Investment and Technologies for Net-zero Carbon Infrastructure

Ea Energy Analyses

EU-CHINA
Energy Cooperation Platform
中国 - 欧盟能源合作平台

Beijing

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Agenda

- Background & Objectives
- Introduction
- Key Background Takeaways
- Modelling Approach
- Key Results & Insights
- Scenario Comparisons
- Detailed Findings
- Recommendations
- Conclusion & Key Takeaways

Project Context

- Net-zero targets for 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

- Objective of facilitating cooperation for achieving net zero targets.

What does net-zero mean?

0

Every time you <u>only</u> go "low" you need to find somewhere to go <u>negative</u>

The tremendous challenge in both EU and China – new infrastructure needed

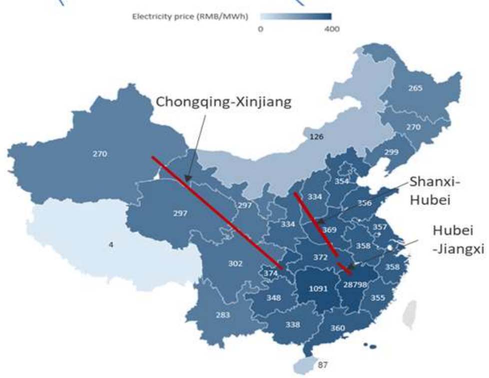
Achieving net-zero will require

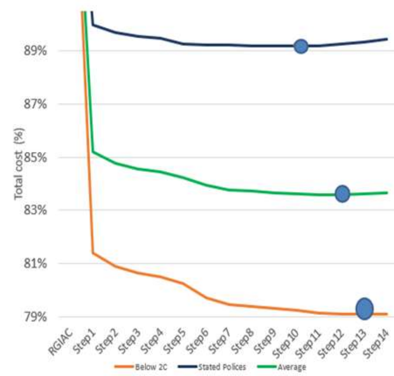
- Transforming energy infrastructure, planning, and regulation.
- Coordinated development across energy carriers and sectors.
- Modeling analyses essential for successful sector-coupling & coordination.

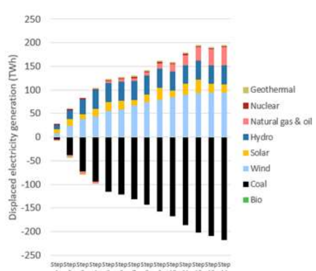
Introduction – About the Project

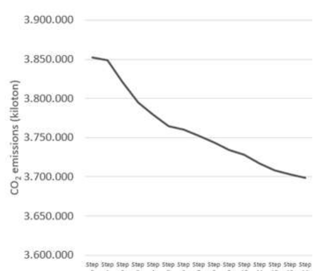
- Builds of collaboration on coordinated grid planning
- Project participants:
  - State Grid Energy Research Institute (SGERI)
  - China Electricity Council (CEC)
  - ERI-CET project, represented by Kaare Sandholt
  - Ea Energy Analyses (Ea)
  - ECECP (ICF)
- Work packages and reports
  - WP1: Inception
  - WP2: Energy System Scenarios for Carbon Neutrality
  - WP3: Power generation planning in the context of Carbon Neutrality and Power Market Reform
  - WP4: Carbon Capture, utilisation, PtX and Hydrogen
  - WP5: Modelling and planning of net-zero carbon infrastructure
  - WP6: Finalisation

Joint previous project:
ENTSO-E Grid Planning Modelling Showcase for China (ECECP)









- B1: Socio-economic welfare
  - RES fuel savings
  - Emission cost savings
  - (CO2 emission changes)
- B3: RES integration
- C1: CAPEX
- C2: OPEX

Main take aways:

Effective grid planning in China can enable integration of growing shares of renewables and advance the clean energy transition.

Demonstration of critical linkage between grid planning and power market reform.

