Accelerating offshore wind development enhances energy security and promotes carbon neutrality in China's coastal regions

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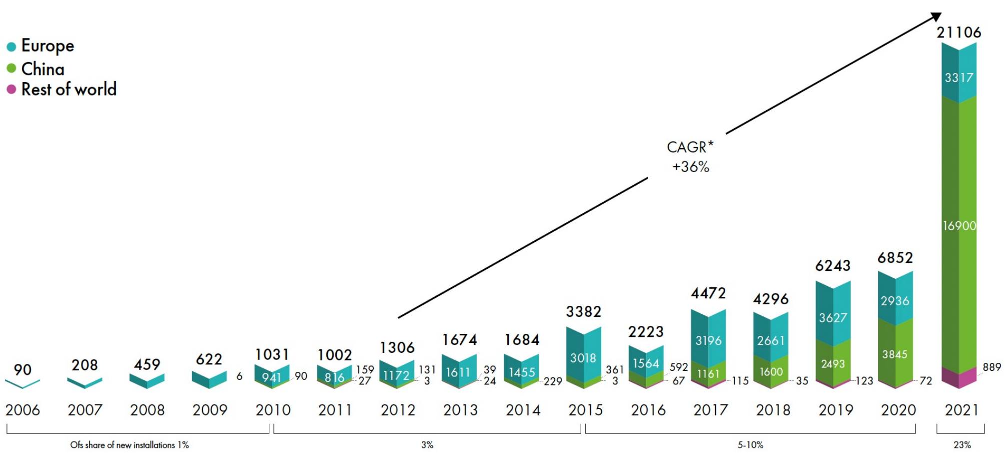
Background - Global Offshore wind market grows rapidly

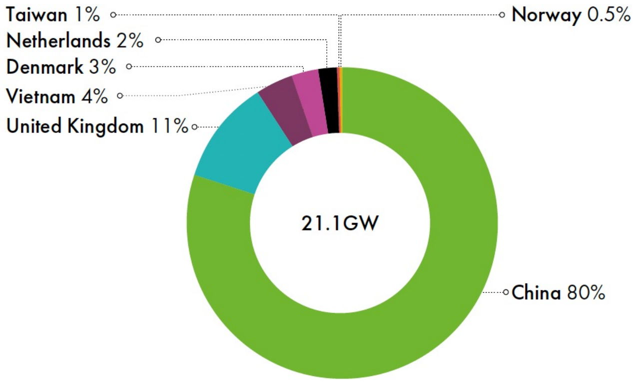
- The global offshore market grew on average by 36% per year in the past decade, bringing total installations to 56 GW by the end of 2021.

New offshore installations 2006-2021 (MW)

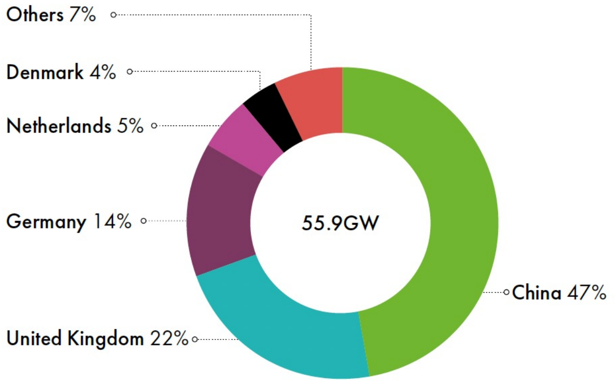


Market status 2021

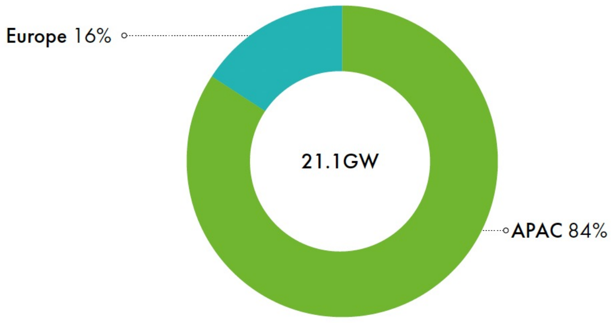
New offshore wind installations by market



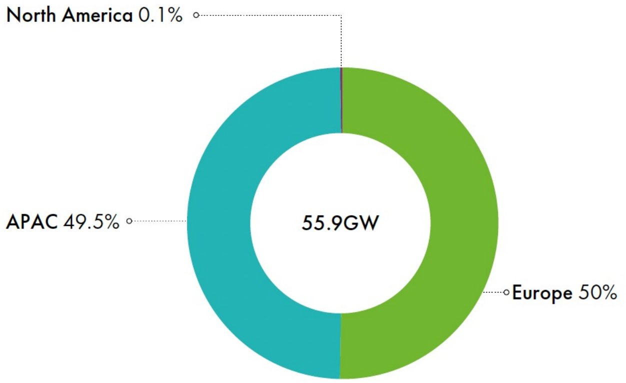
Total offshore wind installations by market



New offshore wind installations by region



Total offshore wind installations by region



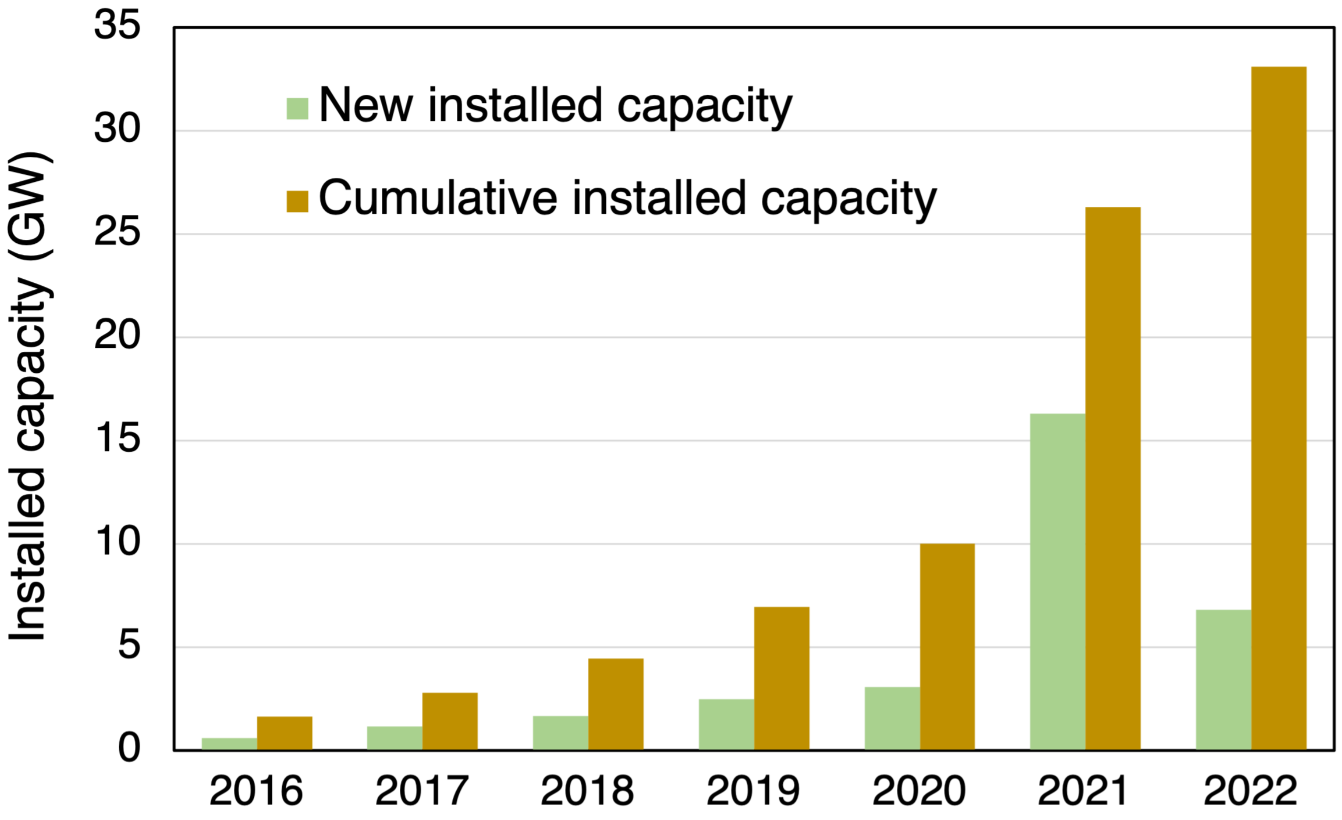
Source: GWEC Market Intelligence, June 2022

GWEC | GLOBAL OFFSHORE WIND REPORT 2022

Background - China led the world in annual offshore wind installations

- Feed- in tariff level of 850 yuan per MWh for the projects connect to the grid ends by the end of 2021.
- In the next 3 years the offshore wind industry in China is expected to develop “slow” due to the subsidy reduction and because the whole industry needs adjustment after the “rushing year-2021”.

Installed capacity of offshore in China from 2016-2022



Data source: NEA, 36氪研究院, 智研咨询

Motivations for offshore wind development

- The imbalance of local energy sources and high electricity demand in coastal provinces.

- The cost of offshore wind has decreased rapidly in recent years.

- Developing offshore wind will enhance energy security, and bring economic opportunities, creating potential for new energy-industry hubs (OSW, green hydrogen/storage, green steel, and etc.).

Research Questions

Research Questions

1. Could China accelerate offshore wind (OSW) development to meet growing electricity demand for coastal provinces in China?

2. What's the impact of OSW on phasing down coal power generation in eastern coastal regions, and on ambitions of subnational leadership on clean energy?

