Energy security in the context of energy transition – Lessons and Challenges within Europe and within China

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A net zero future

- Paris Agreement (2015): World leaders stressed limiting global warming to 1.5°C by 2100 to mitigate climate change's adverse impacts.
- Net-zero pledges by the EU and China.
  - China Dual Carbon targets: Carbon peak before 2030 and net-zero before 2060
  - EU Fit for 55 package: Target of 55% reduction of GHG by 2030 and climate neutral by 2050

The 'target' model – energy system in 2050/2060:

- Emphasizes renewables as primary energy source.
- Focuses on electrifying numerous energy services.
- Offers diverse flexibility and storage solutions.
- Utilizes carbon capture tech to capture hard-to-abate sector emissions.
- Integration of separate systems
- Electricity markets and interconnected grids for efficient energy resource allocation

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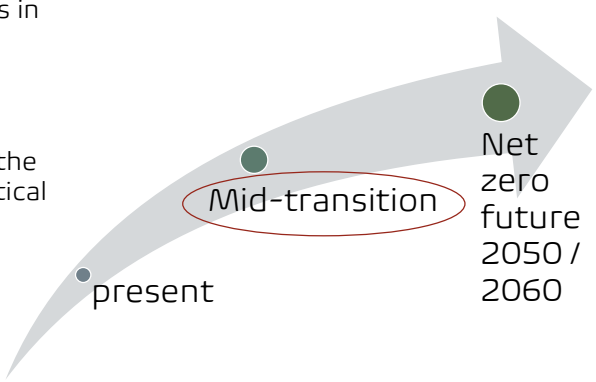
The transitional stage brings the need for a redefinition of *energy security*

- The "mid-transition" phase poses challenges in coexisting fossil-fuel and carbon-neutral systems, impacting infrastructure and decision-making.
- China and the EU share many challenges to reach their zero- carbon targets. However, the history, the decision processes and the political and regulatory framework are different.

1) What does energy security mean for an energy system under transition?
2) How is the weather going to impact an energy system dominated by VRE?



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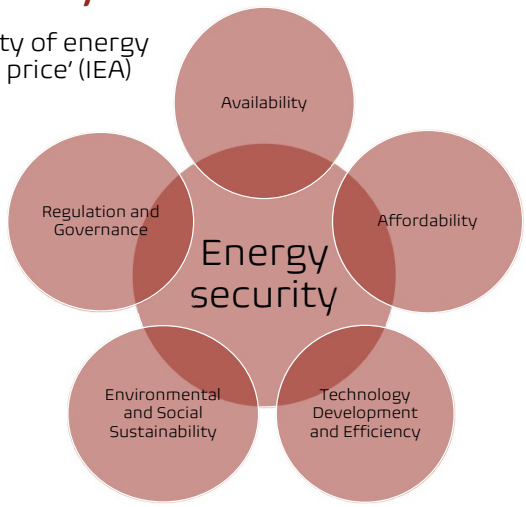
Energy security

'uninterrupted availability of energy sources at an affordable price' (IEA)



Energy security dimensions. Based on: Sovacool & Mukherjee (2011)

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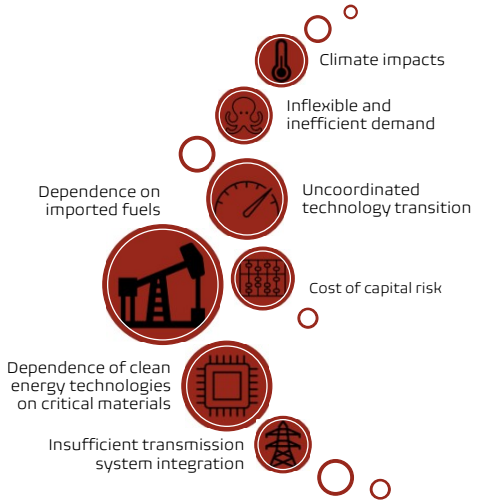
Energy security risks during transition



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Energy security risks during transition

EU and China common trends and Differences:

- Decreasing dependency on imported fuels in both China and EU due to net zero targets.
- China holds dominance in global technology and material supply chains; EU reliant on world markets and agreements.
- EU more advanced in implementing market mechanisms, smart meters, and consumer price reactions compared to China.
- Climate effects anticipated in both regions, impacting energy systems.
- Insufficient transmission systems pose barriers to large-scale renewable deployment.