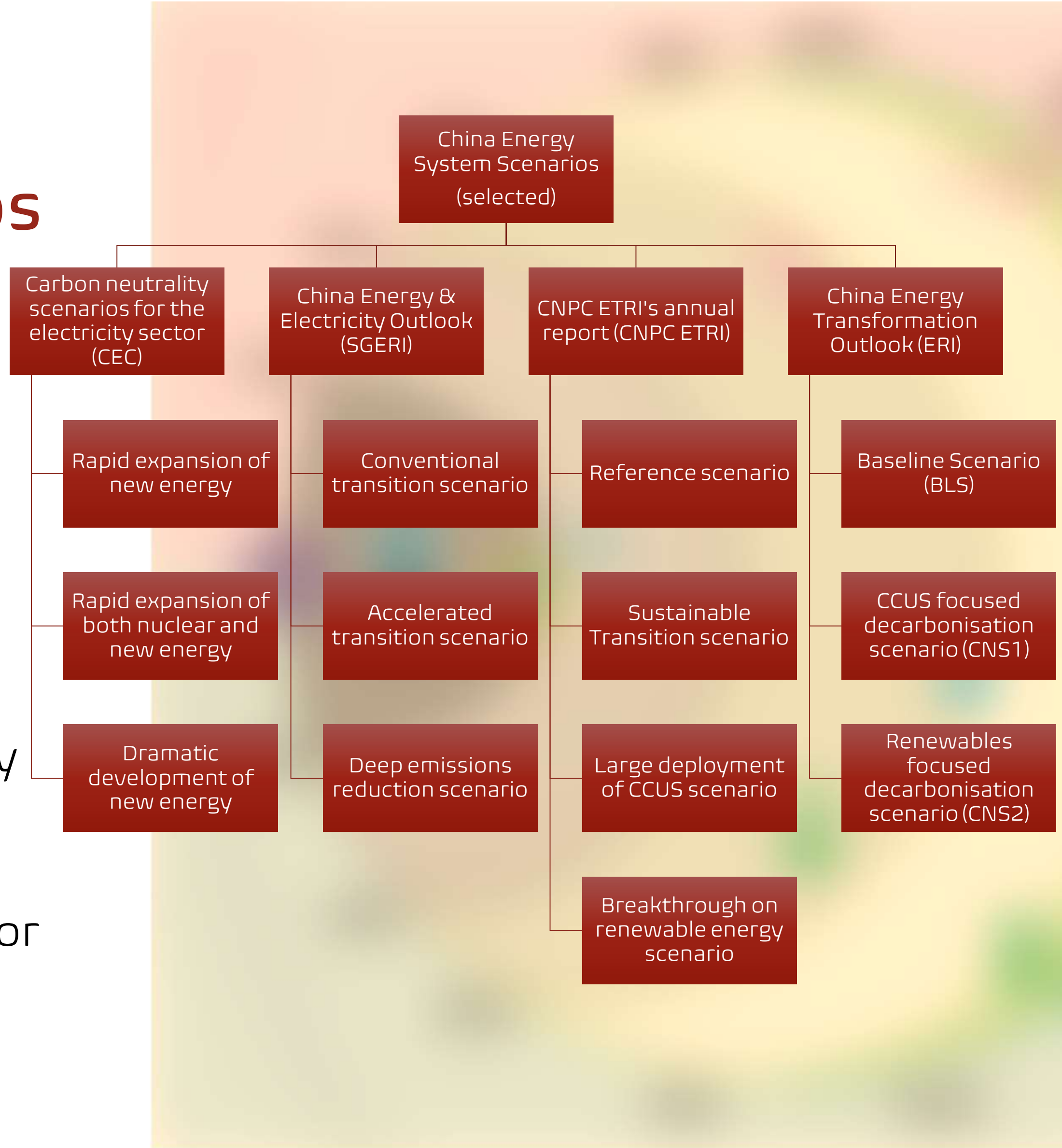
Modelling results indicate that a market-based approach of planning transmission expansions, inspired by the ENTSO-E approach, can lead to significant CO2 emission reductions from China's power system.

ENTSO-E Grid Planning Modelling Showcase for China Report (ENGLISH)

ENTSO-e 中国电网规划建模展示報告(中文版)

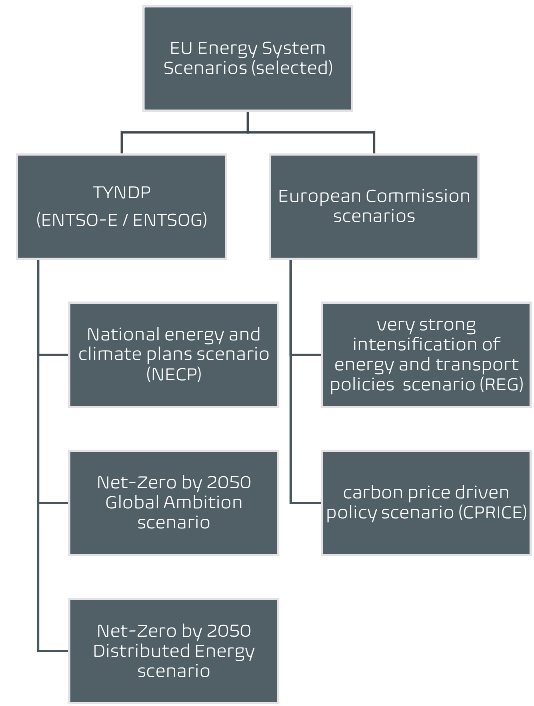
Common features of Chinese and EU scenarios