3. What's the impact of OSW on the regional grids/network development pattern of China's power system?

Scenario Design

Scenario Design – six scenarios

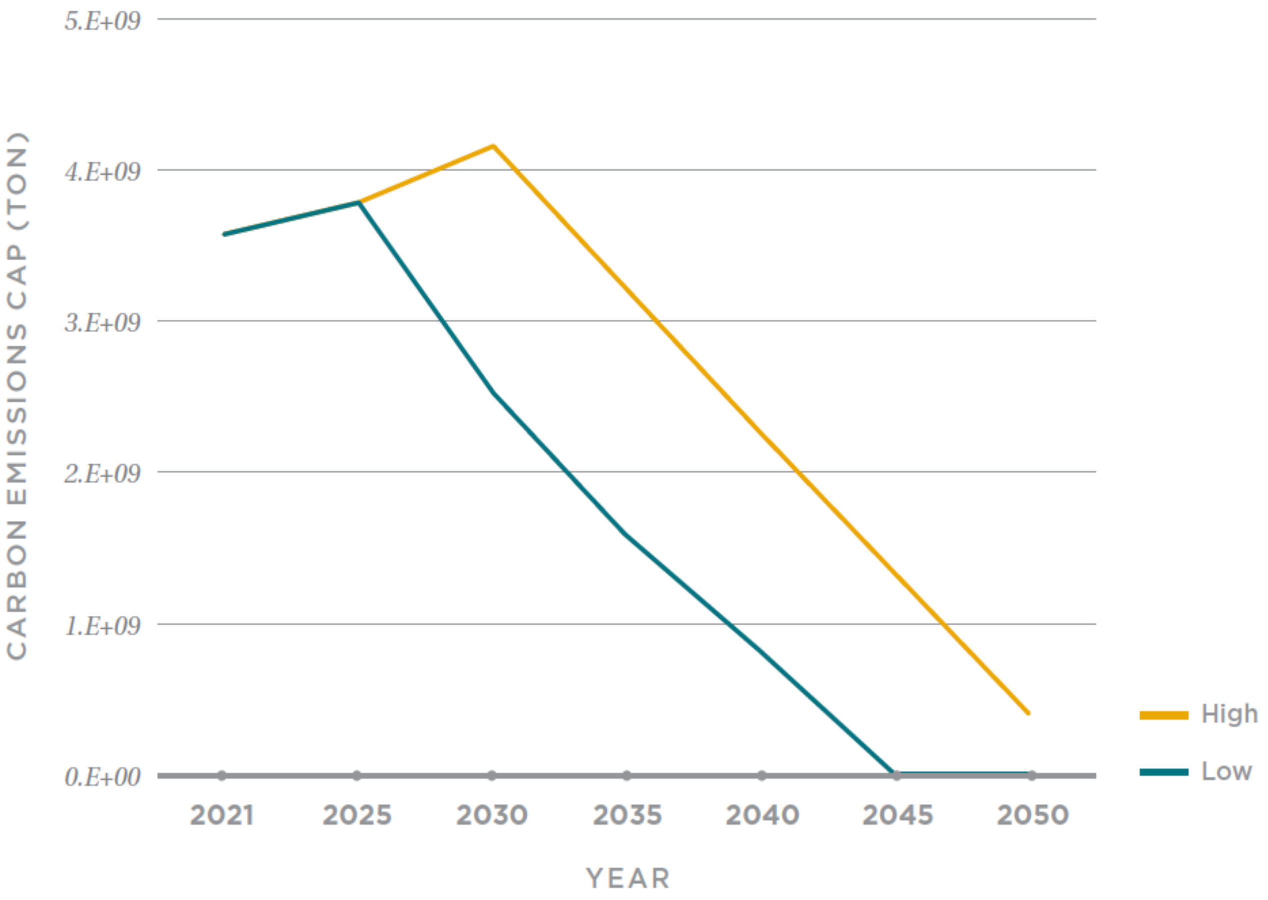
Scenarios	Carbon cap	RE cost	OSW capacity constraint
1. Carbon_high_cost_high	High	High	No constraint (cost-minimization)
2. Carbon_high_cost_low		Low	
3. Carbon_low_cost_high	Low	High	No constraint (cost-minimization)
4. Carbon_low_cost_low (Base)		Low	
5. Carbon_low_cost_low_moderate_OSW (MOSW)			We assume the cost of OSW decrease rapidly (43%) from 2025-2050 based on ATB dataset.
6. Carbon_low_cost_low_high_OSW (HOSW)			We assume the installed capacity of OSW can achieve 80% of 14th Five-Year Energy Plan (80GW) by 2025. The installed capacity of OSW reach 400GW by 2035 based on 80% carbon-free electricity system research and further reach 1000GW by 2050 based on our assumption.

Scenario Design – Carbon Emission Caps

Two carbon emission scenarios

- High carbon emission cap (achieve 100% emission reduction by 2045)

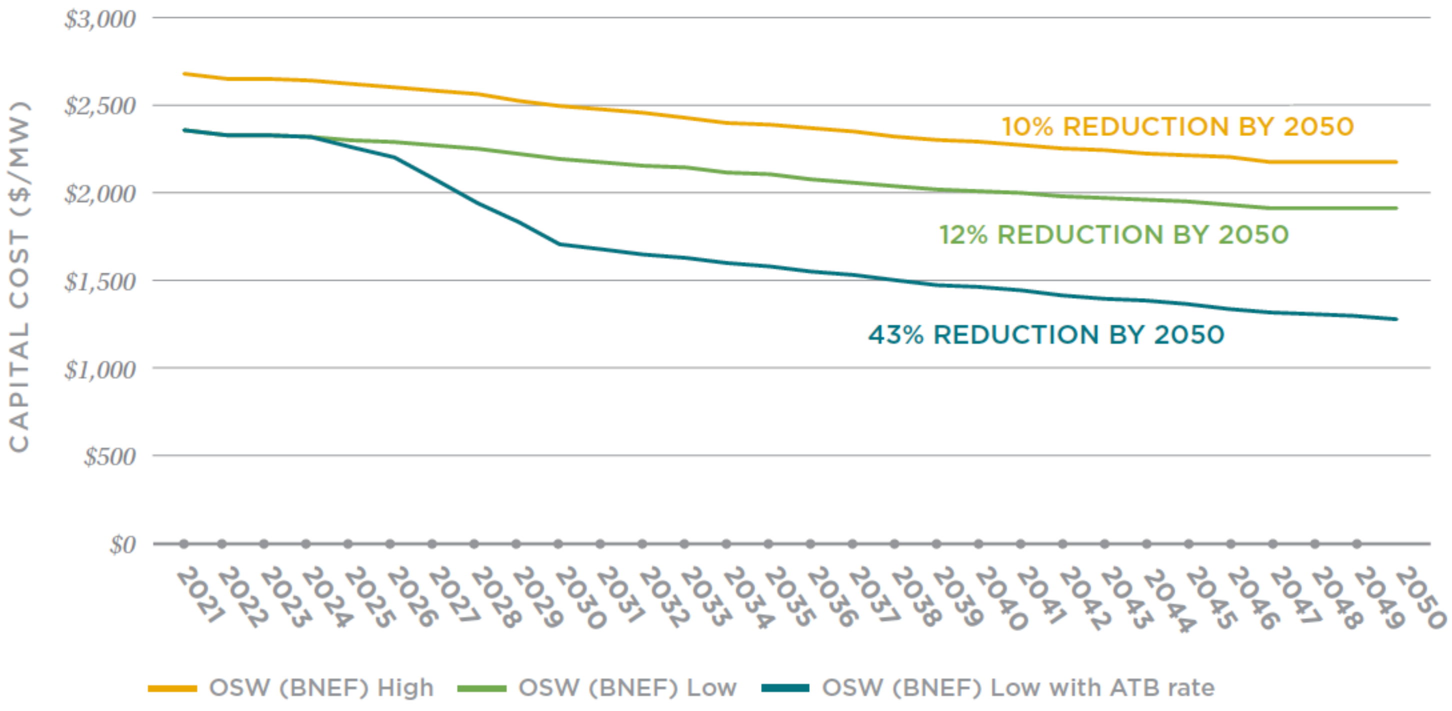
- Low carbon emission cap (achieve 90% emission reduction by 2050 compared to 2021)



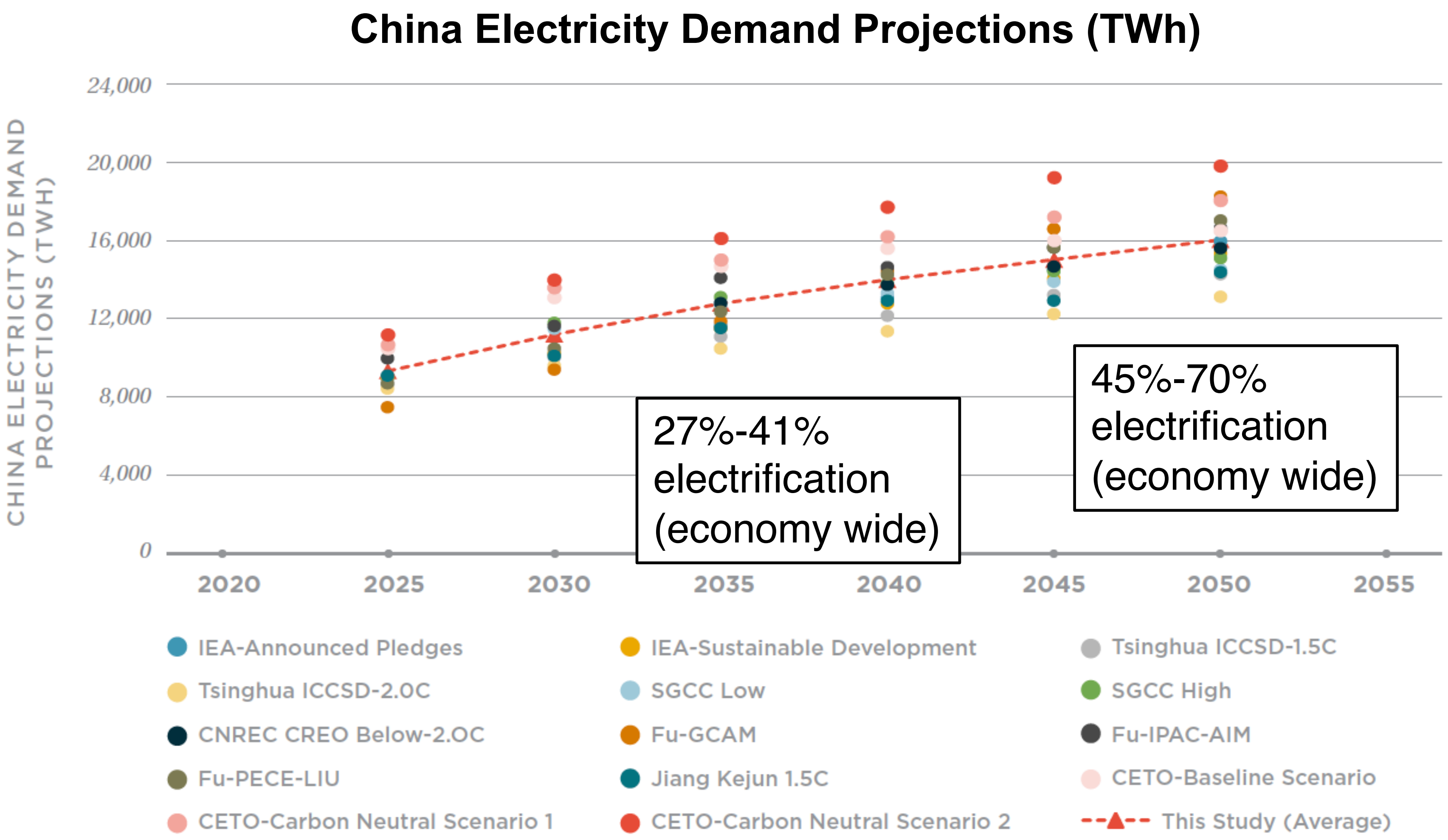
Scenario Design – Costs of offshore wind

