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Sectoral decarbonization pathways for the EU and China from a Dual-IAM Assessment| PROMETHEUS and GCAM insights

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Paris Agreement goals:

Limit warming to well below 2°C, ideally 1.5°C.

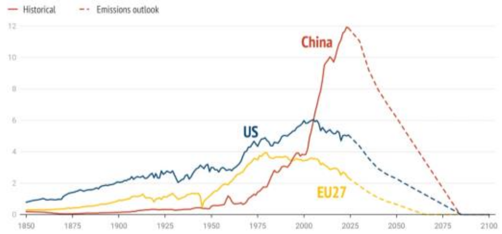
Role of NDCs and LTTs:

Short-term and long-term national commitments toward net-zero

Urgency:

Growing concerns about whether current climate policies are sufficient and timely.

Importance of the EU and China



- Together responsible for **~37% of global CO_2 emissions**.

decisive role in shaping the global climate outcome

- Both have **ambitious climate targets**:
  - **EU: Net-zero** by 2050, **90%** reduction by 2040.
  - **China**: Peak emissions **before 2030**, carbon neutrality by 2060

- **Distinct challenges**:
  - **EU**: Policy driven (Governance, equity across Member States, NECP coherence).
  - **China**: Infrastructure driven--Coal dependency, export-driven industry, balancing growth with climate action.

Key Research Questions

What are the key technological, economic, and policy barriers that could hinder deep decarbonization?

How do post-2030 transitions compare across the two economies, and what lessons can be drawn for the next round of NDC submissions?

What are the sectoral transformations required for the EU and China to meet their mid-century climate neutrality goals?

Reason Behind

Setting ambitious targets alone is insufficient

The timing and sequencing of climate action

Achieving net zero requires a deep understanding of how each sector contributes to emissions

Research Gap and Study Contribution

Problem	Literature	Solution
Existing studies often focus on **single regions or sectors** ***Which*** Limits our ability to evaluate how differences in policy frameworks , energy system structures and technology deployment capacities influence the pace and depth of decarbonisation	Few offer **direct, systematic comparisons** between major emitters like EU and China.	❑ A **comparative analysis** under the NDC-LTT framework. ❑ Insights into **sectoral transformations**, **technology shifts**, and **policy barriers**. ❑ Lessons for the **next round of NDCs** and global climate cooperation. ❑ **Dual-model** approach

IAMs (Integrated Assessment Models):

Key tools to assess feasibility, costs, and sectoral impacts.

Key characteristics of the two models comprising the study ensemble

Model Name	Model Type	Horizon	Technological detail	Key features	Applications
GCAM	Partial equilibrium	Recursive-dynamic (myopic)	Energy technologies, land-use changes, carbon capture and storage (CCS)	Market equilibrium model, integrated multi-sector modeling	Global climate change mitigation, decarbonization strategies, integrated assessment across sectors
PROMETHEUS	Energy-system	Recursive-dynamic (myopic)	Energy technologies, energy efficiency, CCS, CDR	Energy system simulation, climate change mitigation policies,	Energy policy evaluation, decarbonization pathways, long-term energy planning