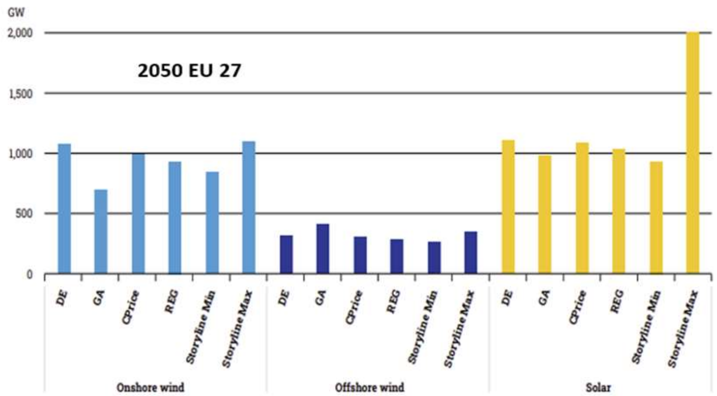
- Scenarios aim for CO2 neutrality: Chinese by 2060; European by 2050.
- Both phase out fossil fuels, favouring wind and solar.
- Electrification, sector coupling, and energy efficiency are key strategies.
- Hydrogen and P2X address hard-to-abate sectors like transport and heavy industry.
- System flexibility, grid expansion, and regional power exchange are crucial for transition.



EU scenarios

- ENTSOG and ENTSO-E publish joint Scenario Reports
  - Common scenarios are pivotal in the European TYNDPs for power and gas.
  - Fundamental for integrated energy system planning across sectors.
- Benchmarking the ENTSO scenarios with the European Commission scenarios shows overall good alignment.



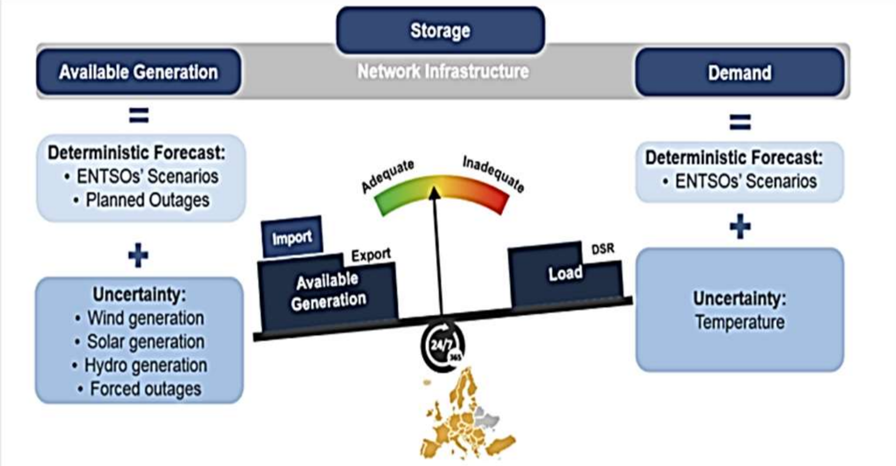


Key trends for the energy system transformation

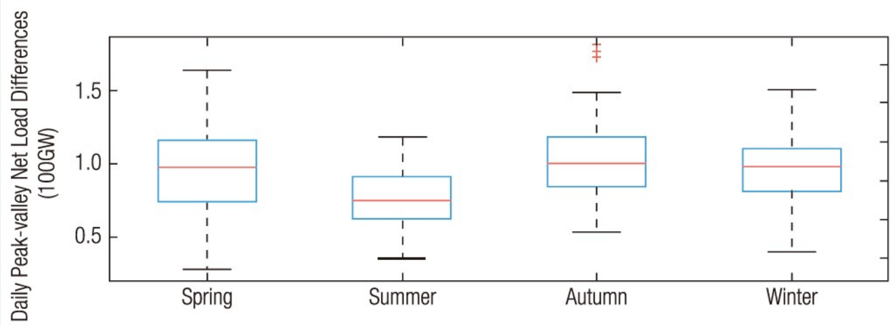
- Energy efficiency improvement on the demand - side is needed to ensure the pace of supply-side deployments can keep up with and sustain the required economic growth.
- Green energy supply - technological progress and cost reductions enable RE to provide clean energy in bulk, particularly through electricity from wind and solar.
- Electrification in industry, transport and buildings will support switching away from fossil fuels in end-use consumption, in conjunction with the decarbonisation of the electricity supply.
- Hydrogen becomes an important energy carrier, creating a link between the abundant supply of cheap green electricity, and the hardest -to- abate sectors. Green hydrogen, combined with captured carbon, allows for the creation of fuels for hard-to-abate sectors such as heavy transport, shipping, and aviation.