Two cost scenarios and one additional cost test

- BNEF_high
- BNEF_low
- BNEF_low with ATB decrease rate



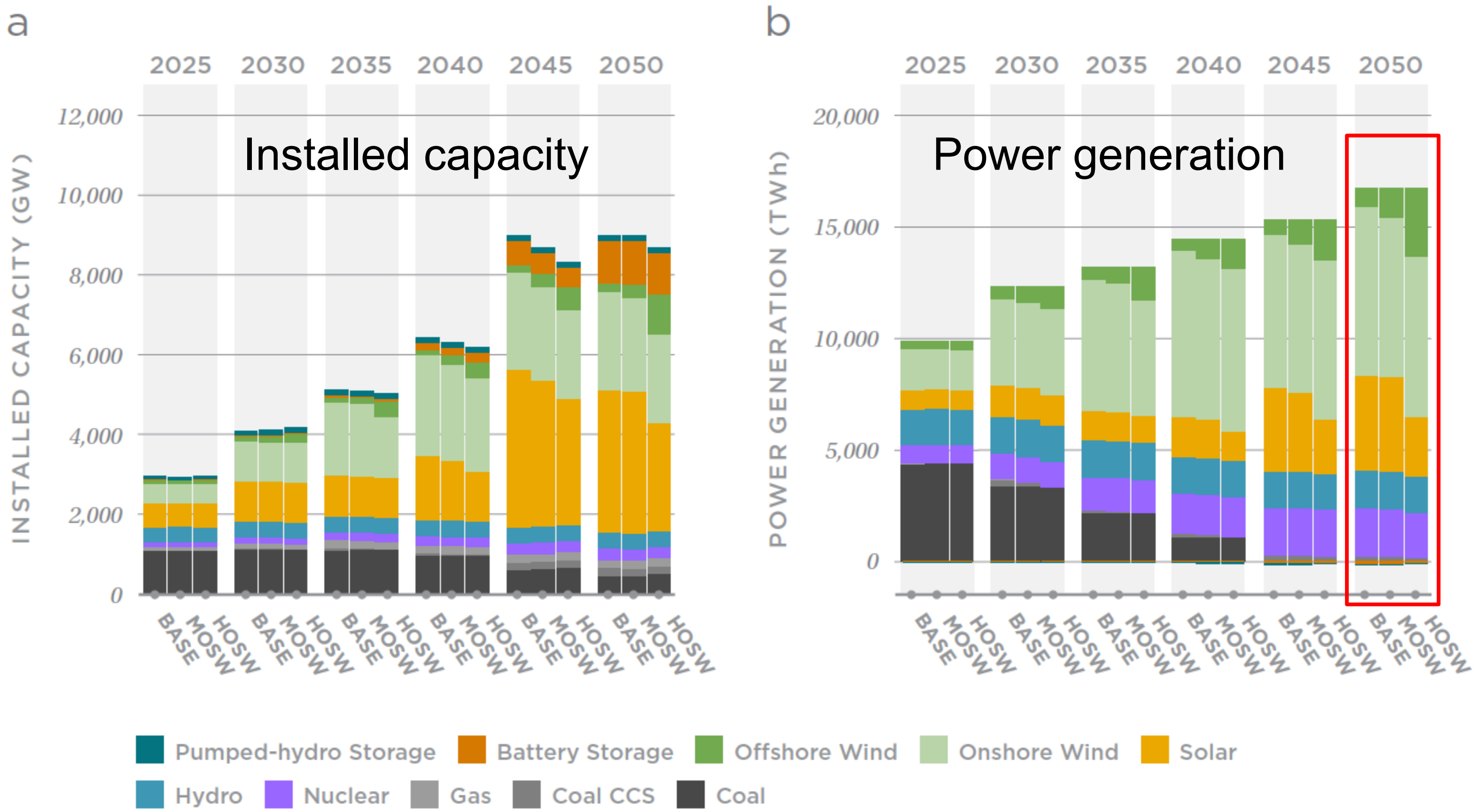
Model input – Electricity demand



Results

Installed capacity & power generation of offshore wind under three key scenarios

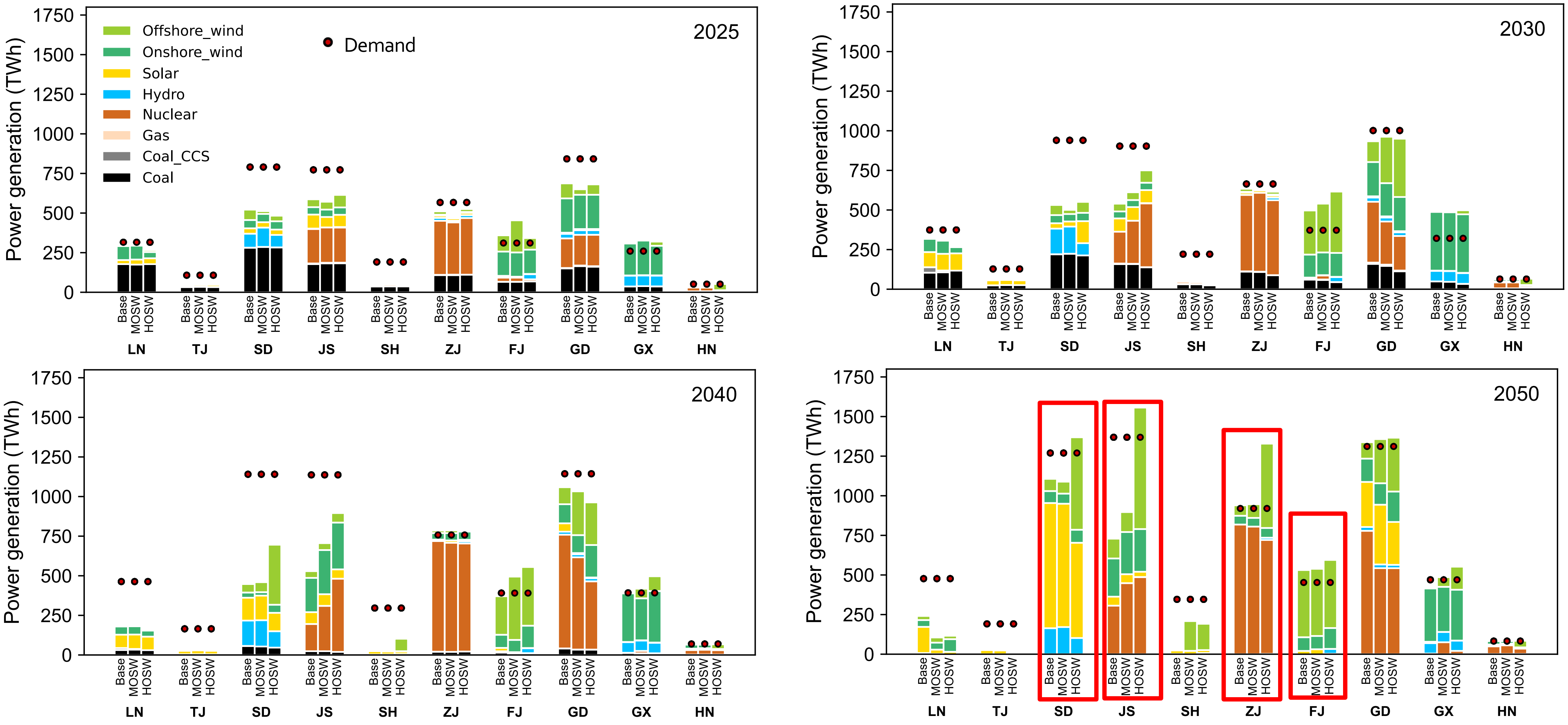
Offshore wind	Scenarios	2025	2030	2035	2040	2045	2050	Total costs (Billion $)
Installed capacity(GW)	Base	70	120	120	120	203	221	5,618
	MOSW	70	150	158	229	319	328	5,576
	HOSW	85	228	400	420	590	1000	5,613



