China's Carbon Capture Utilization and Storage (CCUS): Development Status and Prospect

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The Administrative Center for China's Agenda 21

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New requirements for carbon peaking and carbon neutrality goals

Technology status and challenges

Future Development Outlook

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Emission reduction efforts

Relative emission reduction "*rates*"

↓

Absolute emission reduction "*volume*"

2009.12

Pre-Copenhagen commitments:

By 2020, China aimed to reduce its CO_2 emissions per unit of GDP **by 40%-45%** from 2005 levels.

2015.6

Nationally Determined Contributions:

China aimed to reduce CO_2 emissions per unit of **GDP by 60%-65%** by 2030 compare to 2005 levels.

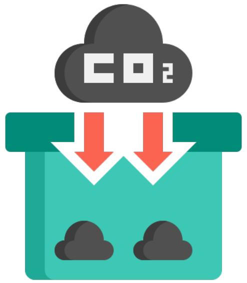
2020.9.22

Long-term Objectives:

China strives to **peak carbon emissions** by 2030 and **achieve carbon neutrality** by 2060.

Not only should we focus on the modification of low-carbon technologies, but also the ***decarbonization technologies such as CCUS***.

Example: Decarbonization technologies for power systems



	General coal-fired units*	Ultra-supercritical coal-fired units	CCUS
Emission factor	0.8177 tCO_2 /MWh	Decrease of more than 10 %	Zero emission
Coal consumption	305.5 gce/kWh	≤ 276 gce/kWh	
		Improved low-carbon technology	**Decarbonization technology, e.g., CCUS**

*: For units with a capacity of 600 MW and above, the emission factor is the baseline value of the national carbon market in 2022; the coal consumption for power supply is the national average value in 2020.

Emission reduction strategy

Energy Control

↓

Carbon Control

Kaya formula

$$CO_2 \text{ emissions} = \text{Population} \times \frac{\text{GDP}}{\text{Population}} \times \frac{\text{Energy consumption}}{\text{GDP}} \times \frac{\text{Carbon emissions}}{\text{Energy consumption}}$$

2021 Central Economic Work Conference:

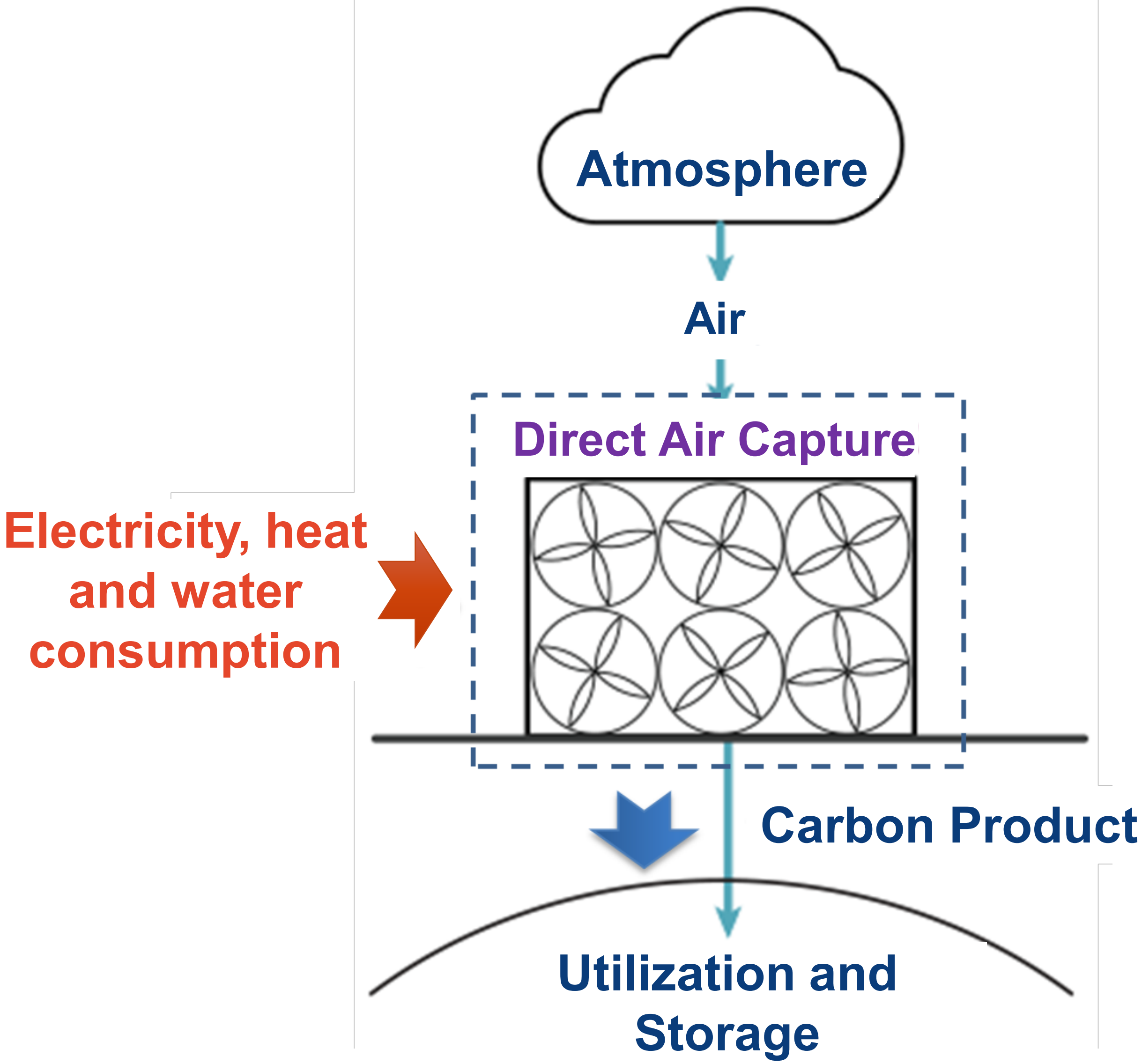
- Renewable energy and raw material energy consumption are not included in the total energy consumption control.
- Create conditions to transition from “dual control” of energy consumption to **“dual control” of carbon emissions volume and intensity as soon as possible**.