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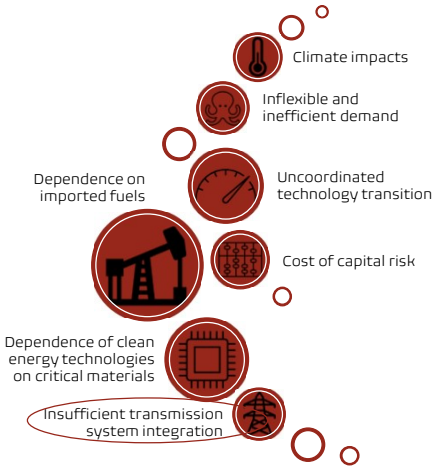
Energy security risks during transition



Insufficient transmission system integration
→ vulnerability and potential disruptions in the energy supply that can occur due to inadequate integrated infrastructure for transmitting electricity.

This can lead to inefficiencies, congestion, and limitations in the flow of energy from generation sources to consumption centres, especially in regions heavily reliant on VRE.

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Risk of insufficient transmission system integration in China

The case of Guangdong and Fujian:

- Electricity consumption in Guangdong is 790 TWh and is 1.7 times more than that in Fujian in 2022.
- Non-fossil fuel generation accounts for around 48% of total power generation in Fujian, while the VRE share in Guangdong was just above 30% in 2022.
- Hydro power in Fujian and hydro power transmitted from Yunnan to Guangdong are associated with different watersheds, with distinct inflow characteristics. In addition, the summer comes later in Fujian than in Guangdong.
- Insufficient transmission system integration led to challenges in meeting rising electricity demands and harnessing renewable energy potential.
- A grid connection was approved by NDRC in 2020 and was put into operation in 2022.
- According to Fujian Daily, the connection started to provide mutual benefits to both provinces in the summer of 2023.
- Agreement: Fujian provides electricity to Guangdong from March to June and from October to November, while Guangdong provides electricity to Fujian in July, August, September and December, thus resolving the tensions between local production and demand.
- The connection also provides the flexibility to accommodate a higher share of wind and solar power in the system by integrating the interprovincial spot market.

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Risk of insufficient transmission system integration in the EU

Transmission System Needs:

ENTSO-E study: 64 GW of cross-border capacity needs by 2030 and additional 24 GW by 2040.

Additional storage and CO2-free peaking units are essential for a carbon-free power system.

Efficiency & Cost Savings: Addressing system needs could save 9 billion euros/year (2025-2040), reduce renewable energy curtailment by 42 TWh/year in 2040, and cut CO_2 emissions by 31 Mton/year

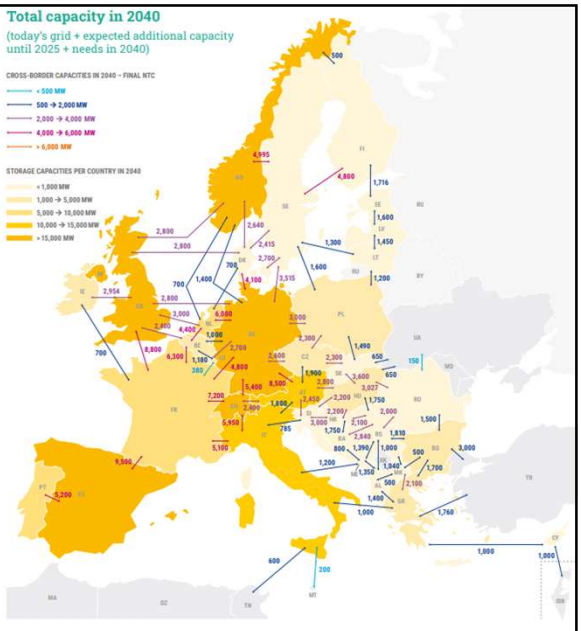

Figure 1.4 – Total cross-border capacities and storage capacities in 2040 (for cross-border increases: capacities expected around 2025 plus capacity increases identified in the system needs study for the 2040 horizon; for storage: capacities in the National Trends 2030 scenario plus capacity increases identified in the system needs study for the 2040 horizon). To not overcharge the map, only the highest value is displayed on borders where the value is not the same in both directions.[2] Source: ENTSO-E (2023) System Needs Study

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Insufficient transmission system integration - Proposed mitigation measures

China

- Integrating the transmission system into the market mechanism, for example through implicit capacity auction in the market coupling mechanism.
- Expanding cross-regional infrastructure to transmit renewable power, pursuing transmission rescheduling, netting supply-demand imbalances and expanding resource-sharing areas.
- Accelerating the development of energy storage.