5% → 8% → 18%

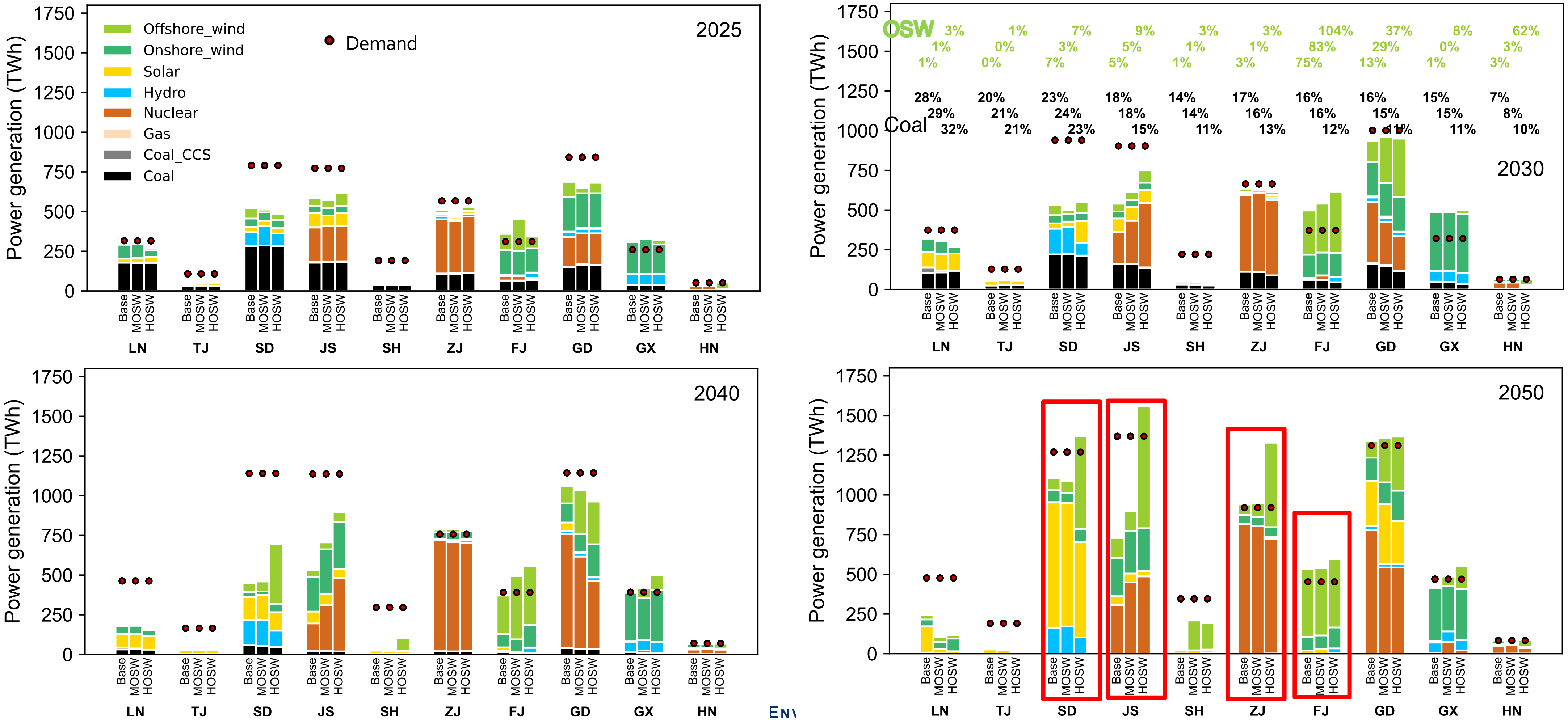
Coastal provinces could achieve energy independence - Power generation

- Certain coastal provinces, such as SD, JS, ZJ and FJ switch from being electricity importer to exporter from 2025-2050.



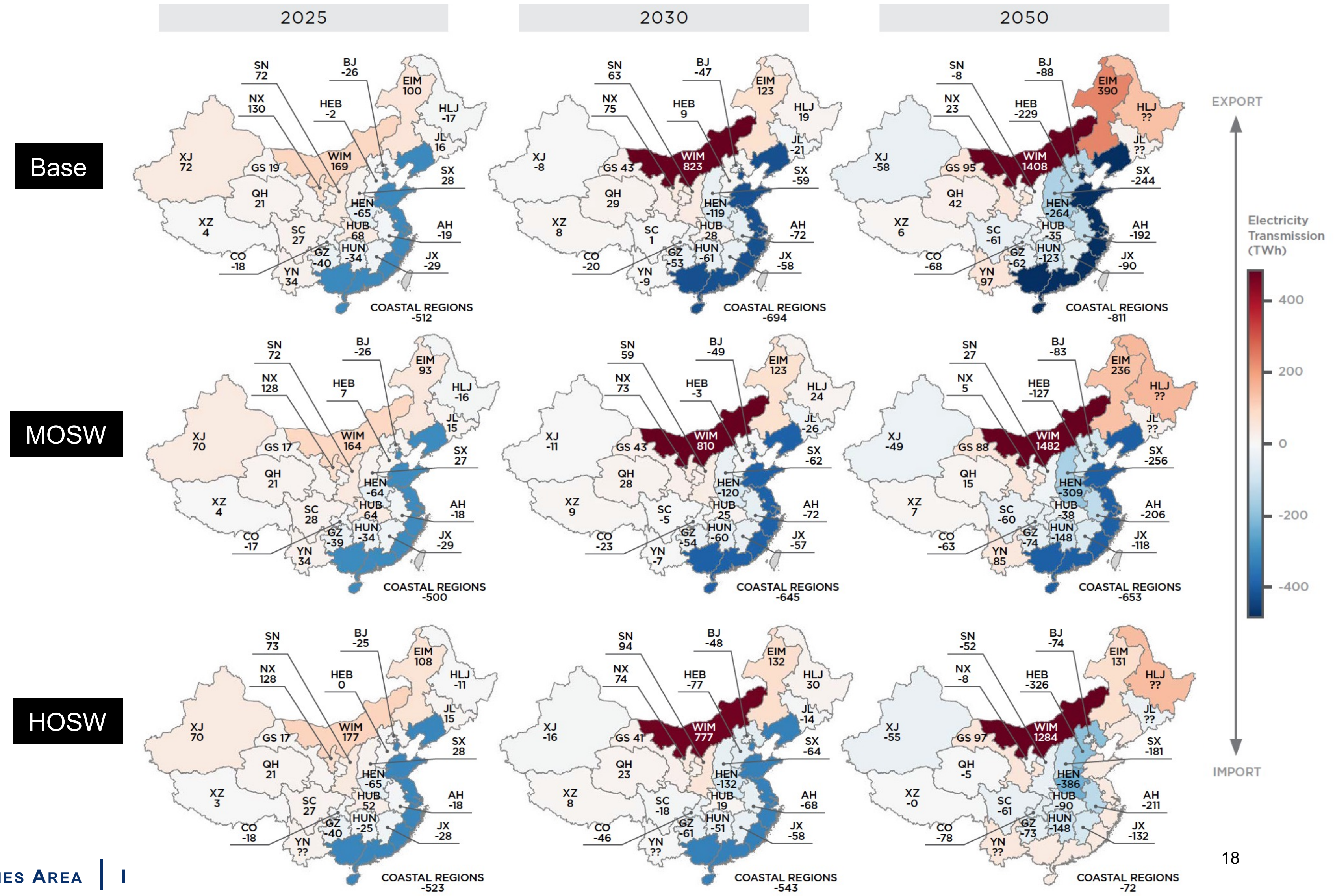
Coastal provinces could achieve energy independence - Power generation

- Certain coastal provinces, such as SD, JS, ZJ and FJ switch from being electricity importer to exporter from 2025-2050.
- Accelerating offshore wind development also promotes the phase-down of coal power.



Net electricity transmission for coastal provinces

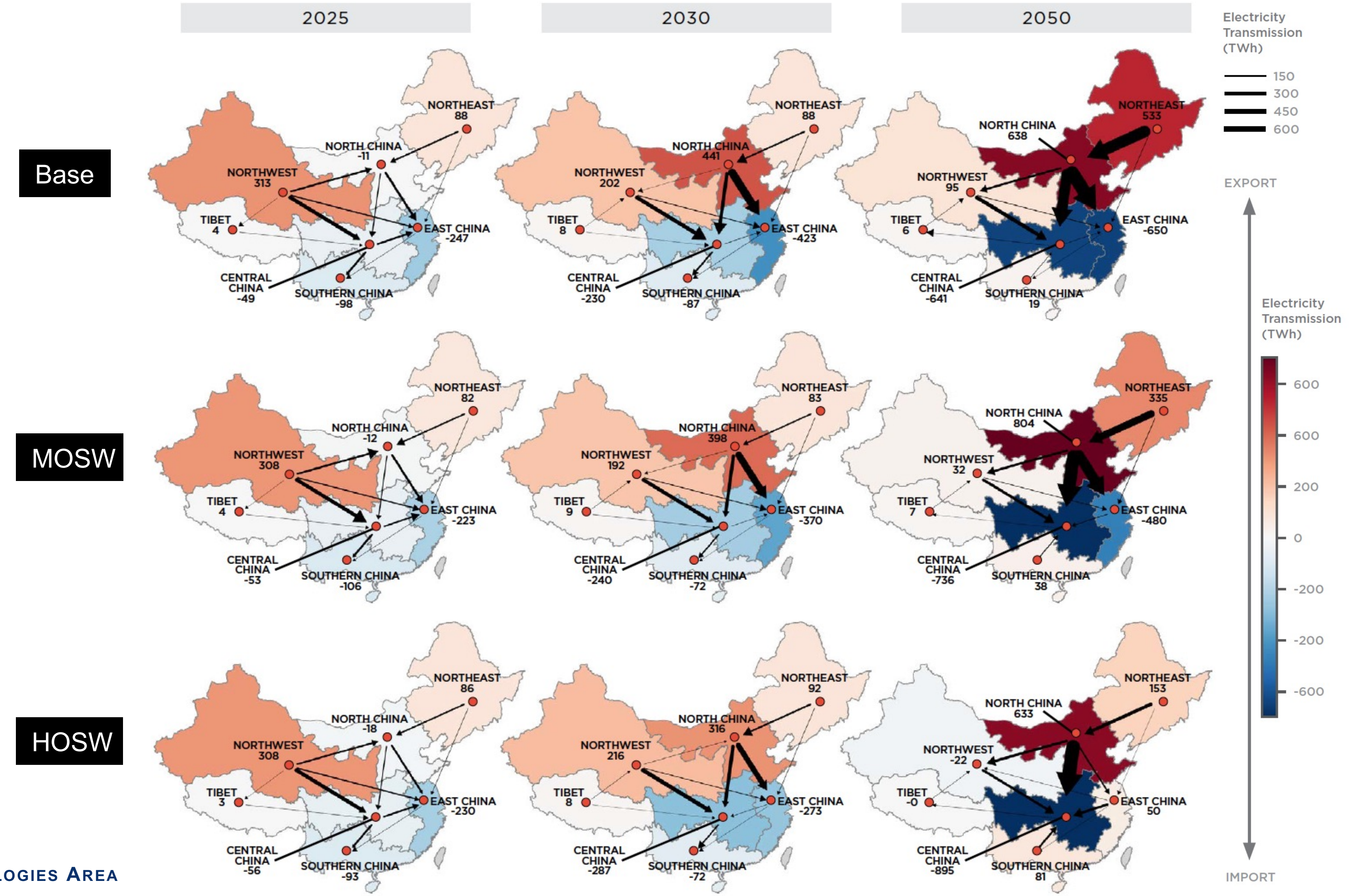
- Coastal provinces are always importing electricity from 2025-2050 in the Base and MOSW scenarios.
- In the HOSW scenario, coastal provinces transition from being electricity importers to exporters by 2050.



