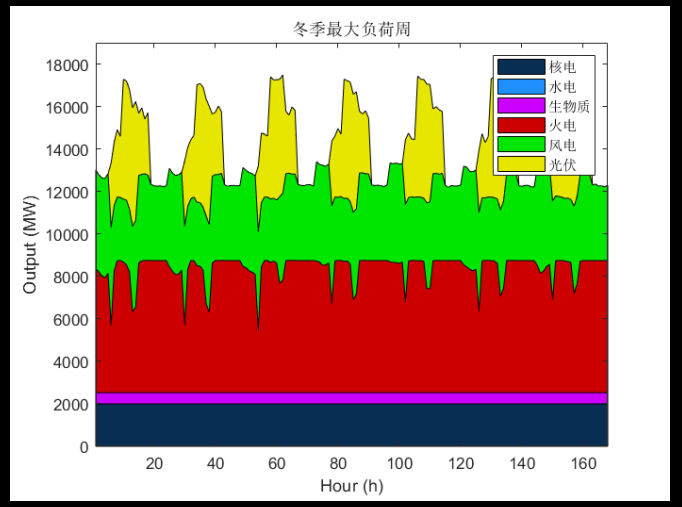
Summer in 1.5DC scenario, 2030



Winter in BAU scenario, 2030



Winter in low-carbon scenario, 2030



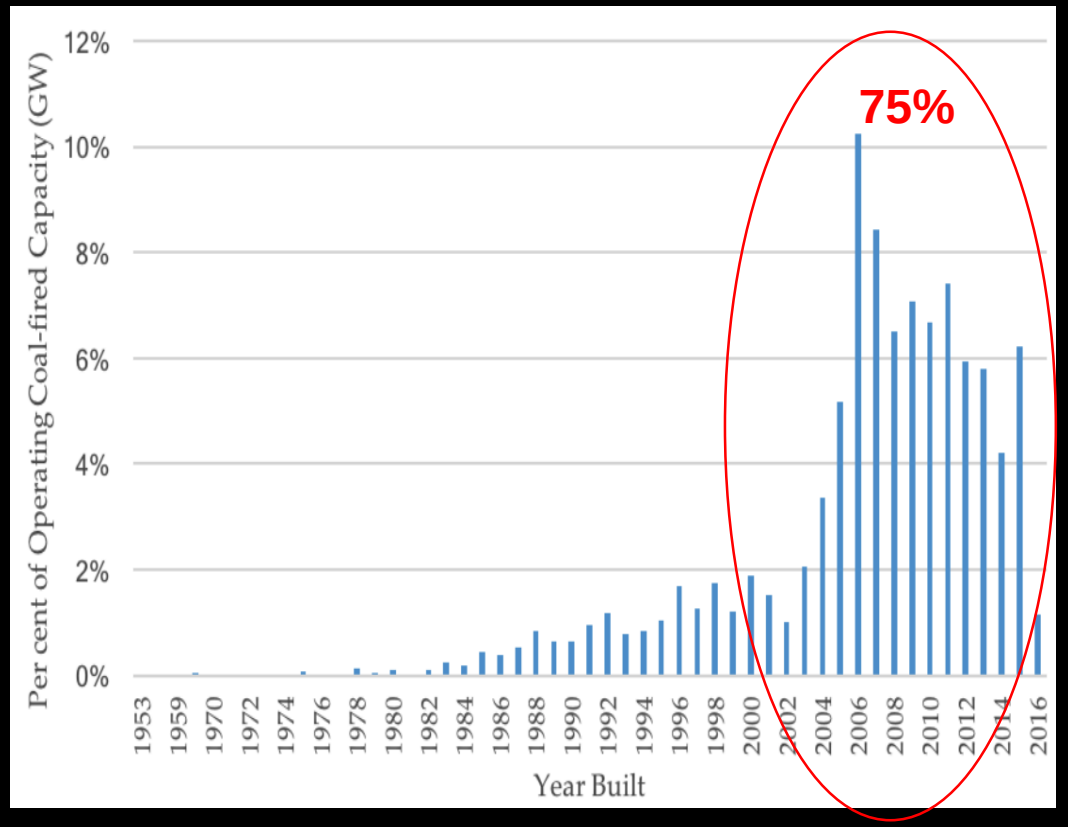
Winter in 1.5DC scenario, 2030

Source: NDRC, NCEPU

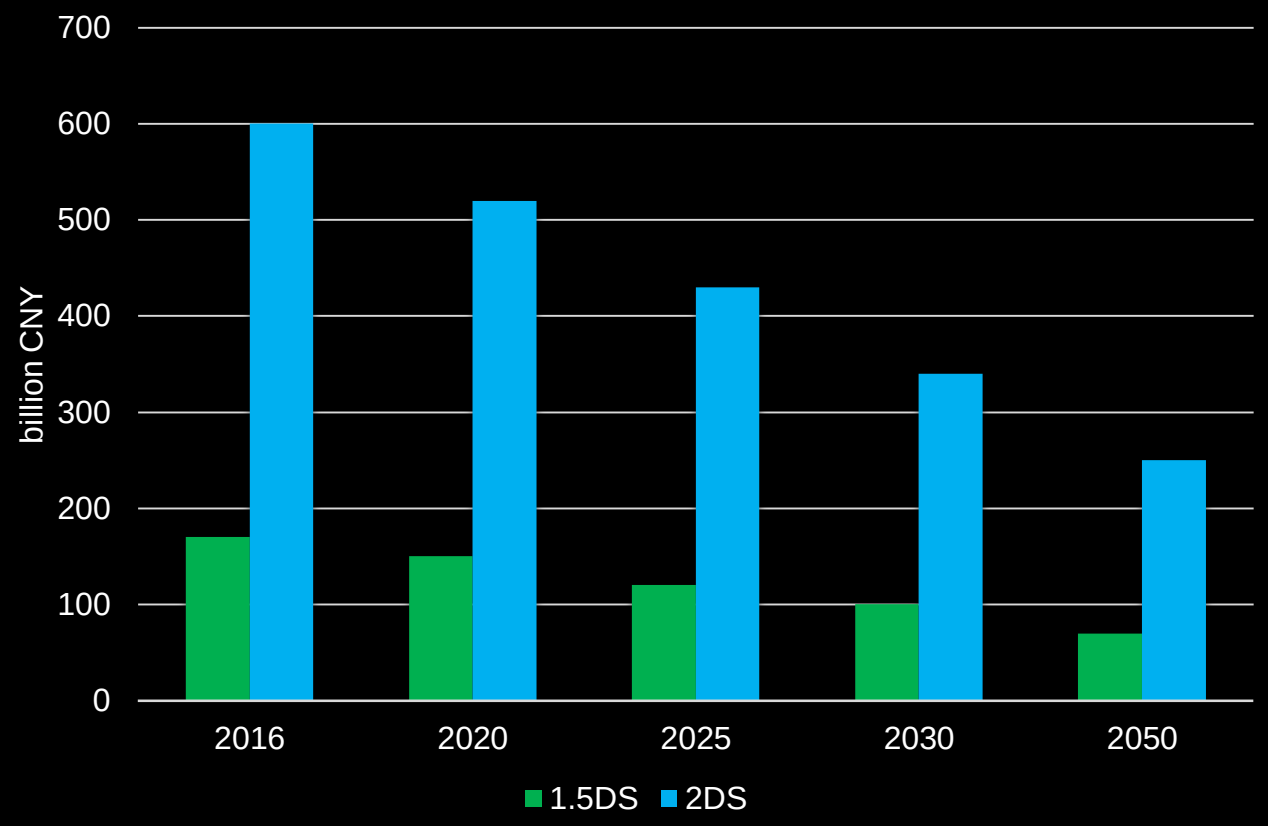
Challenge 2: massive stranded coal assets

- ✓ **With an average plant age of 14 years, retirement plan could lead to high stranding value.**
- ✓ **For the coal fleet built in 2016, if stranding 200GW in 1.5DS and 700GW in 2DS, the stranded assets could be ¥150 and 520 billion (with 2020 as stranding year).**

Operating coal power plant capacity by year built



Stranded asset estimation beginning in 2016, China



Source: 1.5℃ report - NCEPU

Challenge 3: inadequate unconventional biomass resources

- ✓ **The inadequate unconventional biomass resources intrinsically challenge the feasibility of negative emissions in the 1.5℃ scenario.**
- ✓ **Even having enough resources, the LCA footprint of unconventional biomass is a matter of issue.**