The second meeting of the Central Committee for Comprehensively Deepening Reform, July 2023

- The opinions on promoting the gradual shift from dual control of energy consumption to dual control of carbon emissions.

Not only should we focus on the energy-saving technologies, but also the technologies ***reducing emissions with more energy usage***.

Example: Direct Air Carbon Capture (DAC)



Scope of emission reduction

CO_2

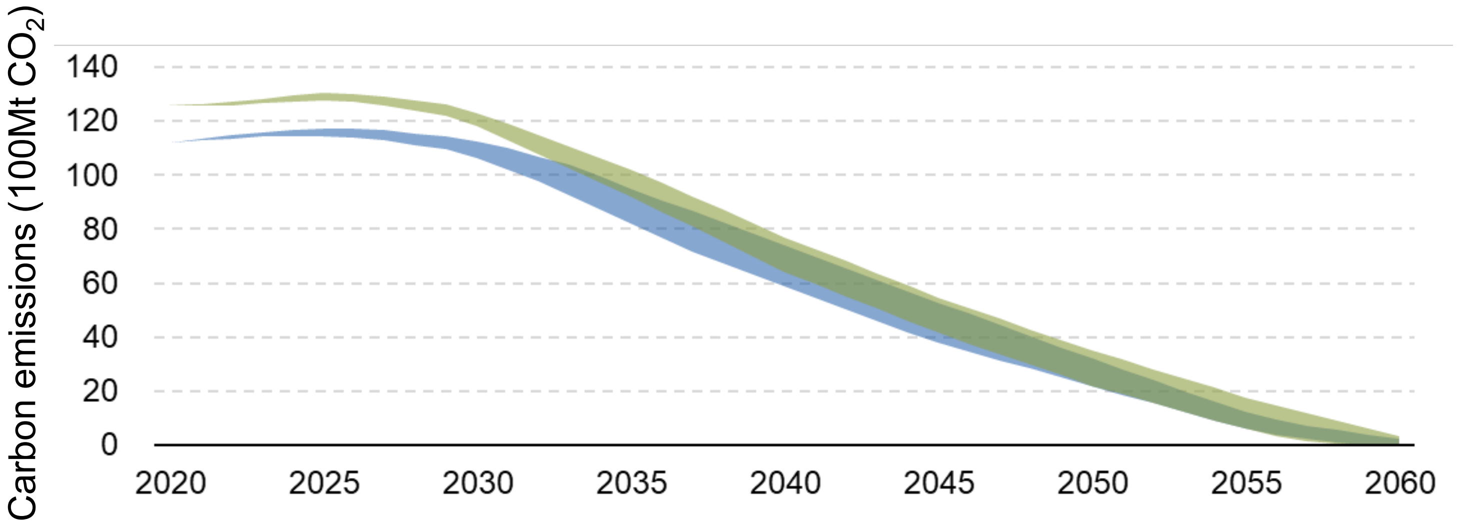
Greenhouse gas

IPCC Sixth Assessment Report:

- Sustained reductions in greenhouse gas emissions will significantly slow global warming over the next two decades and lead to noticeable changes in atmospheric composition within a few years.

28th Conference of the Parties to the UNFCCC:

- At COP30, governments must prepare new nationally determined contributions that **cover the entire economy**, including all greenhouse gases, and align with temperature limitation targets.



Emission reduction pathways under the net-zero targets in China

Example: CO_2 emission reduction, recycling, utilization, removal technologies

Not only should we focus on reducing CO_2 emissions, but also establishing a cycle of CO_2 utilization, storage and removal, to ***offset the remaining GHGs***.

REDUCE

Energy efficiency improvement,
Renewable energy,
Nuclear energy,
Fuel transfer
……