Ensuring system adequacy in net-zero

- Power system adequacy considering generation, transmission, and flexibility
  - ➢ Move towards probabilistic methods
- Effective electricity pricing reflects market dynamics, boosts optimal investments, and encourages efficient consumption.
  - ➢ Manage tension between policy targets, market mechanisms and viability of investments
- Power system flexibility adapts to demand and supply changes, enabling stable integration of renewable sources
  - ➢ New flexible resources developed in time, as existing resources transitioned – eventually phased out
- Energy security requires resilient supply, balancing renewable variability to maintain system stability
  - ➢ Systems increasingly weather dependent



European Resource Adequacy Assessment (ERAA)

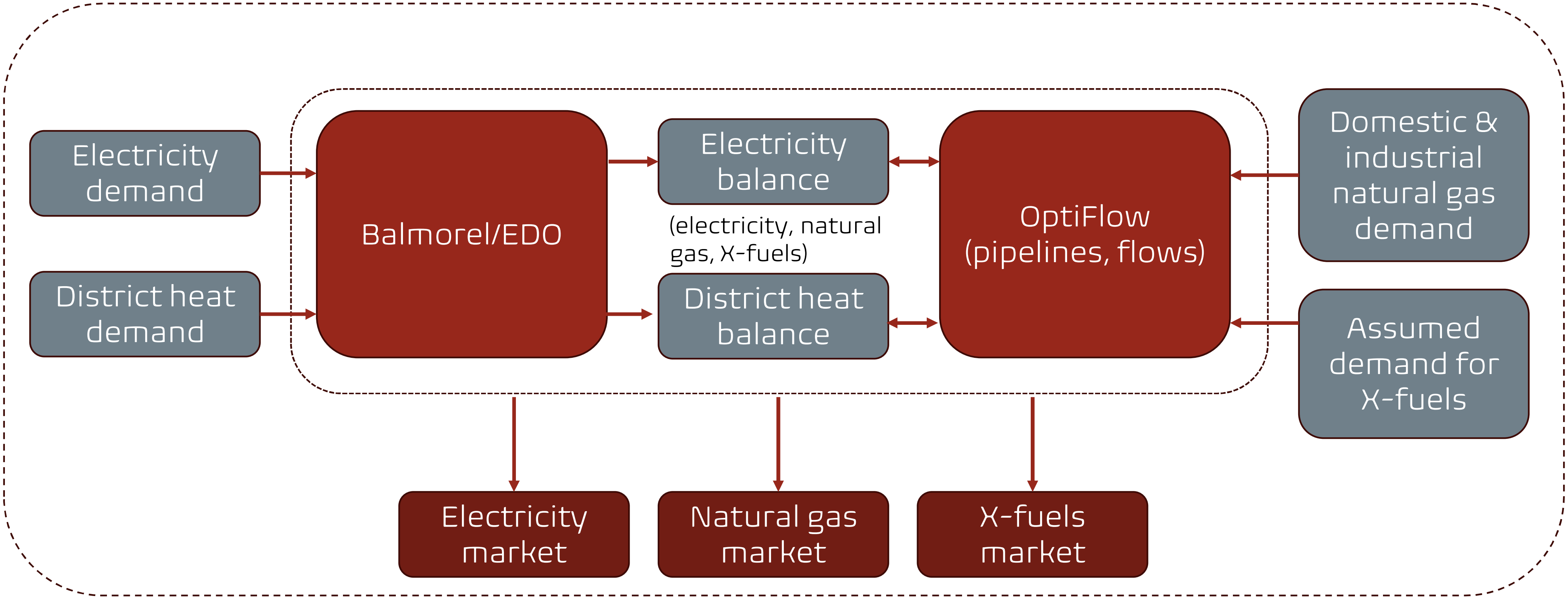


Seasonal characteristics of daily peak-valley net-load differences in North China in 2035 (SGERI)

The target of net-zero increases the requirements for models - Why?

- All studies point to high VRE and electrification as the crux of decarbonisation
- PtX and CCS key technologies for hard to abate consumption
- Key challenge for the power system
  - How to **integrate high VRE** and ensure **system adequacy** with very low fossil-based generation
  - **Power sector models need stronger link with consumption side**, including CCS, PtX,…
- **Need to optimize** power, natural gas, green gas, liquid fuel **infrastructure**