EU

- Building new infrastructure/expand existing transmission where profitable (benefits > costs)
- Adopting CBCA (cross border cost allocation) as a method to cost sharing
- Better utilize existing capacity (e.g., dynamic line rating)
- Integrated generation-transmission planning
- Accelerating the development of energy storage

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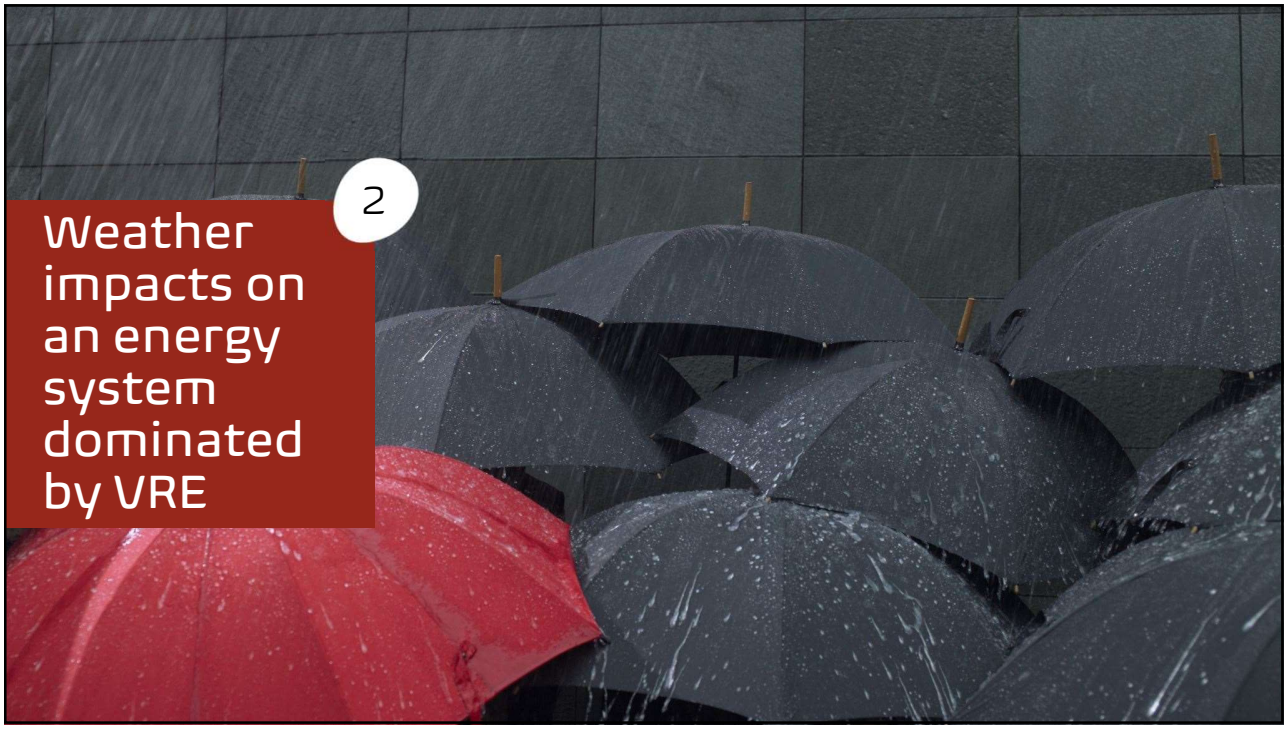

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Weather impacts on energy production (WP2)

- Assumption: EU in 2050 and China in 2060 - electricity systems are fully decarbonised, with a high proportion of VRE
- comparative analysis of the power system adequacy of VRE resources deployed in Europe vis-a-vis China

→ How much do VRE-resources contribute towards maintaining generation adequacy, relative to projected demands and considering changing weather?

Scenario	Onshore wind (GW)	Offshore wind (GW)	Solar PV (GW)	Annual demand (TWh)	Annual VRE coverage (%)
CEC China 2060	1 885	159	3 278	15 701	72%
TYNDP Global Ambition EU 2050	546	342	1 048	3 864	126%

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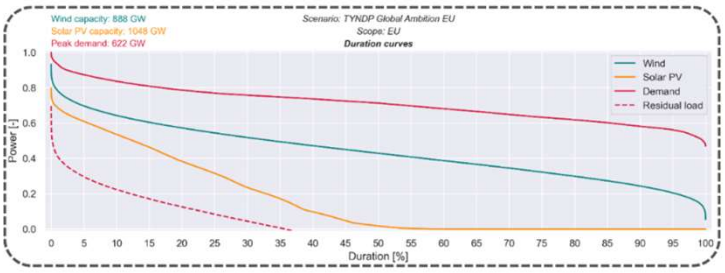
Key concept 1: Duration curves

- A *duration curve* is a statistical measure that shows how long a certain power is maintained in a power system.