RECYCLE

CO_2 chemical composition change
Urea, Fertilizer
Cement,
Synthetic fuels
……

REMOVE

Geological storage,
Direct air capture,
Natural carbon sinks,
……

REUSE

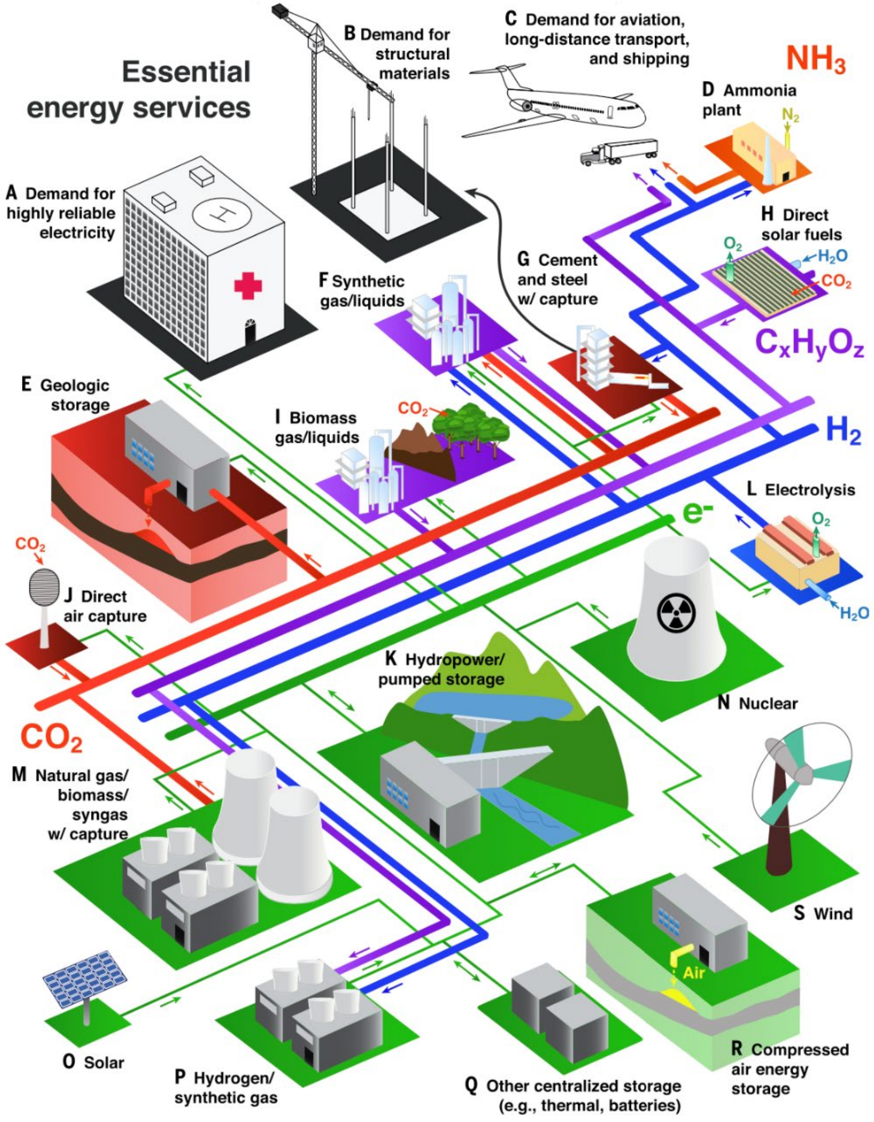
CO_2 chemically unchanged,
Carbonated drinks,
Enhanced Oil Recovery (EOR)
……

Emission reduction targets

Individual

System

Net-zero emission energy systems



🟥 Low/zero carbon utilization of fossil energy, low/zero carbon production of steel and cement

🟦 Hydrogen production and transportation

🟪 Hydrocarbon production and transportation

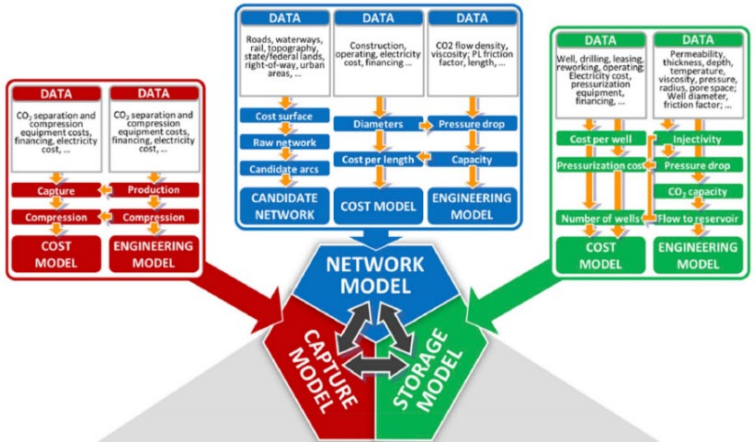
🟩 Electricity generation, transmission, storage and utilization

Image credit: Davis S J , Lewis N S , Matthew S , et al. (2018).

Not only should we focus on key technologies, but also ***integration and construction of technology system***.

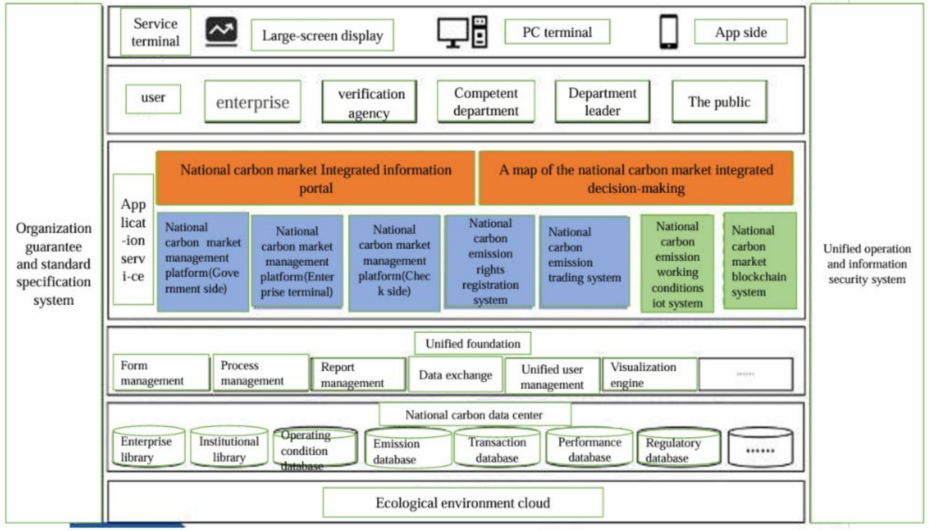
Example: CCUS source-sink matching analysis