Modelling approach: Integrated least-cost optimisation

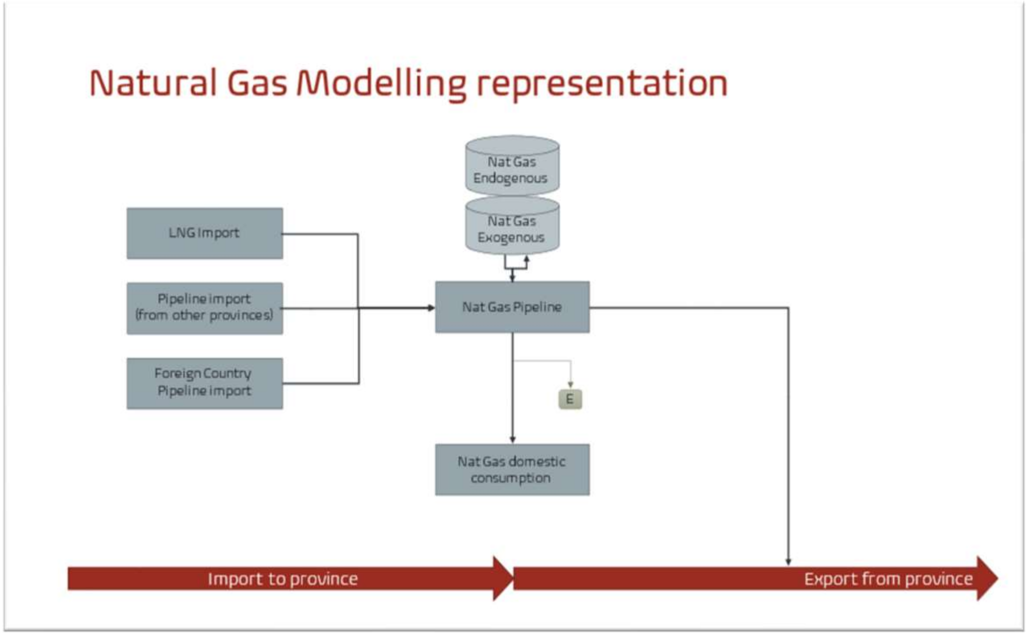


Outcomes: quantities, prices, flows, and infrastructure investments

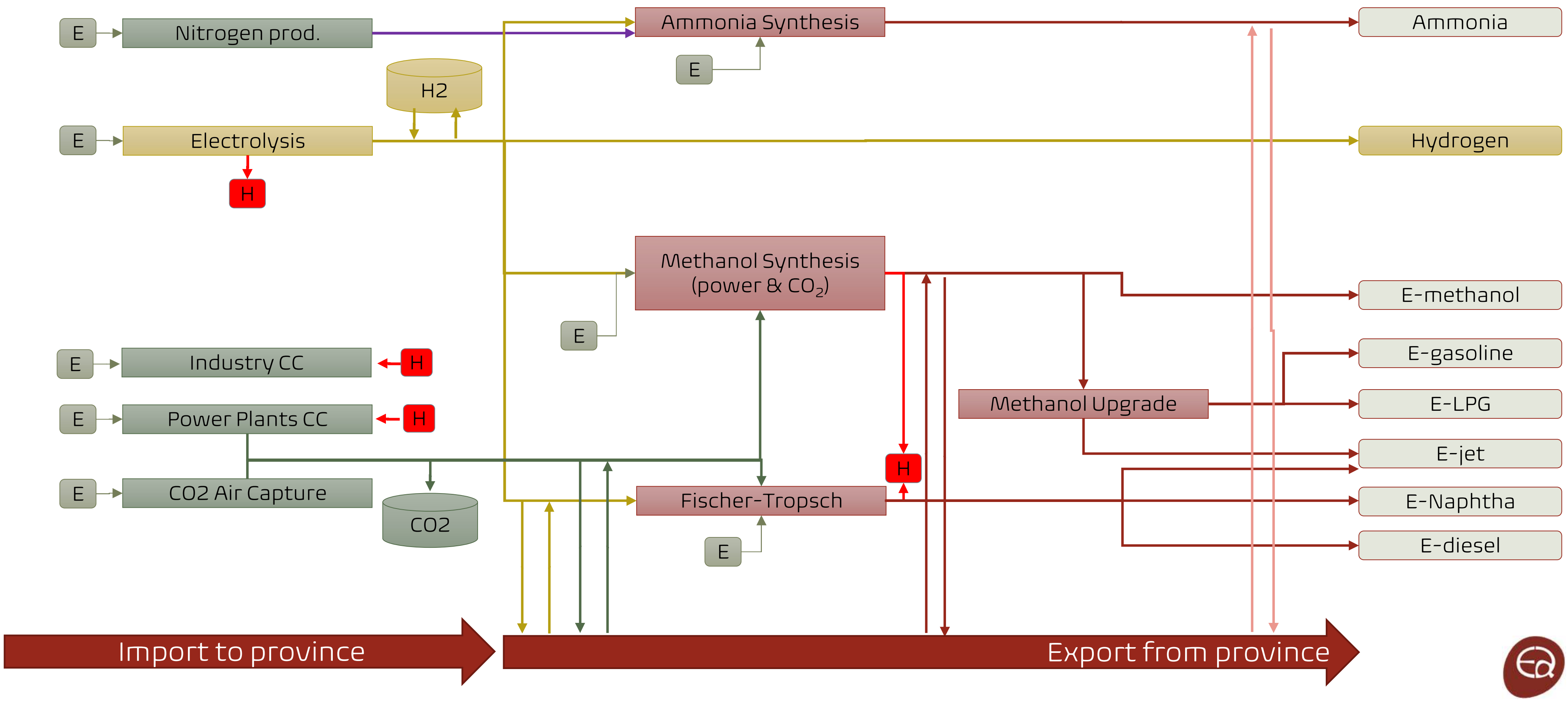
Natural gas modelling

The natural gas modelling takes into account:

- interprovincial gas transmission pipeline capacities,
- natural gas storage capacities (including injection, withdrawal and volume),
- natural gas border capacities for pipeline and LNG imports,
- projected gas supply options (pipeline volumes available),
- projected domestic gas production options,
- as well as the distribution of 'residual' natural gas demands by provinces.