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Scenario Design

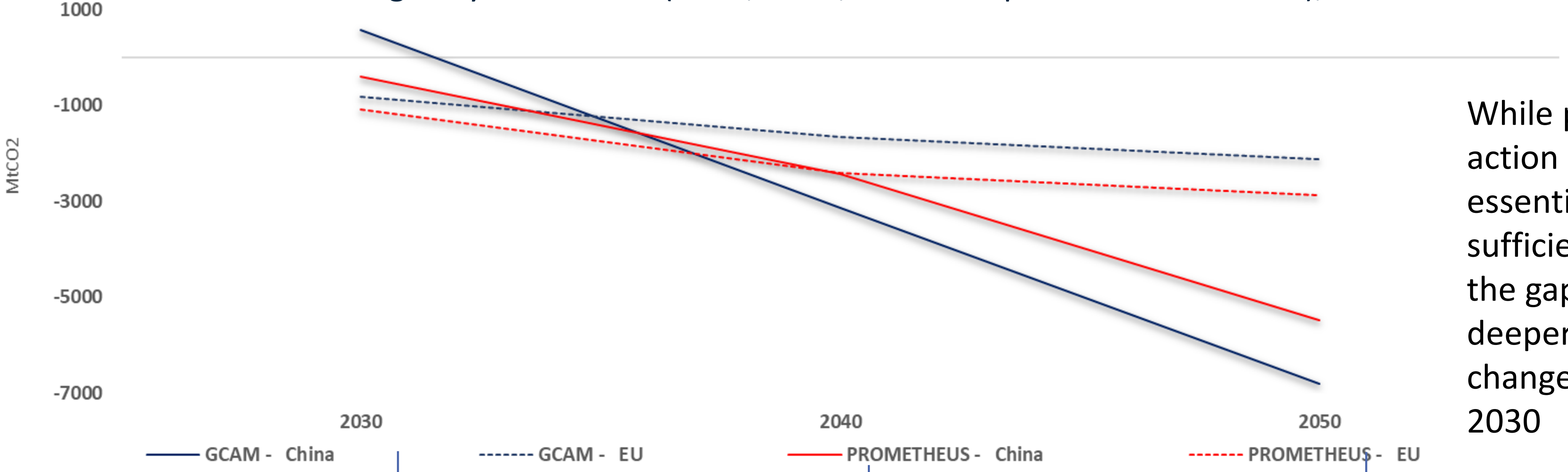
China		EU
• Peak CO_2 emissions before 2030 • Lower CO_2 intensity by >65% vs 2005	**2030** ↓	• 55% GHG emissions by 2030 vs 1990
	2050 ↓	• Climate neutrality (net-zero GHGs) by 2050
• Net zero CO_2 by 2060	**2060**	

Key Assumptions	Description
Socioeconomics (population and GDP)	We used the latest figures from the Europop and UN datasets for population as well as from the IMF short-term outlook and SSP2 long-term trends for GDP growth
Techno economics (power sector)	We used the technology cost assumptions from the IEA's World Energy Outlook 2024, where relevant
Fossil fuel prices	We used historical data from the World Bank, where relevant
Policies	A database of collected climate policies and targets for G20 countries served as a guideline across models; post-Glasgow NDCs and LTTs were used, with NDC targets based on direct interpretation of countries' Paris Agreement pledges (NDC 2.0)

*** The scenarios do not account for the very recently submitted NDC 3.0 of China and the EU***

Can post-2030 Emission reductions close the ambition gap?

Evolution of CO_2 emissions through key milestones (2030, 2040, 2050 compared to 2020 levels), GCAM and PROMETHEUS results



While post-2030 action is essential—is not sufficient to close the gap without deeper systemic change before 2030

- **China's 2030 Emissions Plateau**: China's NDC aims to peak CO_2 emissions before 2030 and reduce carbon intensity by over 65% from 2005 levels.
- **EU's Steady Decline by 2030**: The EU is projected to reduce emissions significantly by 2030 (by 822–1089 Mt CO_2 compared to 2020)
- **Acceleration in the 2040s**: Both regions show rapid emissions reductions post-2030.
- **2050 Net-Zero Goals**: By mid-century, both China and the EU achieve deep decarbonization—but this depends on coordinated policy shifts away from coal/accelerated grid and storage deployment