Comprehensive consideration is given to multi-industry emission sources, proposed pipeline routes, and conditions for various storage sites such as saline aquifers and oil fields in onshore and offshore basins, **conducting CCUS source-sink matching analysis to minimize the total costs.**



Example: carbon market management techniques

To better support the construction of the carbon market, a series of technologies including trading platforms and MRV are required. Additionally, methodologies for incorporating **CCUS into the carbon market** needs to be conducted.



New requirements for carbon peaking and carbon neutrality goals

Rate → Quantity

Besides the low-carbon technology, there is a significant emphasis on the R&D of decarbonization technologies, including CCUS.

Energy → Carbon

Besides the energy-saving technology, there is a significant emphasis on the R&D of DAC and other "Energy-for-Carbon" technologies.

CO_2 → GHG

Besides reducing CO_2 emissions, there is a significant emphasis on utilizing, recycling, and removing technologies to offset greenhouse gases that cannot be cut.

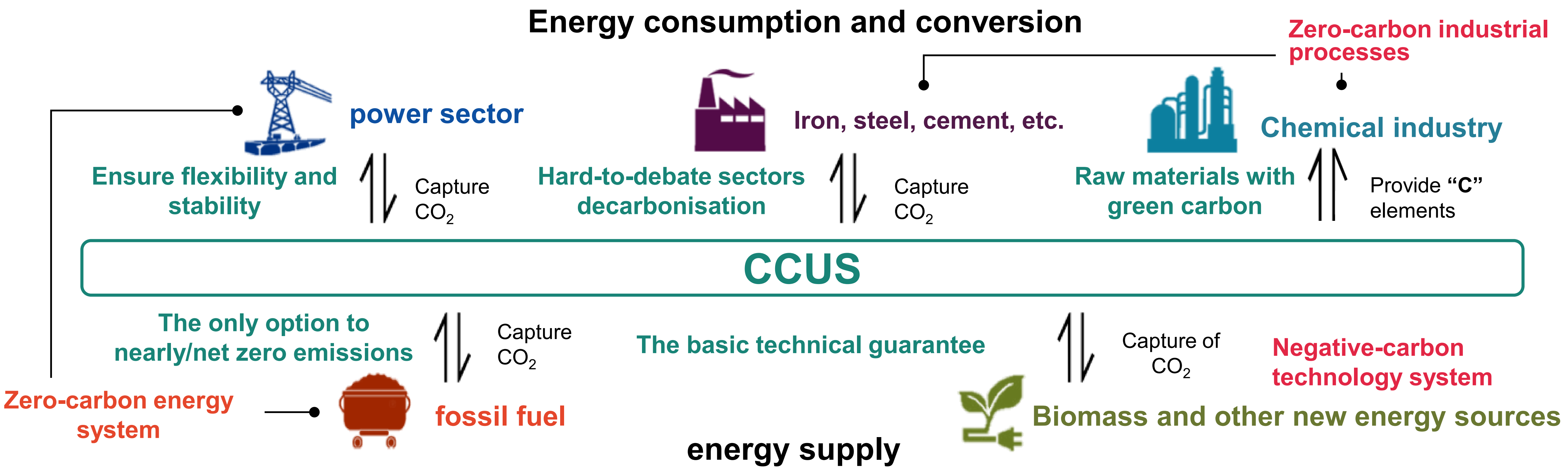
Point → Area

Besides single typical technologies , there is a significant emphasis on the construction of integrated solutions and technological systems.

The role of CCUS technology for carbon neutrality

Strategic technology for large-scale **low-carbon utilization of fossil energy.**

A crucial component of the technology combination for achieving **carbon neutrality**.



Energy consumption and conversion

Zero-carbon industrial processes

power sector

Iron, steel, cement, etc.

Chemical industry

Ensure flexibility and stability

Capture CO_2

Hard-to-debate sectors decarbonisation

Capture CO_2

Raw materials with green carbon

Provide **"C"** elements

CCUS

The only option to nearly/net zero emissions

Capture CO_2

The basic technical guarantee

Capture of CO_2

Negative-carbon technology system

Zero-carbon energy system

fossil fuel

Biomass and other new energy sources

energy supply

Source: Xian Zhang et al, 2021.