CETO model: PtX and CCUS pathways

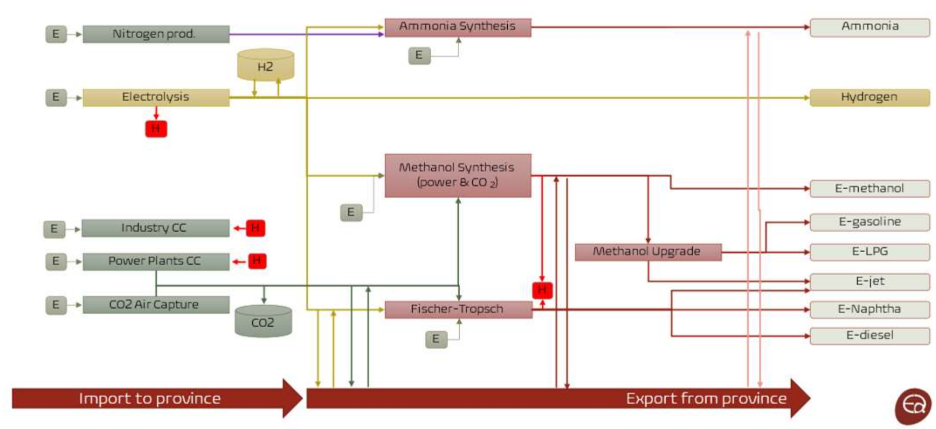


The reference scenario (Scenario 0)

- Reference scenario **without the pipeline infrastructure representation.**
- Natural gas consumption (in the heat and power sector) is according to exogenous prices at provincial level.
- This implies that transport of X-fuels between provinces is based on a variable cost of transport, i.e., a cost per unit of fuel per distance, but **not constrained by a pipeline capacity.**

	Variable cost transport of X's	With X-pipelines
Exogenous natural gas prices without natural gas pipeline infrastructure	Scenario 0	Scenario 2 (P2X-infrastructure scenario)
With natural gas pipeline infrastructure	Scenario 1 (Gas infrastructure scenario)	Scenario 3 (Full infrastructure scenario)

CETO model:PtX and CCUSpathways



Gas infrastructure scenario (Scenario 1)

- Natural gas infrastructure includes pipelines to third countries, LNG terminals and pipeline constraints between provinces.
- X-fuels pipeline infrastructure is not considered
- The natural gas pipeline infrastructure is considered to be as it is in the first year modelled with no investment option for expansion of the infrastructure.

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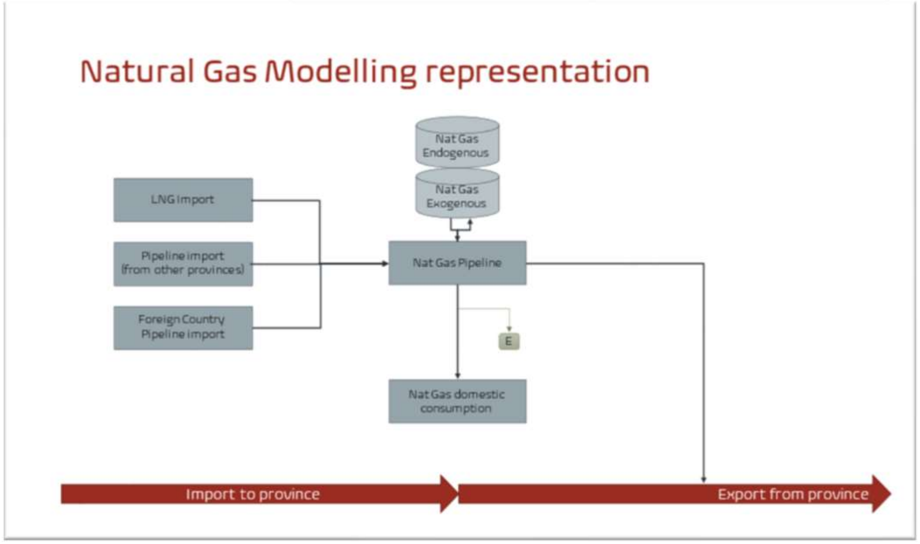

P2X infrastructure scenario (Scenario 2)