Shifts in electricity transmission networks

Transmission flow with direction by power grid

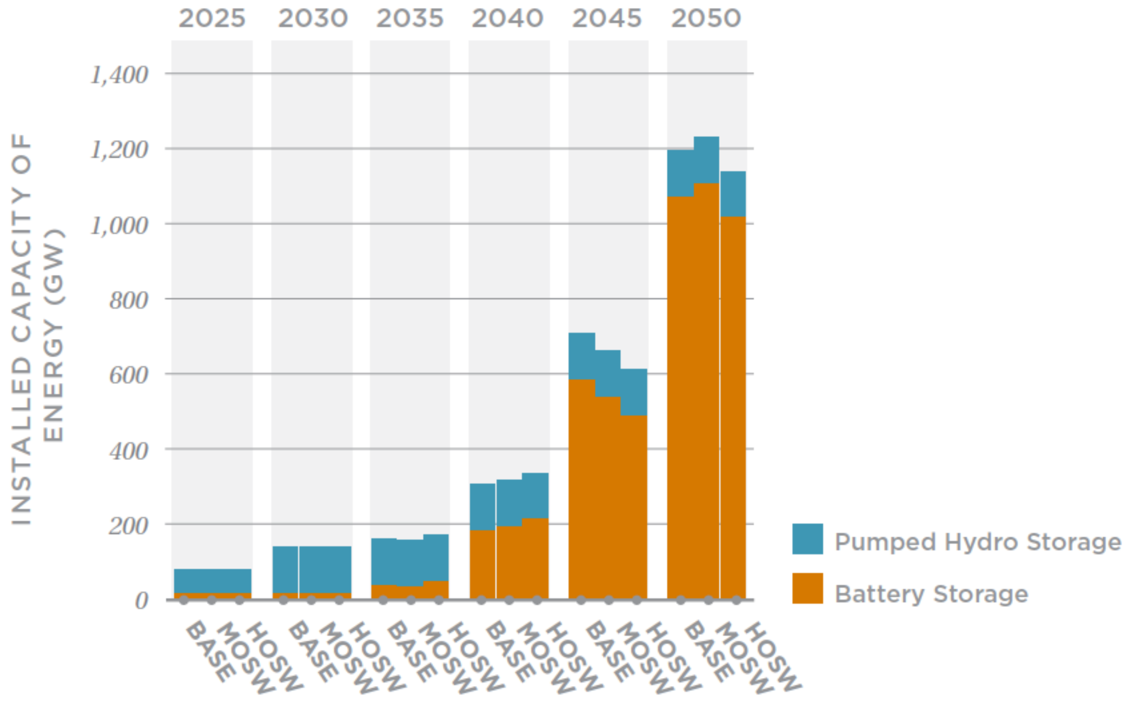
- OSW development changes China's transmission networks, alleviating the transmission load from the northwest regions.
- Central China is projected to emerge as a major electricity demand region.
- Coastal regions will lessen their reliance on the electricity transmitted from other power grids.



Offshore wind deployment reduces energy storage installation

- In the high offshore wind scenario (HOSW), the annual installed capacity of batteries reduces by 5% and 8% in 2050 compared to the Base and the moderate offshore wind scenario.

Installed capacity of energy storage

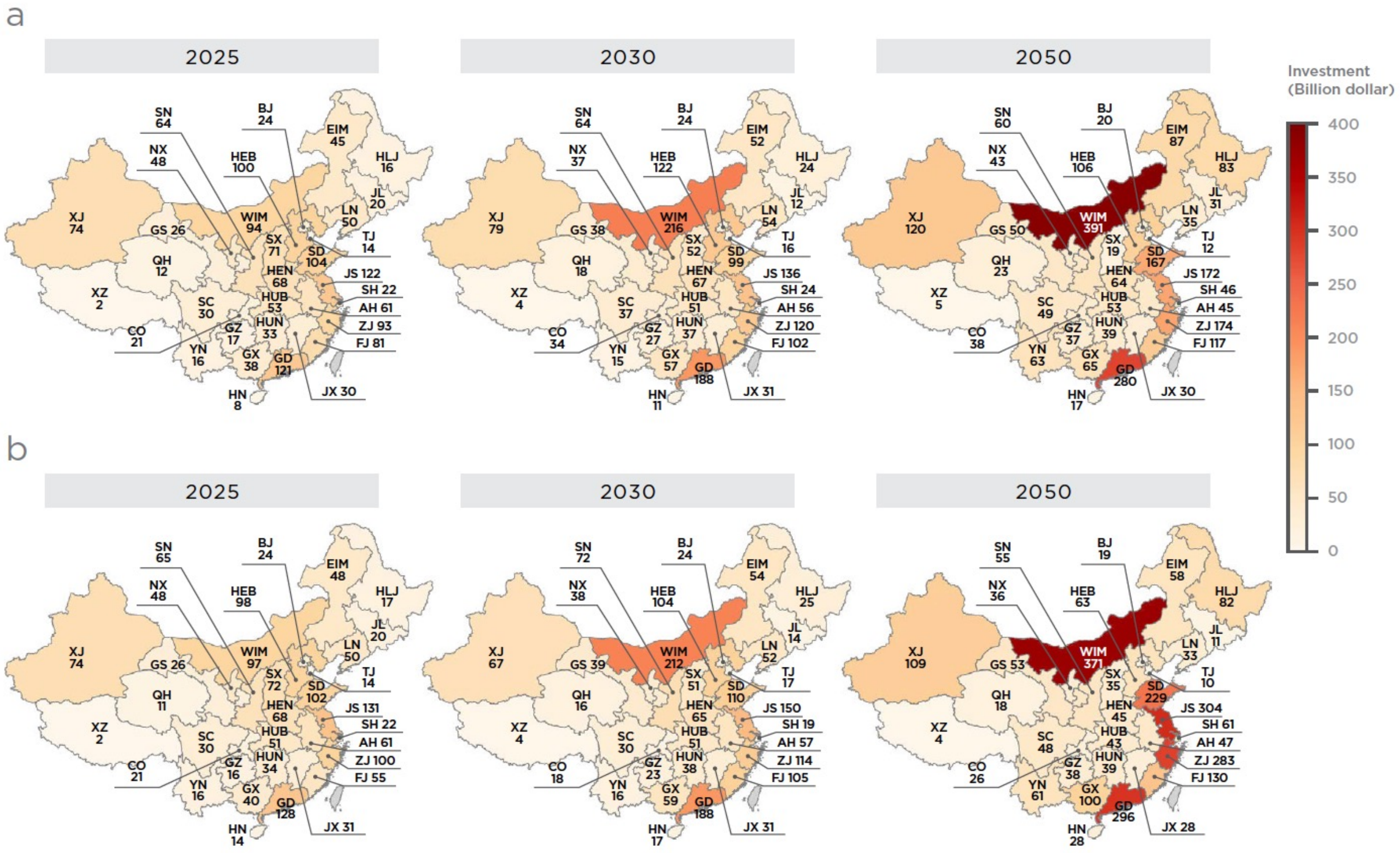


Investments in offshore wind promote high-quality economy development

- Most of the investments are focused on Guangdong, Zhejiang, Jiangsu and Shandong provinces in the coastal region.