New requirements for carbon peaking and carbon neutrality goals

Technology status and challenges

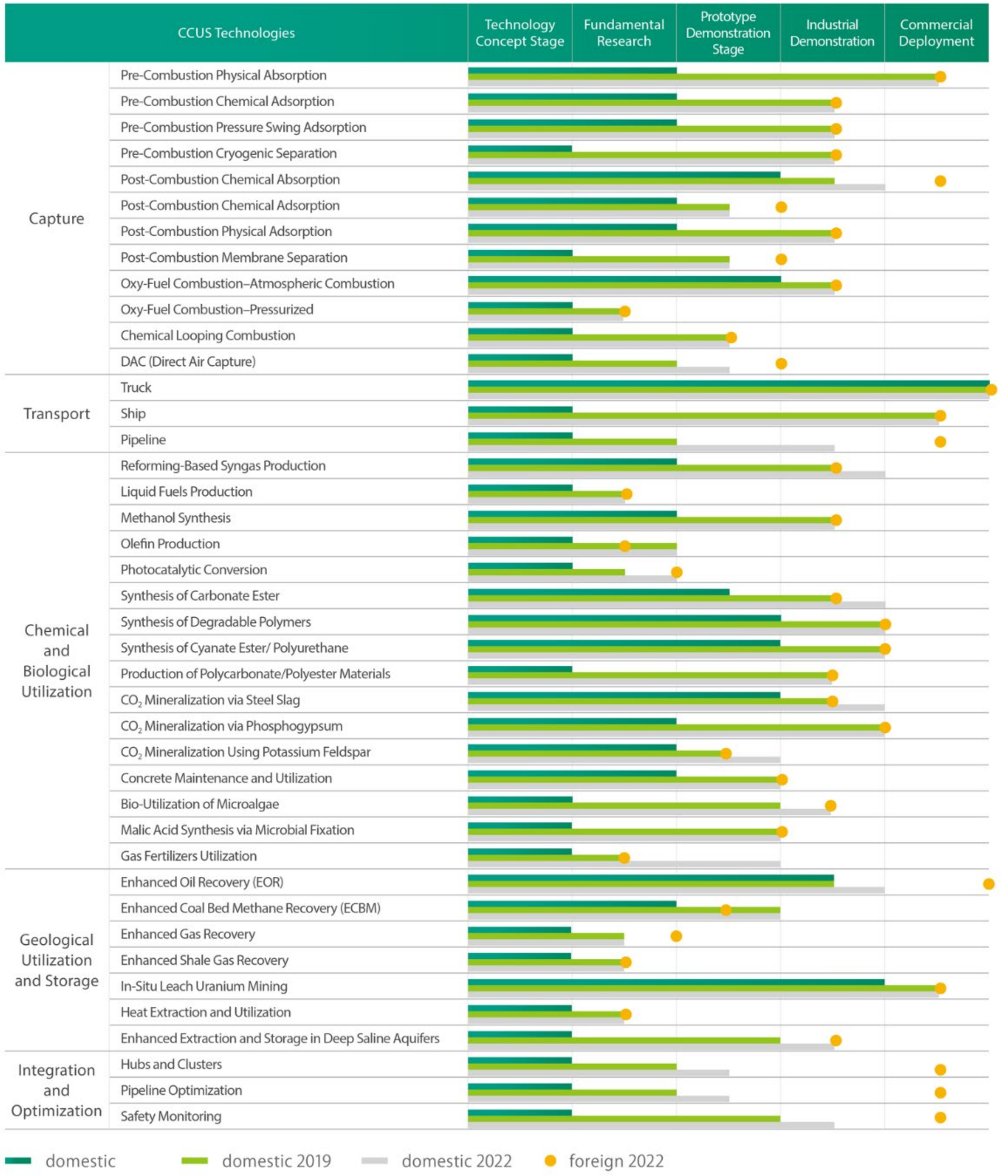
Future Development Outlook

Development status: technological maturity

Most technologies globally are currently at the **industrial demonstration stage**, with transport and integrated optimization technologies developing relatively quickly and having entered the commercial application stage.

In recent years, China has made significant progress in all aspects of CCUS technology, generally **aligning closely with global levels**. However, there are still gaps in key technologies such as pipeline transport, enhanced oil recovery, and integrated optimization compared to the international advanced level.

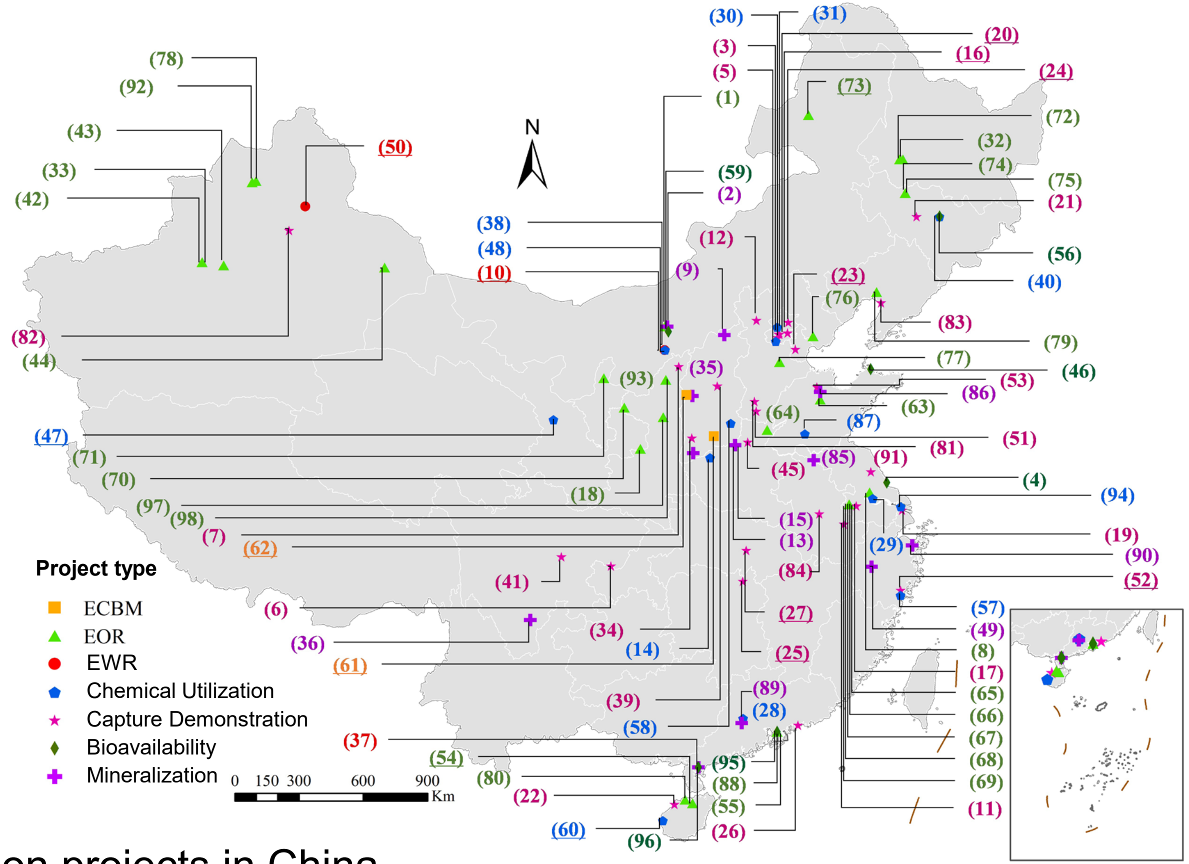
Source: ACCA21, 2023.