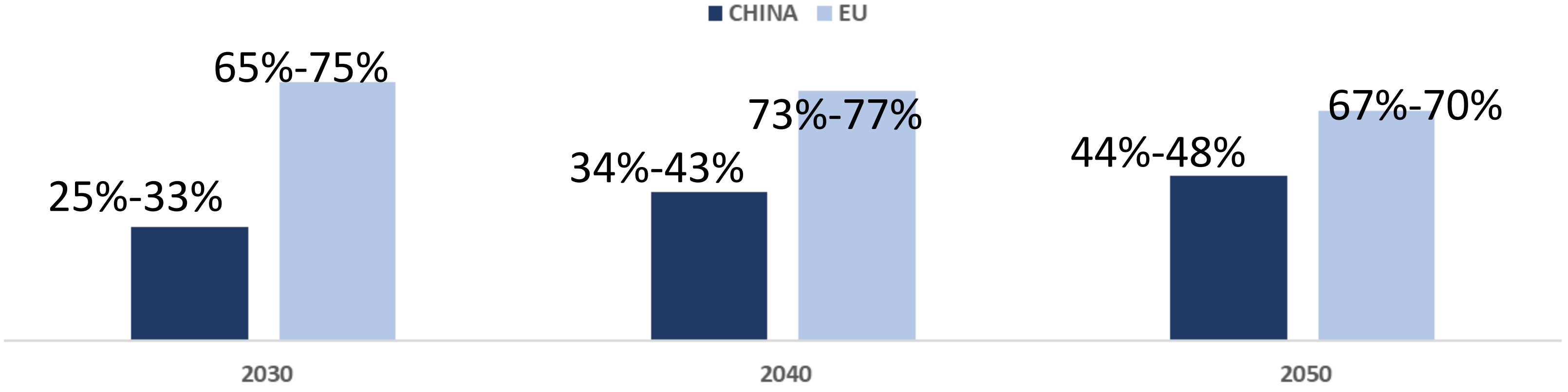
Electricity generation: How fast and far can renewables go?

EU

- Managing high-RES penetration
- Grid balancing & market design
- Scaling long-duration storage and demand response

- RES capacity peak
- Gas use minimized for flexibility

- System stabilizes due to seasonal balancing and grid saturation limits--- Further RES growth requires advanced storage & hydrogen integration



RES share through decades

China

- Replacing legacy coal assets
- Expanding inter-provincial transmission

- Integrating very high shares of solar & wind
- Ensuring reliability with residual fossil back-up

- Near carbon neutrality in power
- Managing the last 20%-30% fossil residuals efficiently (gas remains above 2020 levels for system stability

Is gas an exit or a bridge fuel in building sector?

EU

2030	2040	2050
Bridge Fuel: used to replace coal/oil. Gas declines due to Fit-for-55 and heat pump rollout	**Exit phase begins** aggressive electrification, bans on new gas boilers—efficiency gains	**Exit complete**: near-total elimination, gas used only in niche cases (hydrogen blends)

China

2030	2040	2050
Expansion phase: Gas grows to support urban heating, supported by infrastructure investments	**Bridge Fuel**: still rising, but slower, begins to stabilize as clean heating expands in rural areas	**Transition ongoing**: gradual decline after 2040 as electricity & heat pumps expand, gas remain key in district heating systems

Transport sector: the critical role of electrification in both regions long term commitments

2050 shifts vs 2020 levels

EU

Electricity	Major increase, dominates passenger vehicles
Liquids	Significant decline, mostly synthetic/biofuels remain
Gas	Near elimination in passenger and freight due to policy phase-outs
Hydrogen	Moderate adoption