- Transportation of CO_2, methanol, hydrogen, and ammonia between provinces is restricted by pipeline capacity.
- The pipeline capacity is determined as an endogenous investment option
- Natural gas pipeline infrastructure is represented as in scenario 0

	Variable cost transport of X's	With X-pipelines
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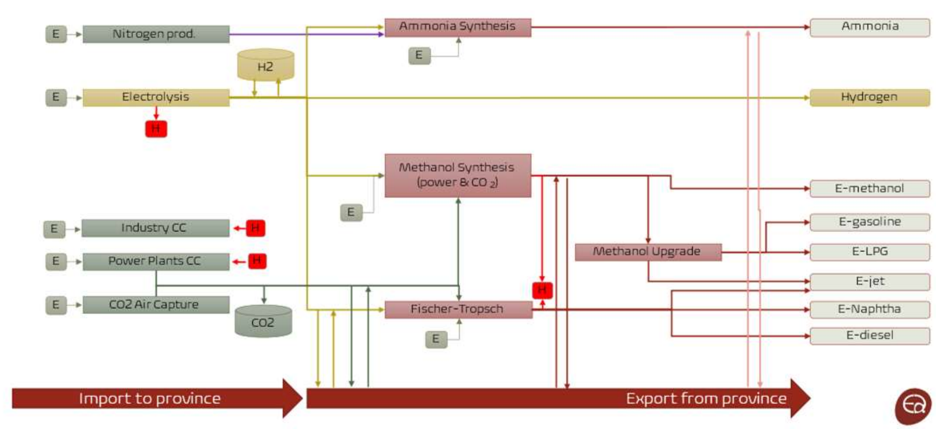

Full infrastructure scenario (Scenario 3)

- Both natural gas and P2X infrastructure are considered.
- No additional investments in the gas infrastructure are allowed, only into ammonia, CO2, methanol, and hydrogen infrastructure.
- This is because at the outset the scenario assumptions describe a situation where use of fossil-fuel gas is falling due to carbon neutrality requirements.

	Variable cost transport of X's	With X-pipelines
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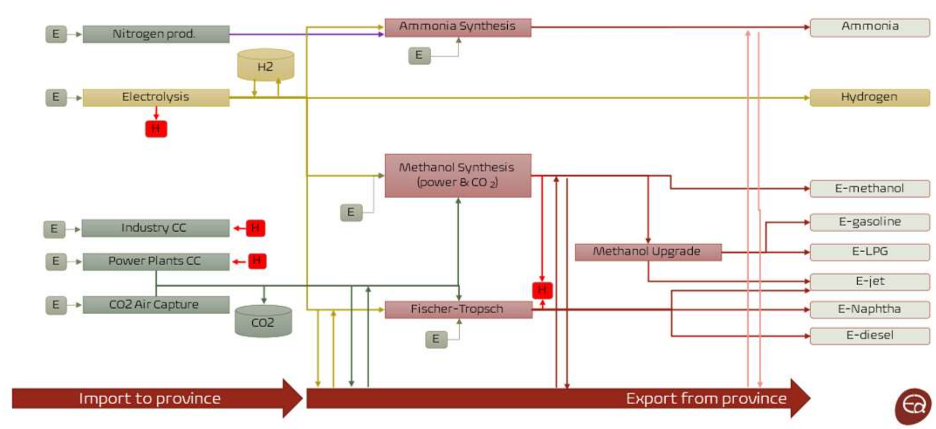
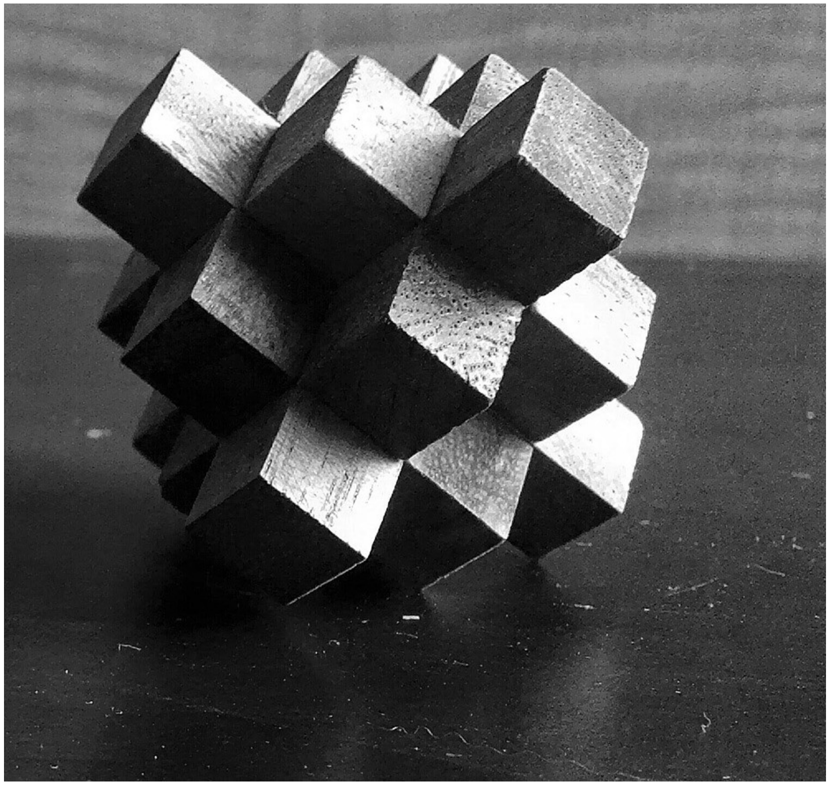
CETO model:PtX and CCUSpathways