Note: Duration curves are based on 20 year of weather data

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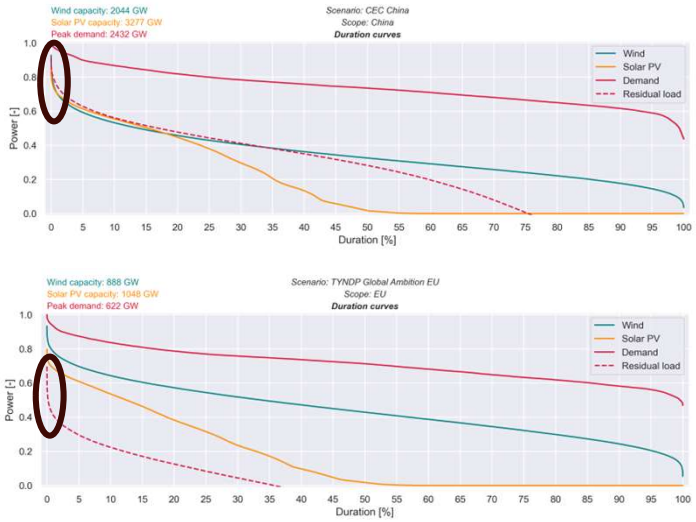
High backup capacity is needed for a low number of operational hours

- Rare weather events result in high residual load in a low amount of hours
- Residual load curves in both China and EU are steep towards their maximum
- Market incentives are needed to build sufficient backup capacity



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Key concept 2: Energy 'droughts'

Energy droughts show the risk of long continuous periods where VRE are insufficient.

A continuous period of time where VRE generation is below a certain threshold or residual load is above a certain threshold in all time steps.

- Energy production droughts
- Residual load droughts (mismatch)

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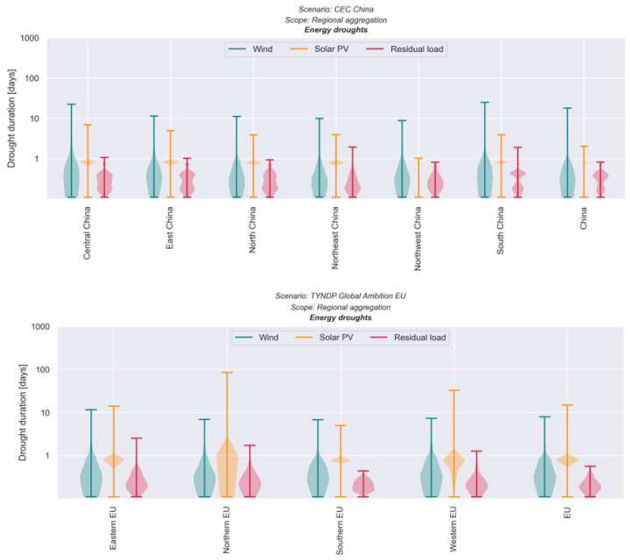
Energy droughts

- Wind energy droughts are of lower duration in the EU (higher average capacity factor, more offshore wind energy)
- Solar energy droughts are most likely be caused by the day-night pattern and usually last less than a day
- The EU is located at a higher latitude than China, which means solar droughts are more affected by seasons.
- Residual load droughts are generally lasting less than a day



Generation < 30 % of capacity
Residual load > 50 % of peak demand

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Key concept 3: Flexibility needs

Flexibility needs:

amount of energy that must be 'shifted around' to balance the residual load within a certain time scale.