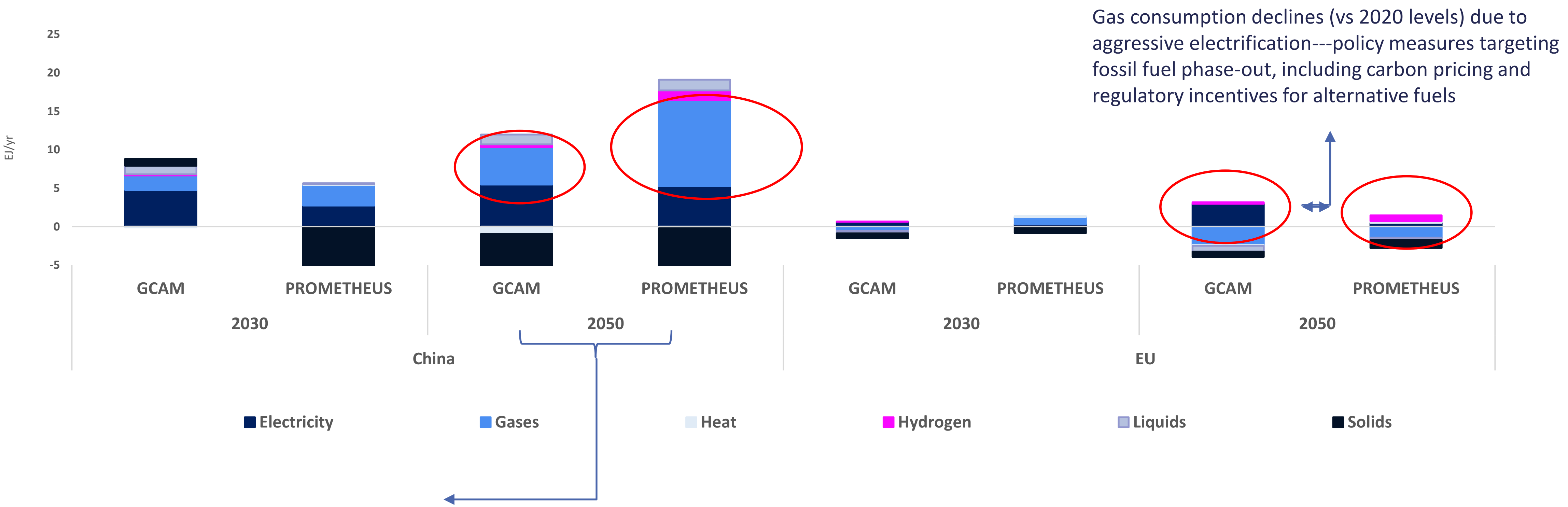
Drivers: Fit-for-55, REPowerEU, building of EV infrastructure

China

Electricity	Significant growth, especially in urban passenger vehicles
Liquids	Decline but still substantial (liquid fuels persist), particularly for aviation, maritime and long-haul
Gas	Gradual increase as a bridge fuel in urban transport, after 2040 slowly decline/still present in regional fleets
Hydrogen	Limited adoption

Drivers: NDC-LTT push for electrification but constrained by fossil-lock-ins

Industry: Gas up or power up?



- Both models agree that **gas** use increases in China (vs 2020 levels) due to continued industrial demand and the role of gas as a cleaner alternative compared to coal in high-temperature processes
- Gas acts as a bridging fuel while electrification and hydrogen gradually scale up

■ Electricity : Continues to expand in both regions

Industry fuel evolution in China and the EU (2030-2050 vs. 2020) GCAM and PROMETHEUS results

Progress by 2030

EU

Coal nearly eliminated; natural gas still used for balancing renewables.

•LNG terminals **expanded** for energy security, risking long-term gas lock-in.

•Fit-for-55 drives electrification and efficiency, but **industrial decarbonization lags.**

•EV adoption grows, but aviation and heavy transport remain f**ossil-dependent**.

•Sectoral policies need strengthening to align short-term energy security with long-term climate goals**.**

China

•Emissions stagnate after decades of rapid growth, driven by renewable expansion (wind, solar).

•**Coal** use slows but remains significant due to grid stability needs;

•Natural gas grows in industrial use and as backup for renewables.

•Electrification advances in transport/buildings, but infrastructure gaps (charging, smart grids) hinder progress.

•China's clean tech leadership offers economic benefits from accelerated decarbonization.

•**Persistent reliance on natural gas and infrastructure lock-in risks**:
both the EU and China continue to depend on natural gas to balance renewable energy

•**Sectoral decarbonization challenges**:
Industrial decarbonization remains a major bottleneck in the EU, while China faces hurdles in electrifying transport and buildings .