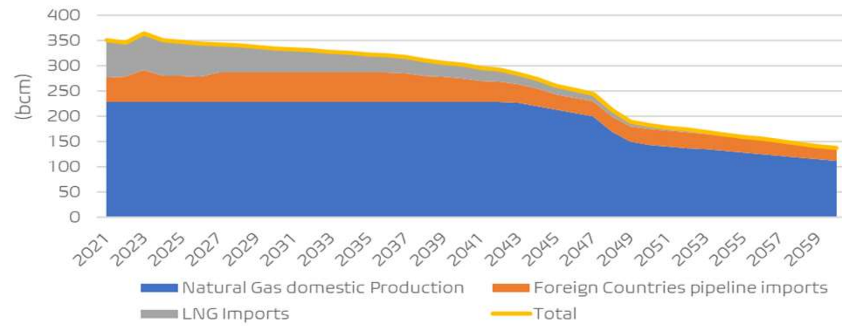
Example questions that this integrated modelling can answer

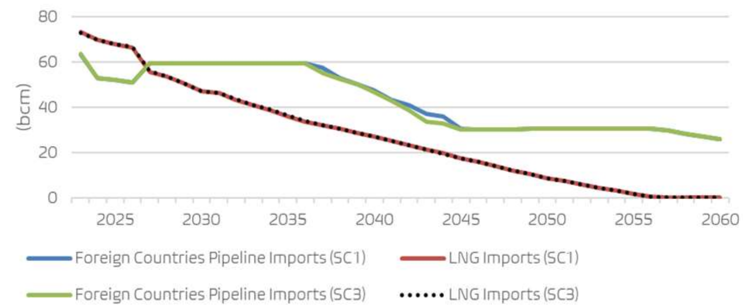
- How do infrastructure considerations affect the role of P2X and CCUS in different scenarios?
- What is the role of natural gas infrastructure in integrated net-zero carbon scenarios?
- How are commodity flows affected by regional differences (CO2 availability, VRE availability, etc)?
- How can natural gas infrastructure be used to enhance hydrogen's role in the net-zero energy system?



Scenario Comparisons

- Implication of adding natural gas pipeline infrastructure.
- Impact of including pipeline capacity on transportation of CO2, e-methanol, ammonia, and hydrogen.
- Integration of both gas and P2X transmission infrastructure.
- Pipeline representation in scenarios.
- Hydrogen infrastructure placement in provinces with high VRE potential.
- CO2 capture installations, placements, and utilities.





H2 Pipeline utilization (Qinghai)			
Year	SC0	SC2	SC3
2030	34%	89%	61%
2040	29%	92%	84%
2050	7%	87%	84%
2060	23%	84%	80%

Selected Model Findings

- The study explores synergies in integrating multiple energy sectors for renewable benefits.
- Provinces like Xinjiang and Qinghai with high VRE potential install hydrogen infrastructure for local use and shipment to provinces like Beijing.
- Scenarios considering physical transmission see higher utilization of natural gas and X-pipelines.
- When modelling competition in energy transportation methods, one gets lower transmission power capacity in a full infrastructure scenario, as pipeline transport can be more cost efficient.
- By 2060, CO2 capture targets regions with CO2-emitting heavy industries; and power plants near with access to biomass sources for negative emissions.
- Provinces with high sequestration potential capture CO2 and import CO2.
- Central, north, and south provinces import CO2, while north-east and north-west provinces export.
- An integrated system optimizes resource use, aiding a cost-efficient transition to net zero.

Conclusions

- China targets net-zero by 2060, EU by 2050.
  - This is a joint challenge – we win or loose together
- Integrated system approach for important efficient energy transition
- Balancing VRE generation with flexible demand is a future challenge.
  - Ensuring adequacy in a VRE dominated system is vital.
- P2X & CCUS crucial for sectors tough to electrify.
  - Fast, large-scale deployment needed in China and EU.
  - Cooperation is essential.
- The integrated model enhances understanding of coordinated energy infrastructure needs.
- The findings show that an integrated system approach better represents the existing resources and ensures that they are used.

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