Level of CCUS technological development

Development status: CCUS demonstration projects in China

As of September 2023, China has more than **100** CCUS demonstration projects in operation or planning. **More than half of** them are in operation, with a capture capacity of 6 million tons/a and an injection capacity of 4 million tons/a.

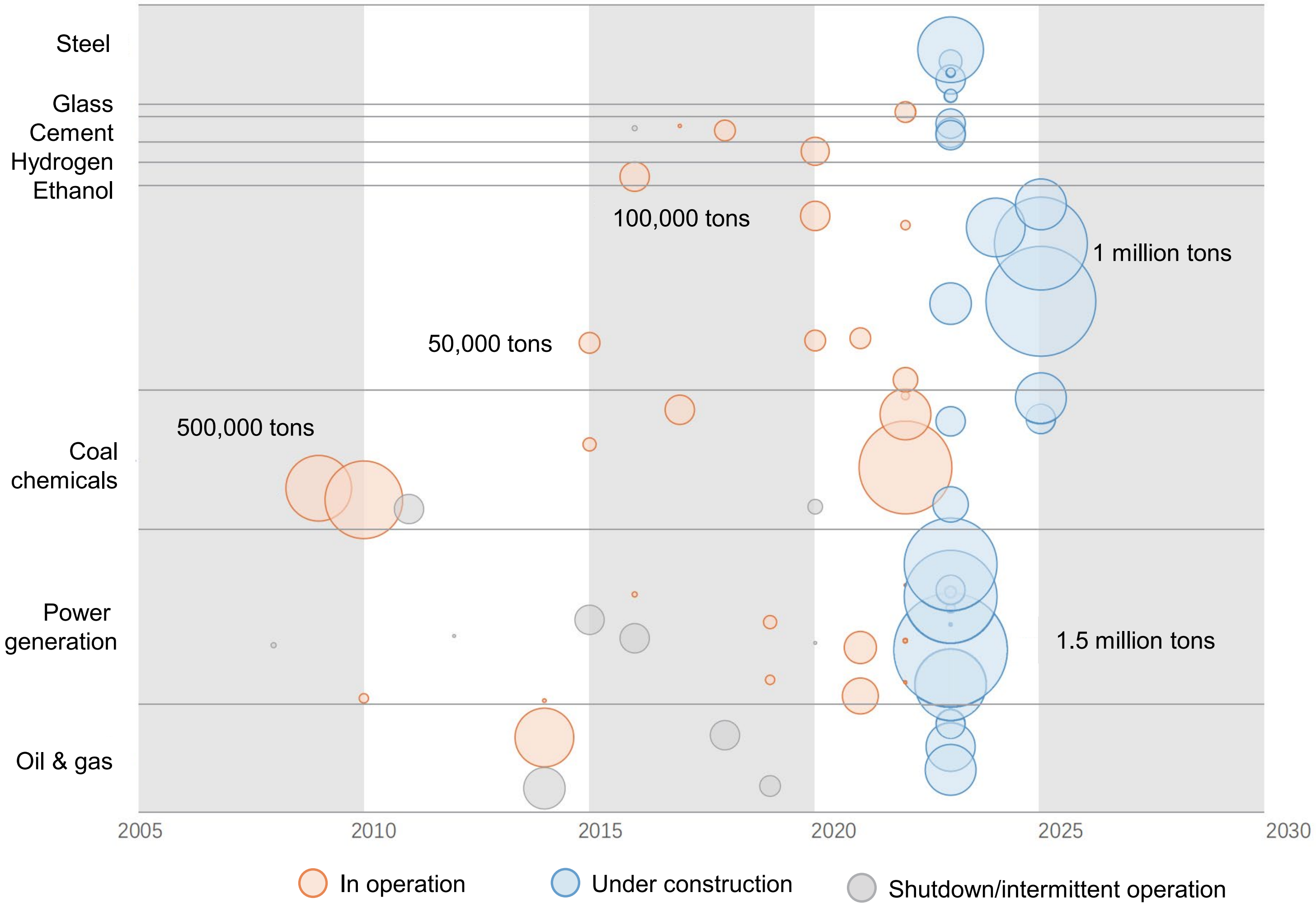


Distribution of CCUS demonstration projects in China

Development status: CCUS demonstration projects in China

The scale of operating projects and planned projects has significantly expanded. More than **40 projects** have a capacity of **100,000 tons** or more, and over 10 projects have a capacity of **500,000 tons** or more.