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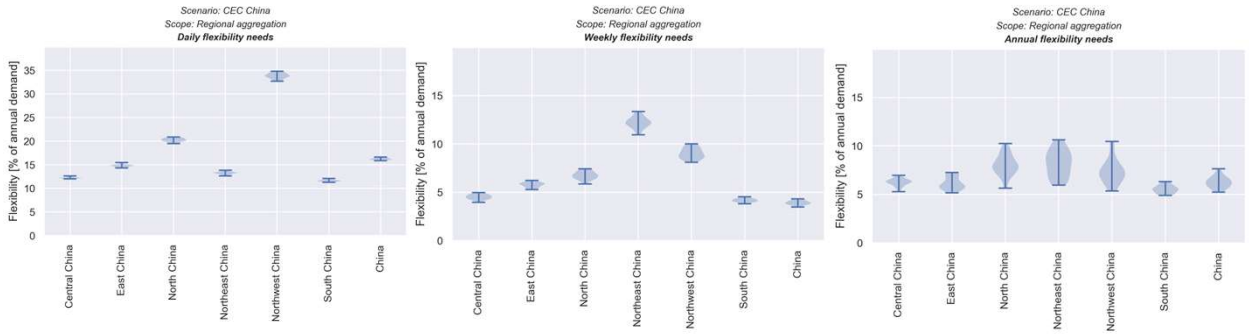
Flexibility needs

- Flexibility needs are most significant for **daily balancing** in VRE-dominated power systems in both the EU and China
- Interconnection between regions lower the flexibility needs



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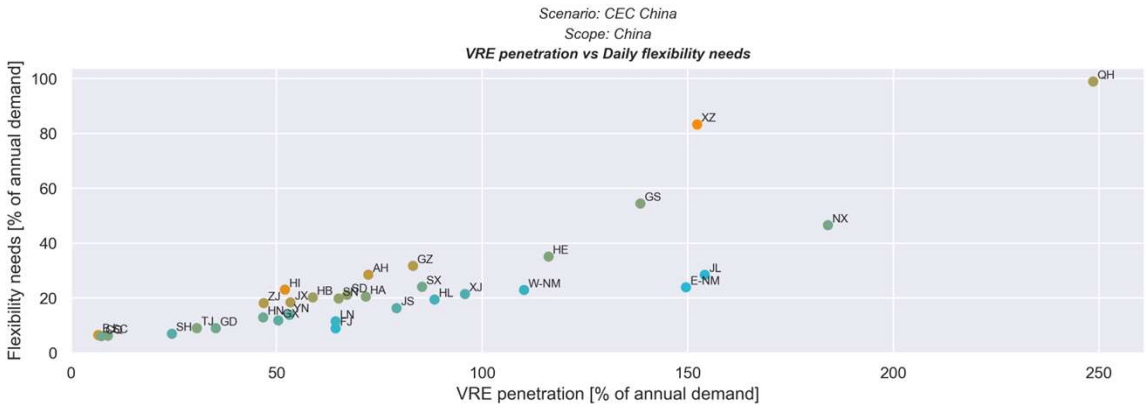
Regions with a higher proportion of solar PV have greater daily flexibility needs



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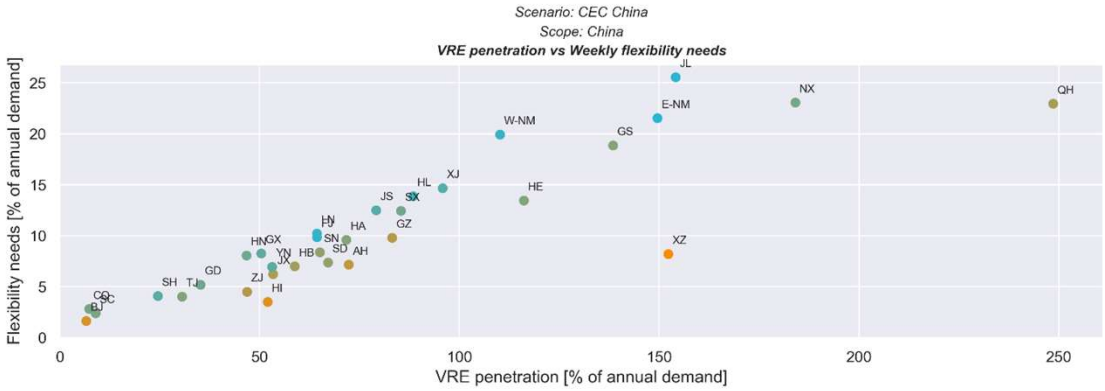
Regions with a higher share of wind energy have greater weekly flexibility needs



Regions with a higher proportion of solar PV have greater daily flexibility needs, while regions with a higher share of wind energy require more flexibility on a weekly basis.

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Conclusions

- As China and the EU aim to decarbonize their energy systems, traditional notions of energy security centred around fossil fuel availability and geopolitical stability are no longer suffice.
- The emphasis shifts towards ensuring reliable access to clean energy technologies, critical materials, and a resilient grid infrastructure.
- Enhanced interconnection between regions in both China and the EU improves energy security by mitigating the adverse effects of weather fluctuations on renewable energy production.

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