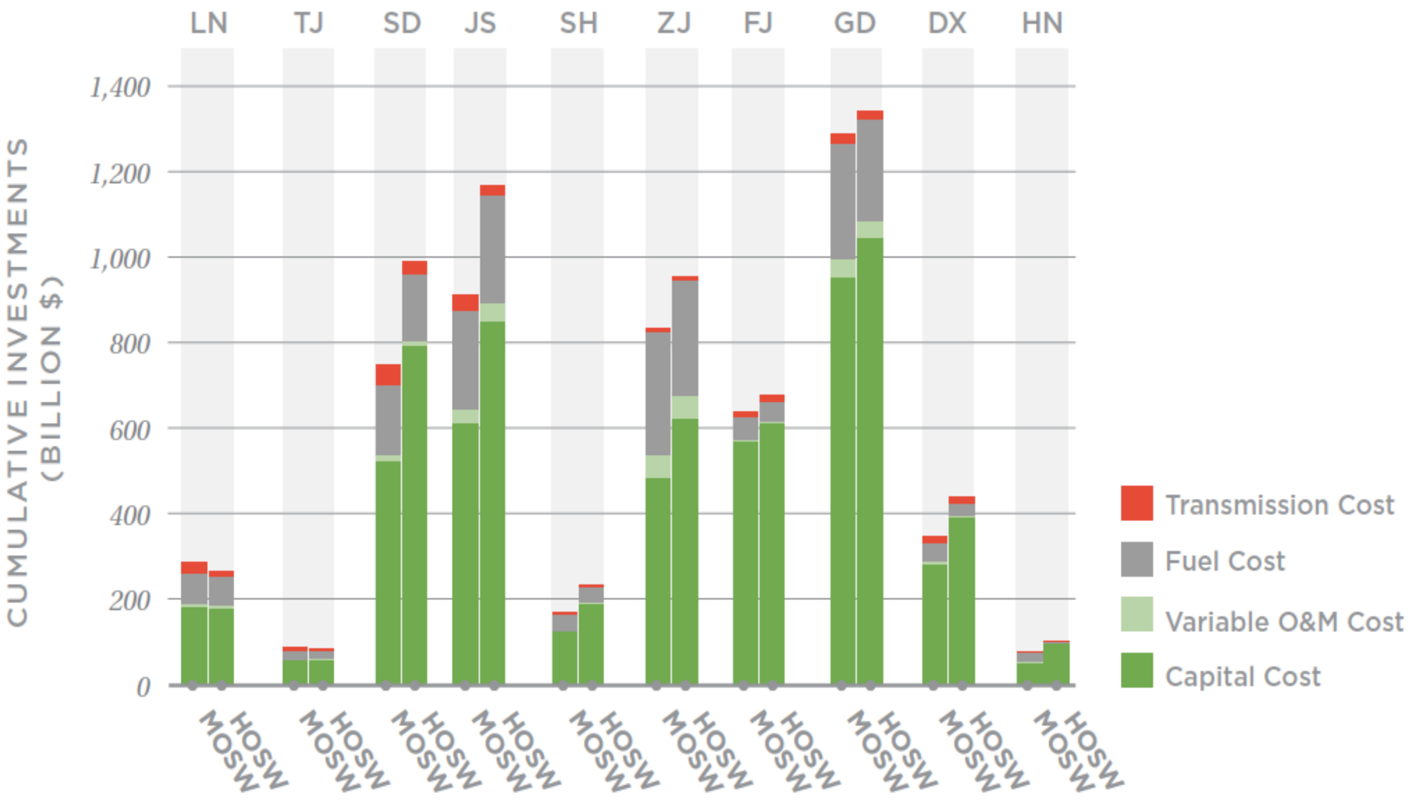
MOSW

HOSW



Comparison of cumulative investments among three key scenarios

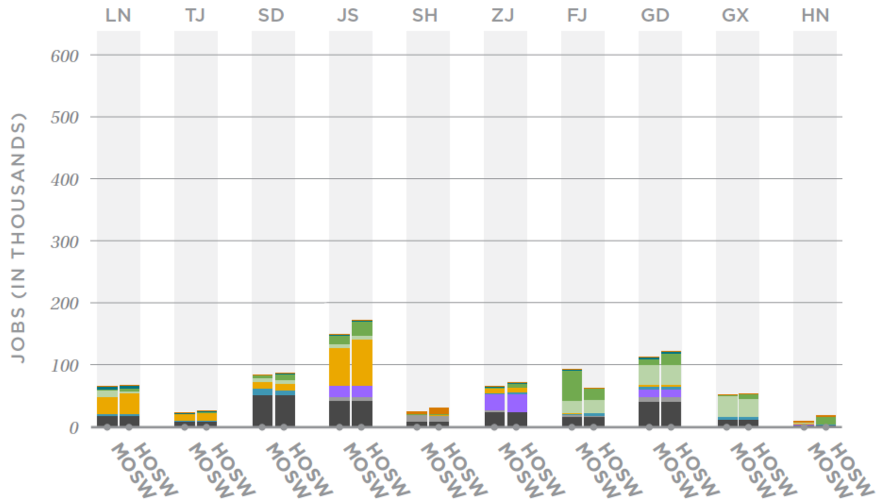
- The average cumulative investment in the high offshore wind (HOSW) scenario is 15% greater than that in the moderate offshore wind (MOSW) scenario. This could stimulate economic growth through job creation, infrastructure development, and the emergence of potential ancillary industries.



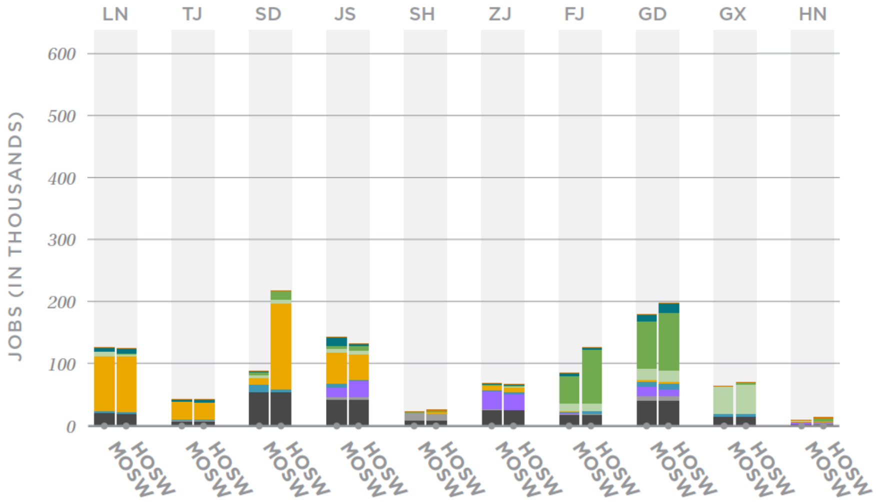
Jobs created by the power generation in the coastal provinces

- In 2050, the HOSW scenario will generate 24% more jobs in coastal provinces, particularly 26% and 145% more in JS and ZJ provinces, respectively, compared to the MOSW scenario.

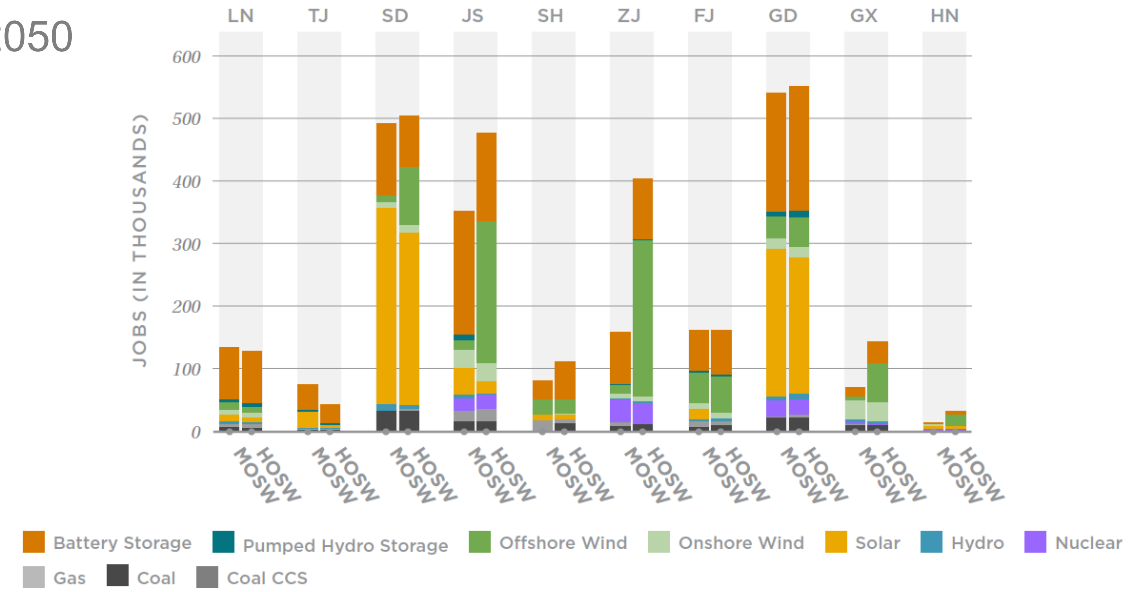
2025



2030



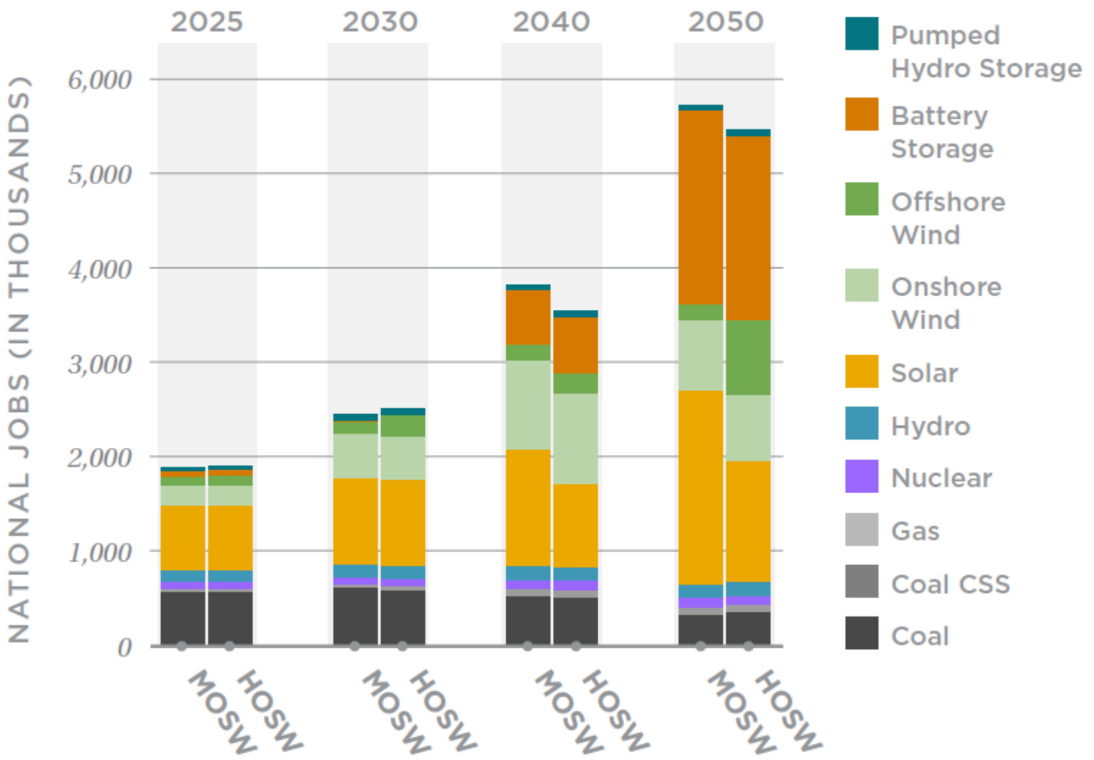
2050



National jobs created by various power generation technologies

- Compared to the MOSW scenario, job creation has a slightly decrease in the HOSW scenario due to lower total installed capacities.