China's CCUS demonstration projects are growing and spreading to different industries , with relevant demonstrations being conducted in all major sectors.

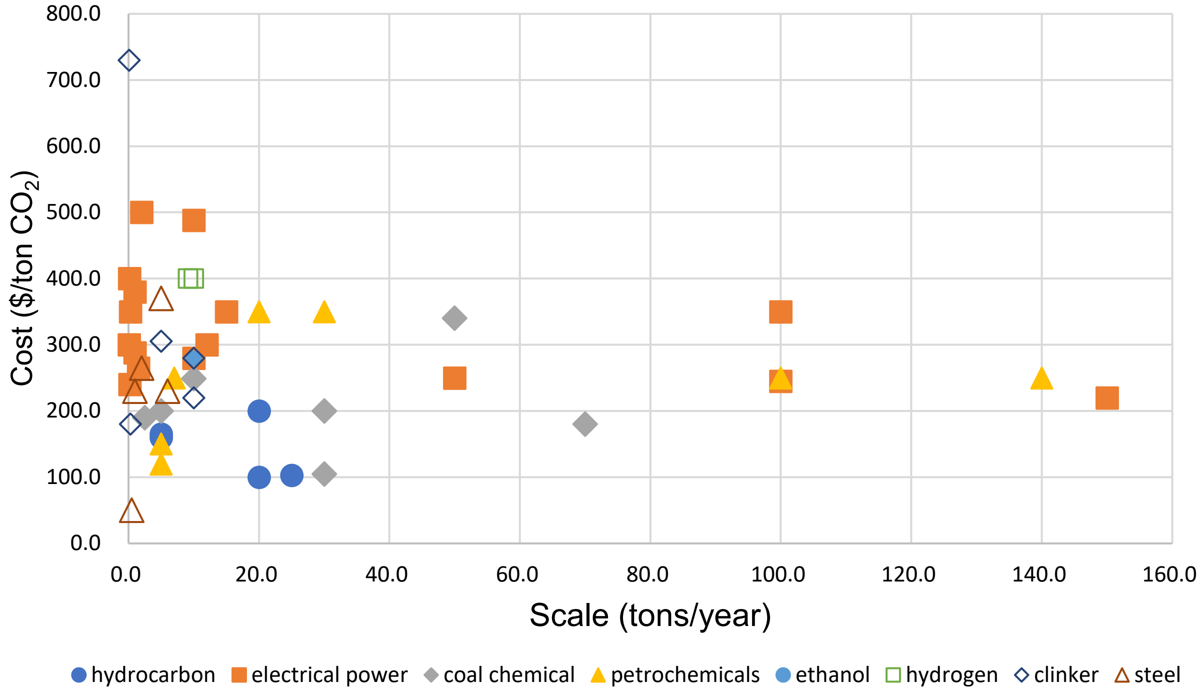


Scale and industry distribution of major CCUS demonstration projects in China

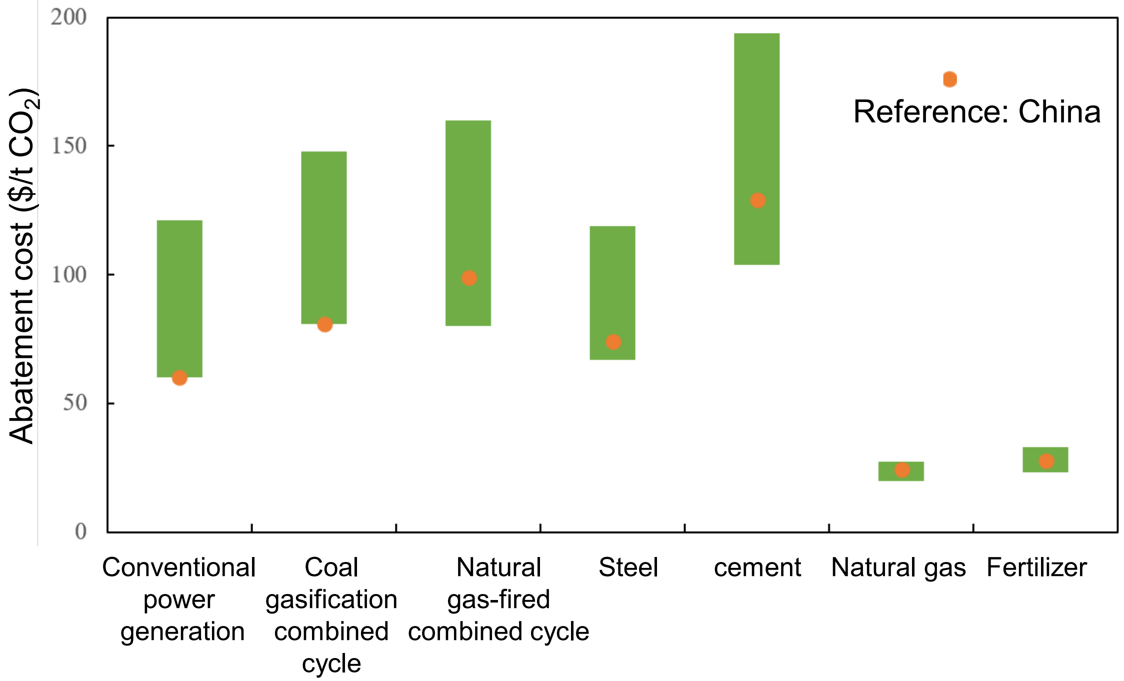
Development status: CCUS technology costs

The net reduction cost of CCUS projects ranges from **100 to 500** CNY/tCO_2.