2018

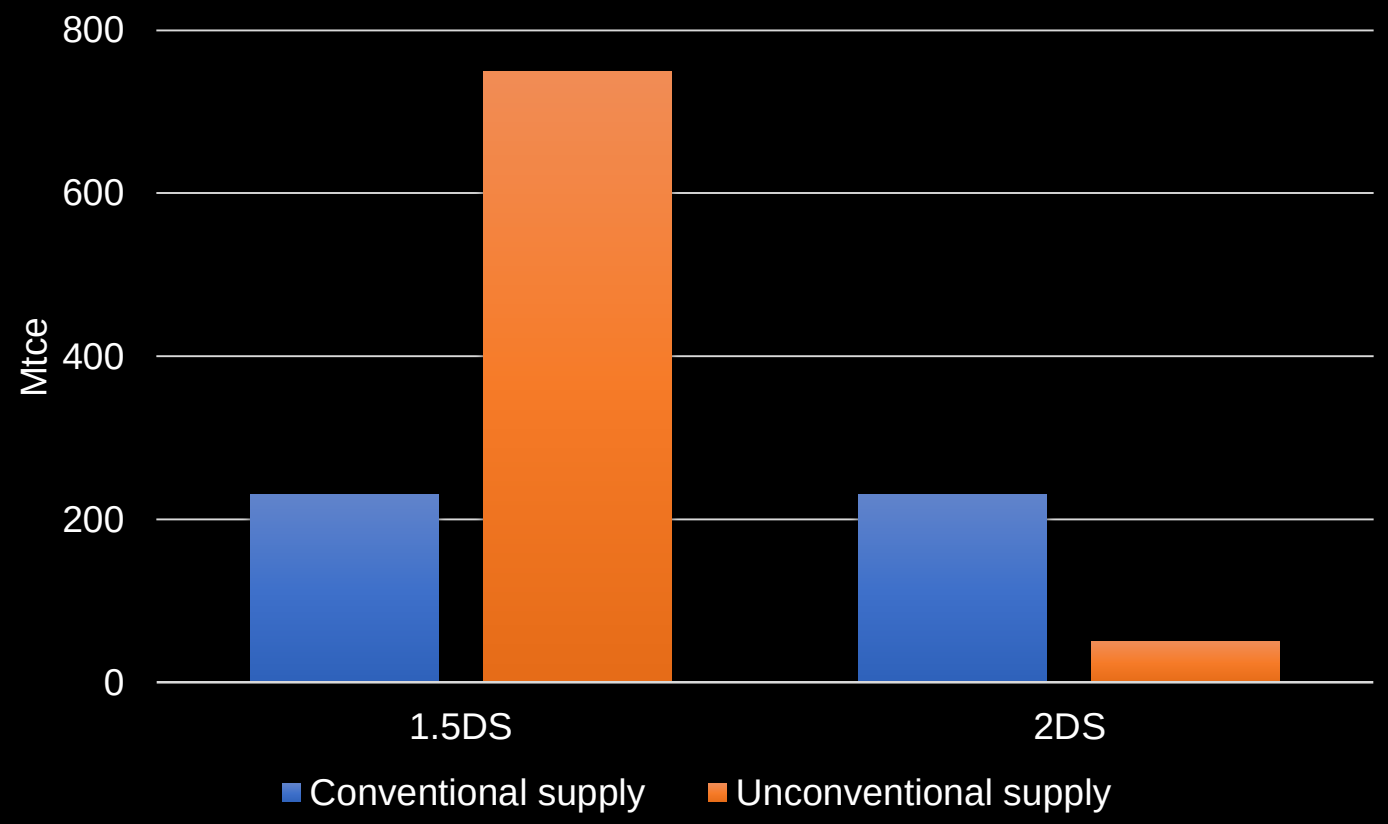
Biomass resources

460 Mtce

Utilization rate

7.6%

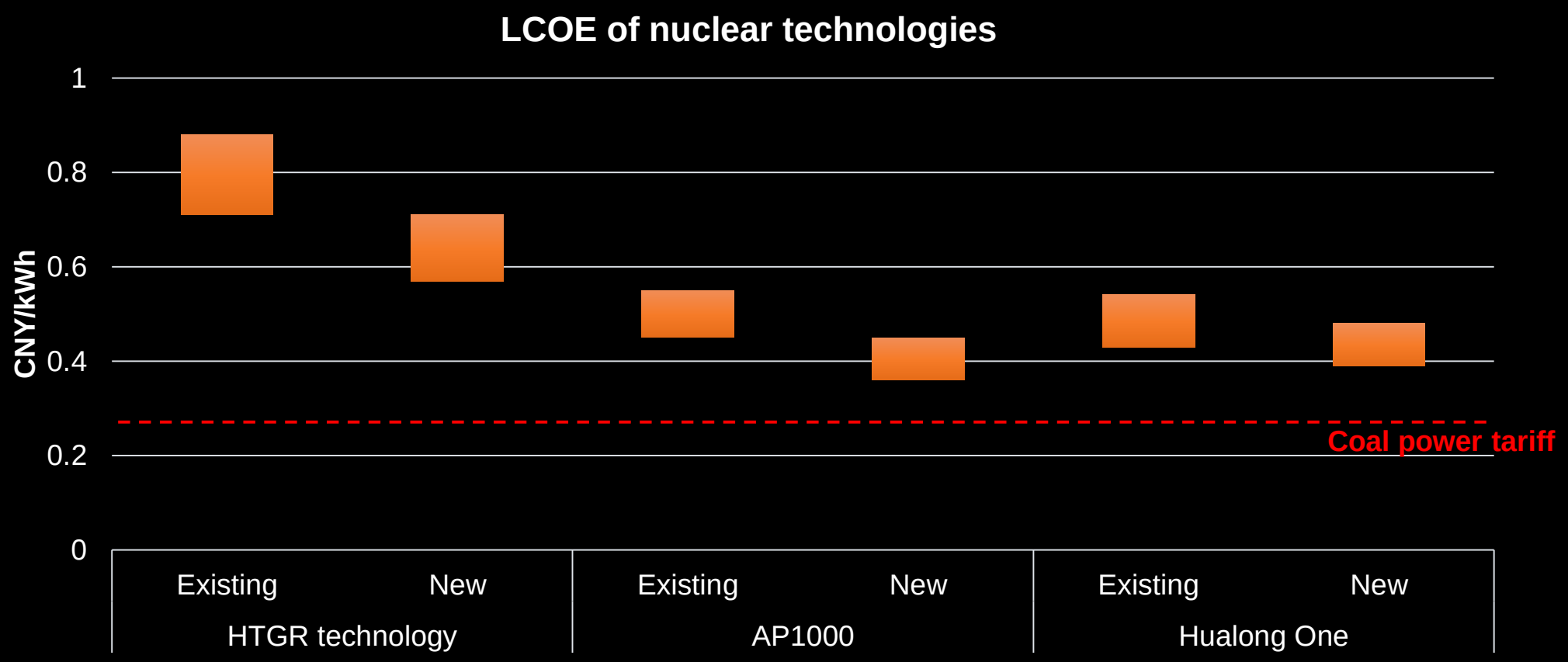
Biomass resource supply in China, 2050



Source: 1.5℃ report - NCEPU

Challenge 4: nuclear power economics

- ✓ **Nuclear power will remain an indispensable base-load power source competitive with coal power.**
- ✓ **The technology innovation of third-generation nuclear (GⅢ) and commercialization process under coming power markets are barriers for expanding nuclear capacity.**



Source: 1.5℃ report - NCEPU

Challenge 5: Energy storage commercialization

Challenges

1. Economics
2. Position definition
3. Commercial model
4. Battery recycling

Energy storage

Source: 1.5℃ report - NCEPU

Challenge 6: Energy efficiency and DR

- ✓ The potential energy conservation share by EE should be 30-40% of total consumption.
- ✓ However, deploying EE in such a large scale is a tremendous challenge to China.