- In the HOSW scenario, coastal provinces account for 52% of the nation's new jobs, surpassing the 44% in the MOSW scenario.



Summary

1. Accelerating the deployment of OSW will

- significantly reduce the reliance on imported electricity for coastal province, particularly for Shandong, Jiangsu, Zhejiang, Fujian, Guangdong and Guangxi which will switch from being electricity importers to exporters.
- effectively accelerate the phase-down of coal power generation in coastal regions.
- induce higher job creation, infrastructure development, and the emergence of potential ancillary industries.
- reshape China's power grid, making it more balanced and less reliant on long-distance transmission.

2. Accelerating OSW deployment from 328 GW to 1000 GW by 2050 will result in only a 1% increase in total system costs.

Policy recommendations

1. *Increase targets for offshore wind capacity and generation*
2. *Incorporate offshore wind development into transmission network planning*
3. *Develop standards & regulations for interconnection of offshore wind projects*
4. *Coordinate offshore wind development with other national priorities*
5. *Strengthen international engagement and collaboration*

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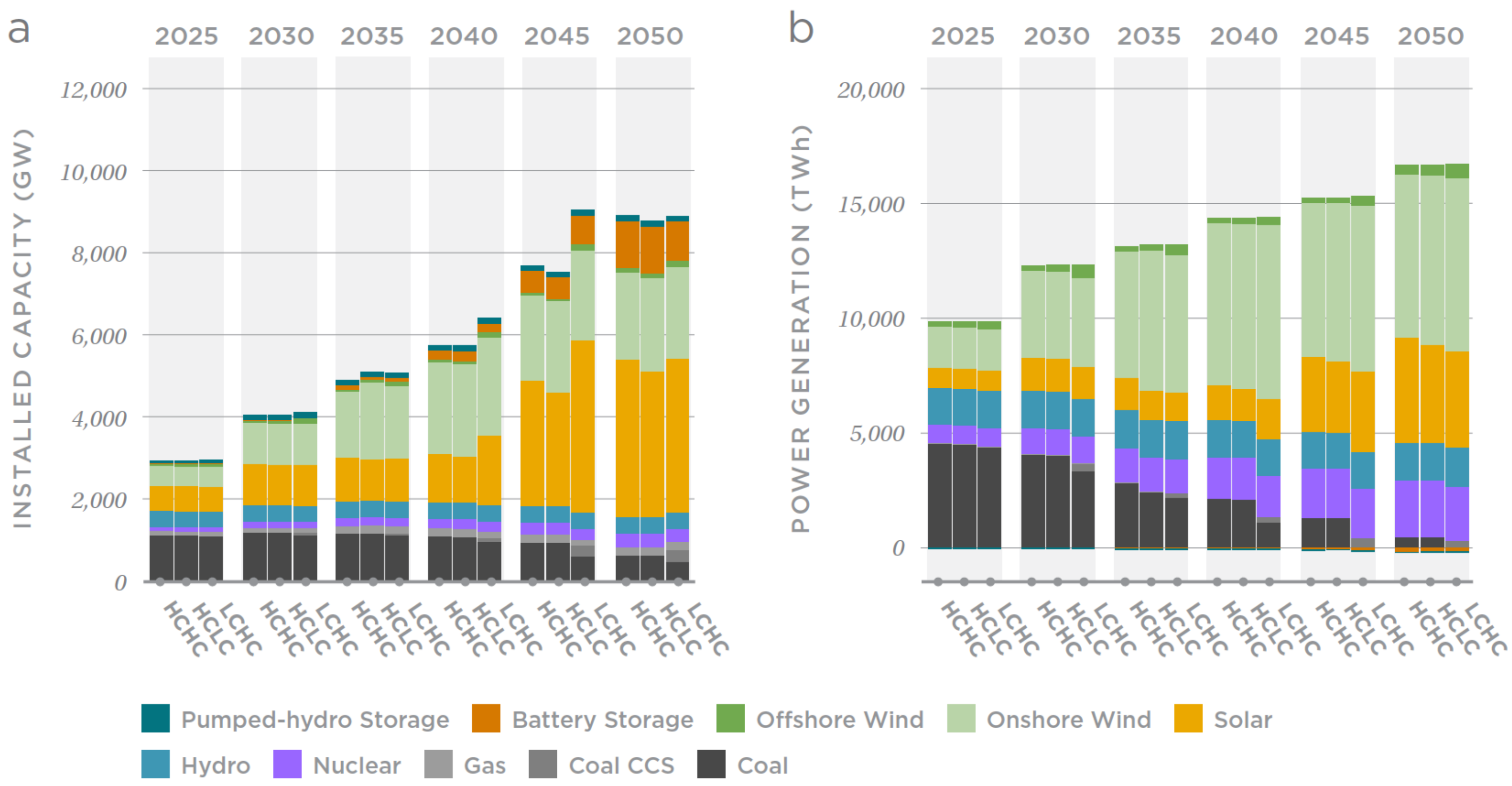
Acknowledgements

This work was funded under Contract No. DE-AC02-05CH11231. For comments and input on this analysis, we also thank Michael O'Boyle, Jiahai Yuan, Nikit Abhyankar, Bo Yuan and Yi Bao.

Sensitivity analysis - installed capacity and power generation



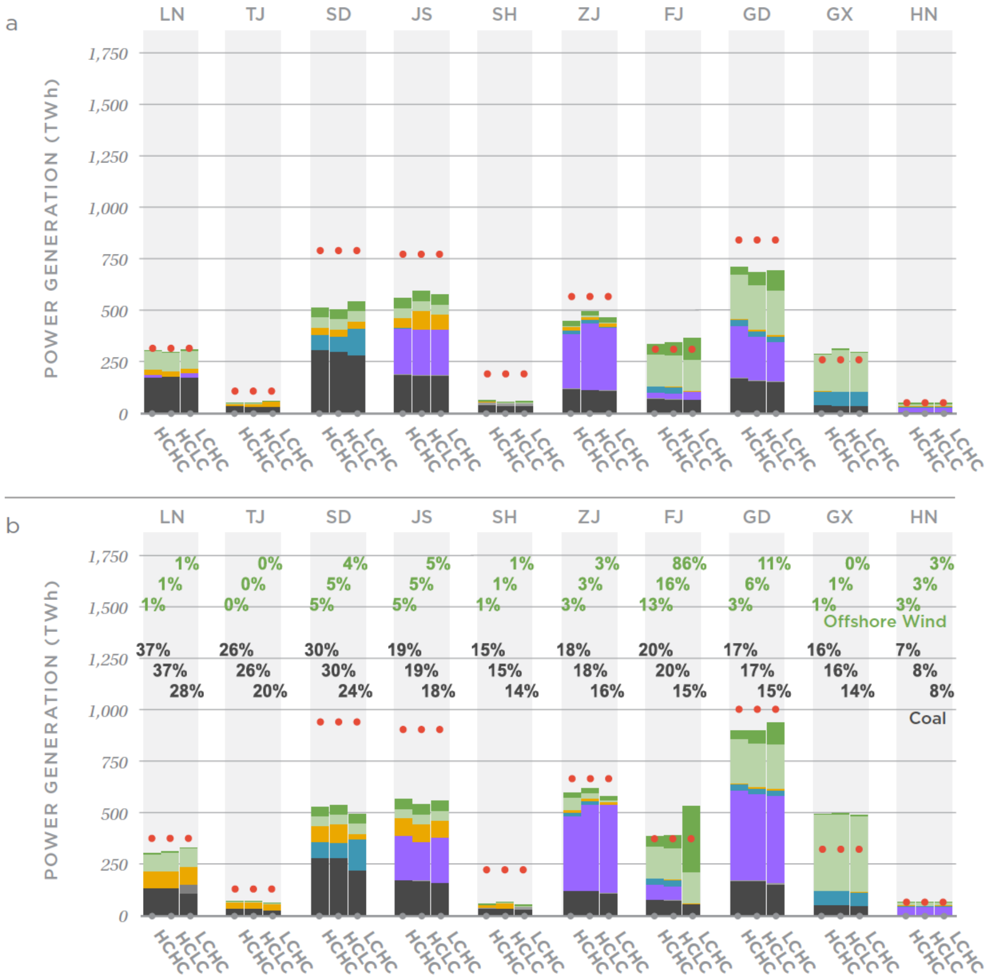
HCHC: high carbon emission cap with high RE costs

HCLC: high carbon emission cap with low RE costs

LCHC: low carbon emission cap with high RE costs

Figure C1. China's optimal (a) installed capacity and (b) power generation mix in three sensitivity scenarios (2025–2050).

Sensitivity analysis - power generation in the coastal provinces



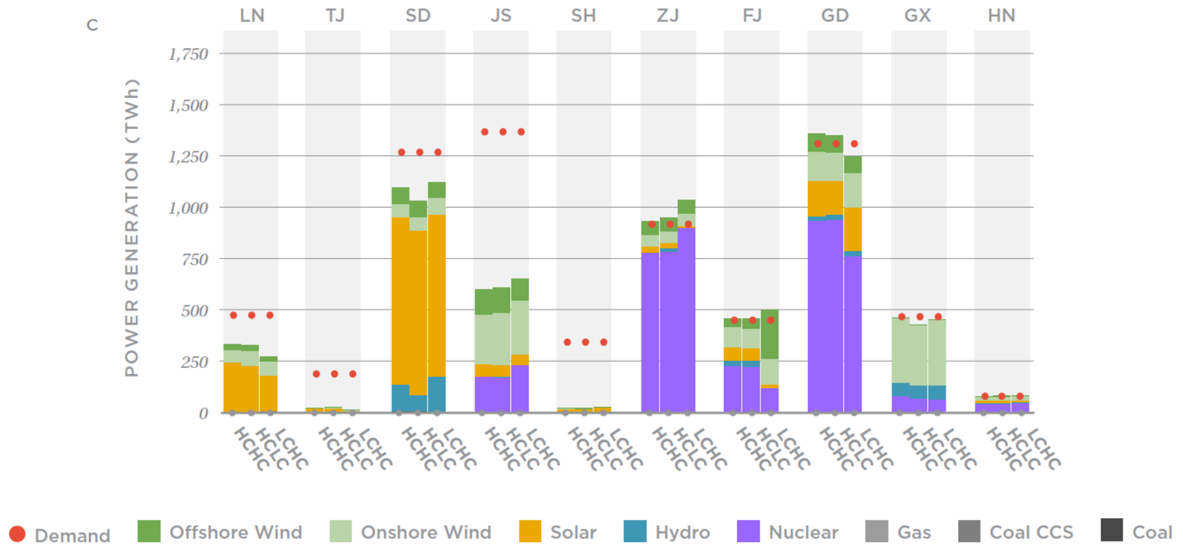


Figure C2. Power generation mix in 10 coastal provinces in (a) 2025, (b) 2030, and (c) 2050.