•**Opportunities through clean tech** :
•China's rapid expansion in wind and solar is helping stabilize emissions, and its role as a clean tech provider offers economic benefits.
•The EU's policy push (e.g., Fit for 55) supports electrification, but success hinges on accelerating innovation and investment in clean energy systems.

Progress by 2040

EU

- **Renewables** dominate electricity; fossil fuels play a minor role.
- **Electrification** expands across buildings, transport, and industry.
- **Hard-to-abate** sectors still rely on fossil fuels.
- Hydrogen and bio-based solutions grow but face **cost** and infrastructure barriers.
- Aviation and maritime remain em**ission-intensive**
- Focus shifts to scaling disruptive technologies and avoiding stranded assets.

China

- **Coal** significantly reduced; renewables and storage dominate power sector.
- Industrial emissions **remain** high due to scale and complexity of heavy industries.
- **CCUS** adoption grows but is limited by cost and storage availability.
- Hydrogen gains traction, but production is still **fossil-based**.
- Policies must prevent gas infrastructure from delaying full renewable transition.

- **Deep power sector decarbonization, but sectoral gaps remain**: Both the EU and China achieve major shifts toward renewable electricity, with fossil fuels playing a minimal role in power generation. However, steel, cement, and chemicals face technical and economic barriers towards their decarbonisation
- **Clean technology deployment faces structural barriers**: While hydrogen, bio-based solutions, and CCS gain traction, their full potential is hindered by high costs, infrastructure delays, and supply chain limitations.
- **Policy alignment and infrastructure risks**: Both regions must ensure that past investments in transitional fuels (like gas) do not delay full decarbonization.

Progress by 2050

EU

Nearly fossil-free energy system with wind and solar dominance.

•**Electrification** is central to the transformations of end-uses

•Industrial electrification and **green h2 slow** due to high-temperature process challenges.

•Hydrogen used in steel and chemicals but **constrained** by cost and infrastructure.

•**Battery EVs** dominate passenger transport; liquid fuels still needed for aviation/maritime.

China

•Emissions **fall** rapidly.

•Energy system transformed with **widespread electrification** and clean energy uptake.

•Industrial and transport sectors still face **residual emissions.**

•Clean tech deployment and infrastructure expansion **critical** to sustaining progress.

•**Persistent challenges in hard-to-abate sectors**: Both regions struggle to fully decarbonize sectors like cement, chemicals, aviation, and freight

•**Final push requires integration, innovation, and policy alignment**: The last steps toward net-zero hinge on scaling disruptive technologies (e.g., green hydrogen, CCUS, CDR), avoiding over-reliance on transitional fuels, and ensuring that sectoral interdependencies do not delay full decarbonization

•**Near-complete fossil fuel phase-out with electrification at the core**: By 2050, the EU achieves a nearly fossil-free energy system, while China follows a similar path, though with a time lag

Conclusions

- **EU's clear early progress**:

The EU shows a strong trajectory toward early emissions reductions through coal phase-out and renewable expansion, but faces long-term challenges in industrial decarbonization, infrastructure deployment, and scaling alternative fuels like hydrogen.

- **China's complex transition**:

China's decarbonization is complicated by energy security concerns and industrial dependencies. Despite rapid renewable growth, fossil fuels remain entrenched in power and industry, especially in hard-to-abate sectors.

- **Need for coordinated infrastructure and policy**:

Both regions require better alignment of infrastructure development and sectoral policies to avoid bottlenecks and ensure systemic transformation toward net-zero.

- **Bridging short- and long-term goals**:

The study emphasizes the importance of aligning short-term energy policies with long-term climate commitments to prevent carbon lock-ins and ensure effective decarbonization.

- **Scientific contribution and future research**:

We highlight the value of cross-sectoral, multi-model analysis and calls for more granular research on specific industries, improved uncertainty quantification, and better modeling of systemic feedback loops.

Thank you!

For further questions you are welcome to send them at:

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