Electricity saving by EE in China, 2020-2050

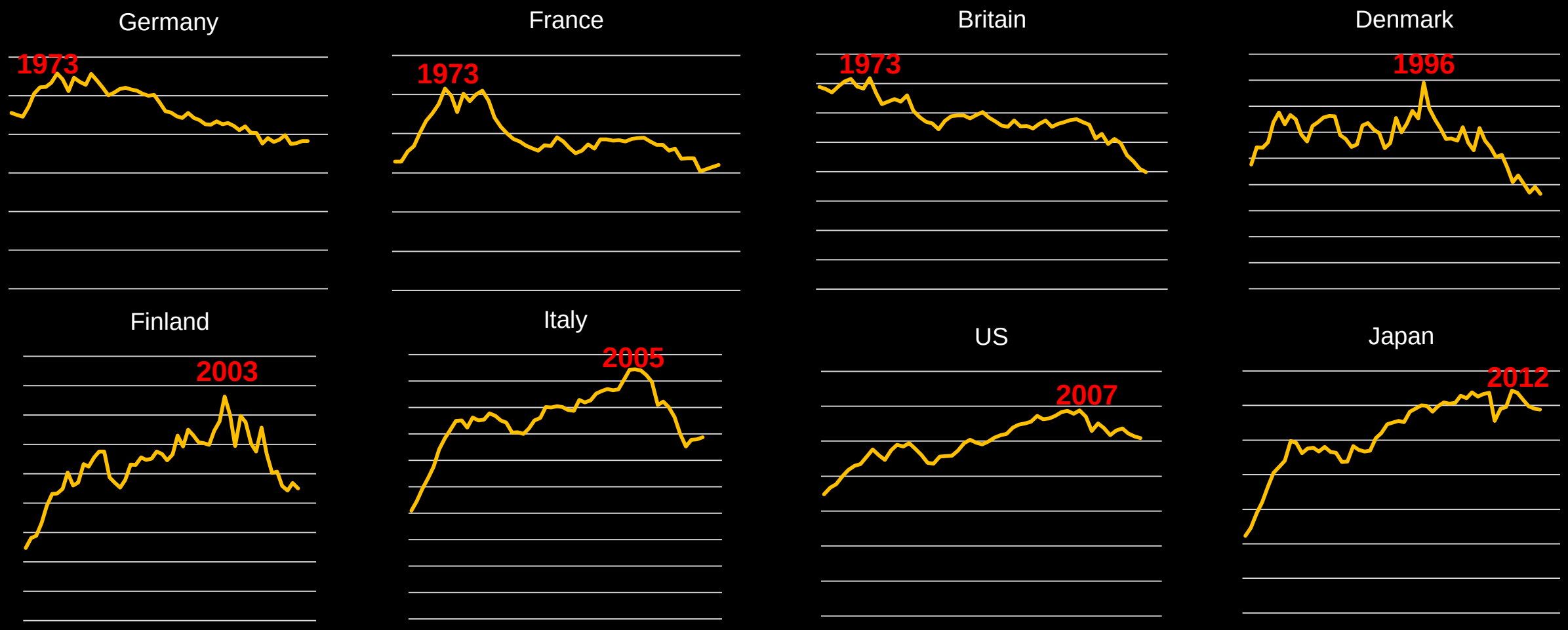
Demand side resources （TWh）	2020	2030	2040	2050
Electric vehicle	3.6	40	100	270
Efficient lightbulb	187.5	375	450	500
Efficient motor	28	60	100	140
Efficient transformer	28	480	640	800
Variable frequency speed governor	17.5	300	400	500
Ice Thermal Storage	1.6	4	80	9.6
High efficiency household appliances	16	40	120	120
Demand response（DR）	2	3.5	50	580
Energy efficiency of building	0	100	1000	1500
Others	0	48	315	156
Total	284	1450	3255	4140

Source: 1.5℃ report - NCEPU

Challenge 7: CO2 Peak to zero in two decades---impossible mission?

- ✓ It is possible for China to achieve zero emissions by 2050 after peaking in 2030?

Carbon emissions in peaked nations, 1965-2017



Wrap-up

- Transition to 1.5/2DS power system is possible but with tremendous challenges.
- We can hypothesize the abatement scenarios, but the pathways remain highly uncertainty.
- Coal power represents the largest barrier to 1.5DS transition: no new build and stranded assets.
- No one-size-fits-all solution: high share of RE is not enough for 1.5 DS transition!
- We suggest to implement more ambitious 2050 Energy Revolution Strategy and roadmap, meanwhile reform the energy system in a retrospective way, making sure that medium and short term targets consistent with long-term vision.
- Time matters! Today's policy and planning, will determine the road towards 2030 and 2050.

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Questions & Comments

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