Green and black percentages in (b) represent the share of offshore wind and coal power generation relative to total power generation in each province under three sensitivity scenarios.

Sensitivity analysis - net transmission flow

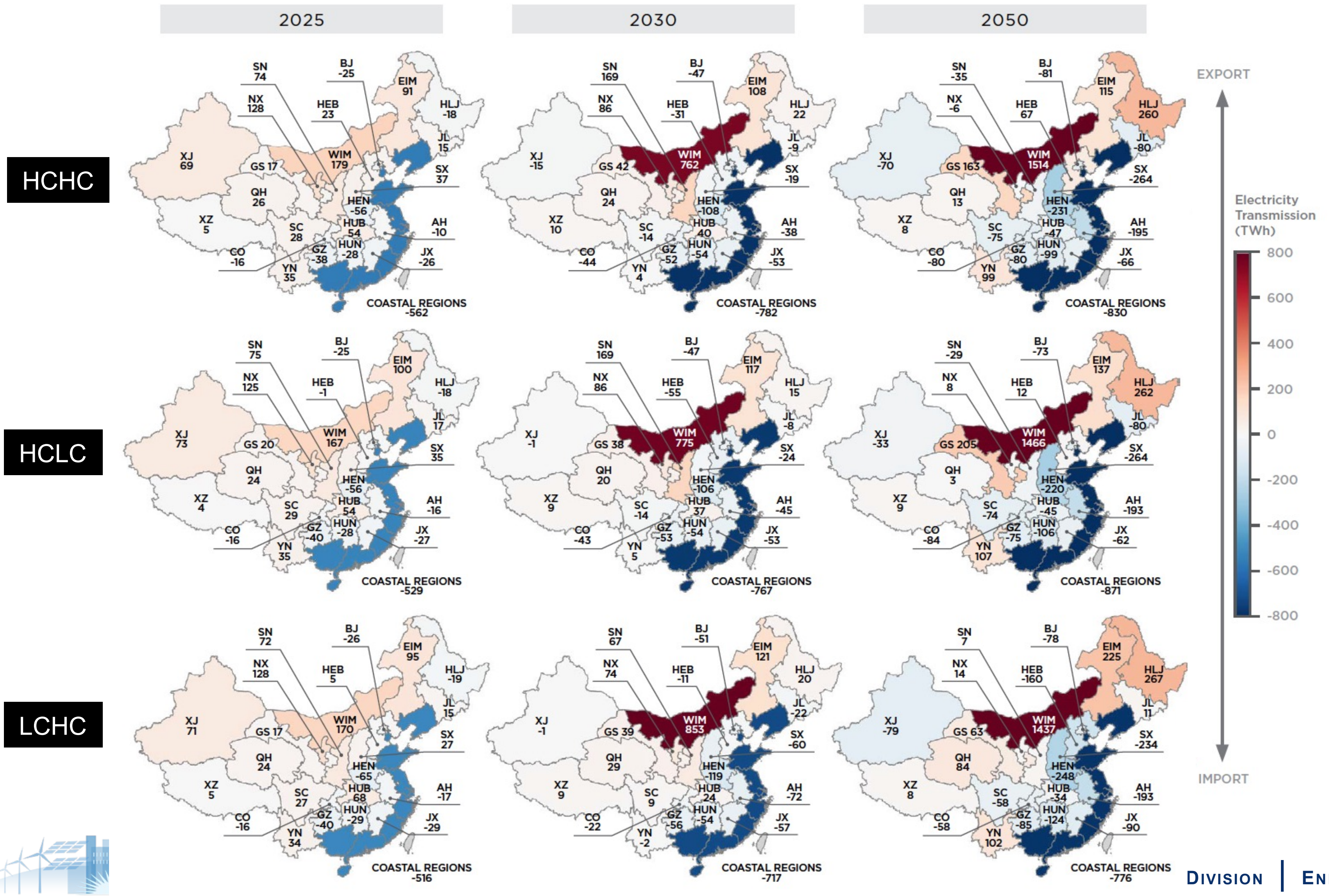


Figure C3. Net transmission flow among coastal provinces in 2025, 2030, and 2050 under (a) HCHC sensitivity scenario, (b) HCLC sensitivity scenario, and (c) LCHC sensitivity scenario.

Sensitivity analysis – transmission flow among six power regions

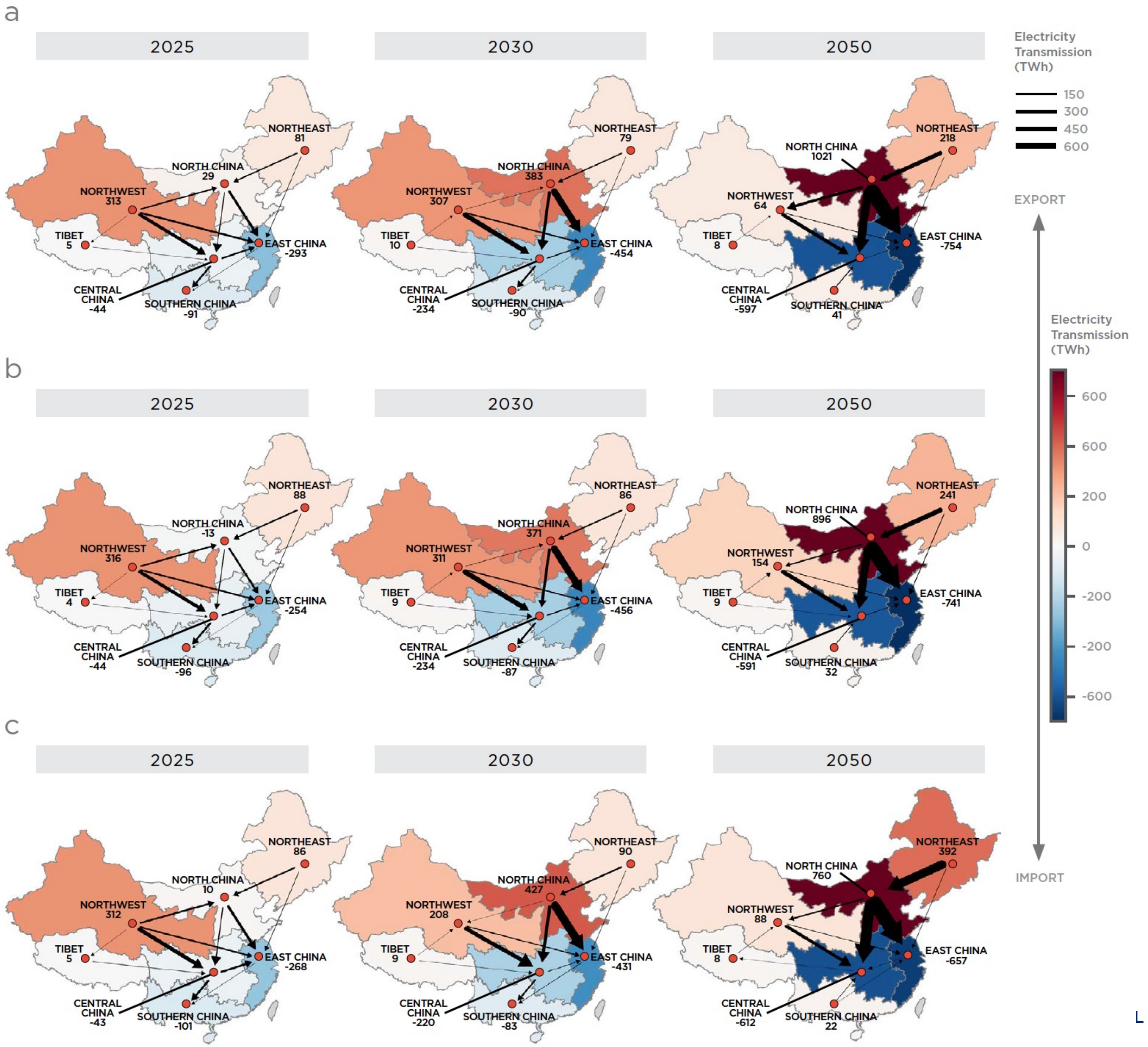


Figure C4. Shifts in transmission flow among six power regions in 2025, 2030, and 2050 under (a) HCHC sensitivity scenario, (b) HCLC sensitivity scenario, and (c) LCHC sensitivity scenario.

All scenario analysis

Installed OSW capacity and total system costs under all scenarios

Scenarios	Carbon Cap	RE Cost	OSW Capacity Constraint	OSW Capacity (GW)						Total Costs (Billion $)
				2025	2030	2035	2040	2045	2050	
1. High_Carbon_High_Cost (HCHC)	High	High	No constraint (cost-minimization)	48	48	48	48	60	117	5796
2. High_Carbon_Low_Cost (HCLC)		Low		56	56	56	56	62	120	5467
3. Low_Carbon_High_cost (LCHC)	Low	High	No constraint (cost-minimization)	70	120	120	120	146	172	5987
4. Low_Carbon_Low_Cost (Base)		Low		70	120	120	120	203	221	5618
5.Low_Carbon_Low_Cost_moderateOSW (MOSW)			Costs decrease rapidly (43%) from 2025-2050 based on ATB database.	70	150	158	229	319	328	5576
6.Low_Carbon_Low_cost_HighOSWcap (HOSW)			Installed capacity reaches 80 GW by 2025, 400 GW by 2035, and 1,000 GW by 2050.	85	228	400	420	590	1000	5613