Overall, the cost of CCUS in China is **relatively low compared to global levels.**



Carbon capture costs for projects of different scales

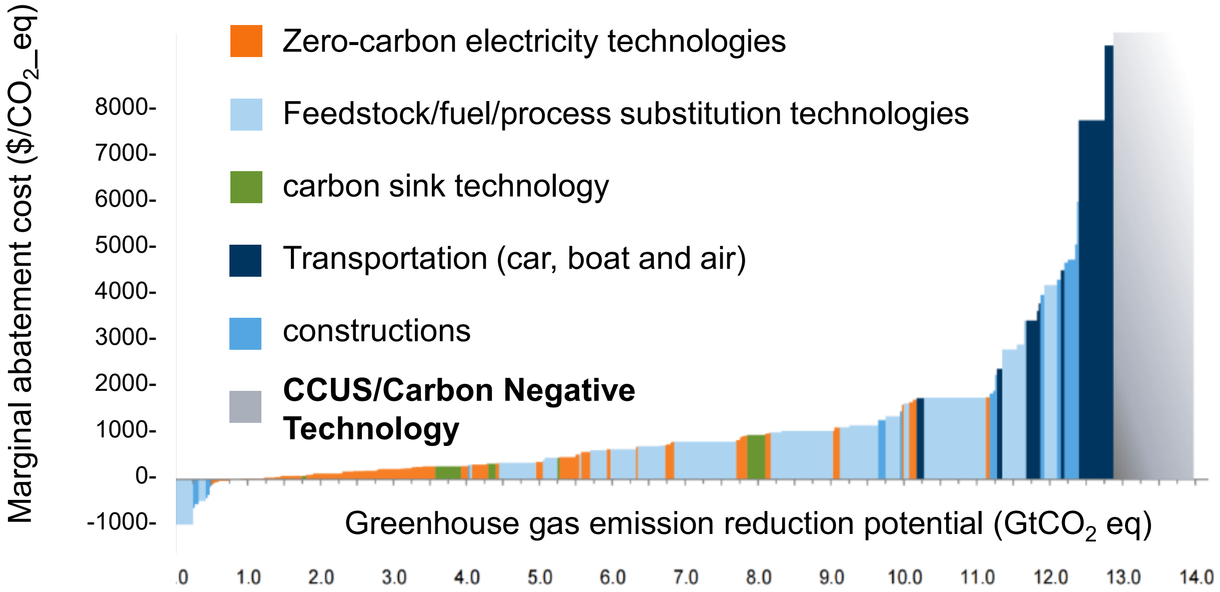


CO_2 avoidance costs for various emission sources using CCUS technology

Source: ACCA21, 2023; GCCSI, 2017.

Challenge 1: High abatement costs

The cost of CCUS technology is **relatively high**, making its competitive advantage less apparent compared to other technologies. This restricts its widespread adoption. The high costs associated with integrating CCUS impose significant pressure on industries such as coal-fired power plants, steel, and cement.



Marginal abatement costs of different abatement technologies

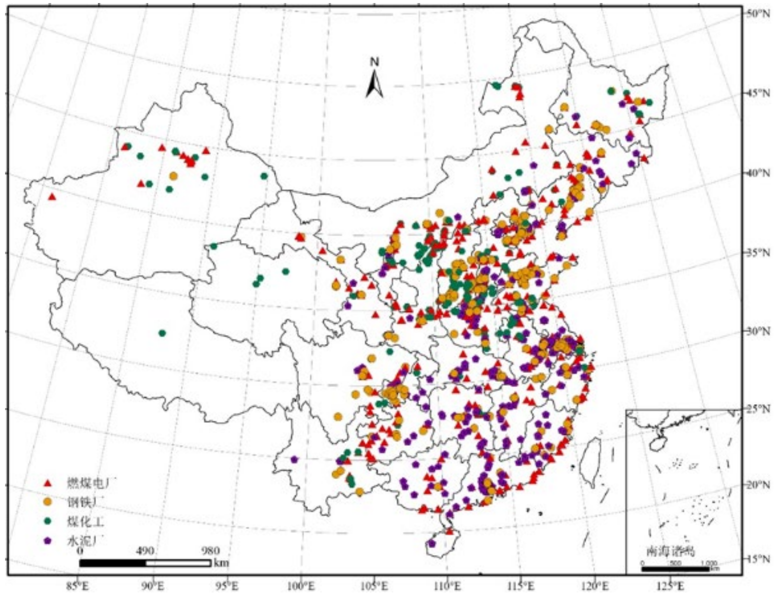
Source: Goldman Sachs, 2021.

Production costs before and after CCUS retrofitting (Estimated results)

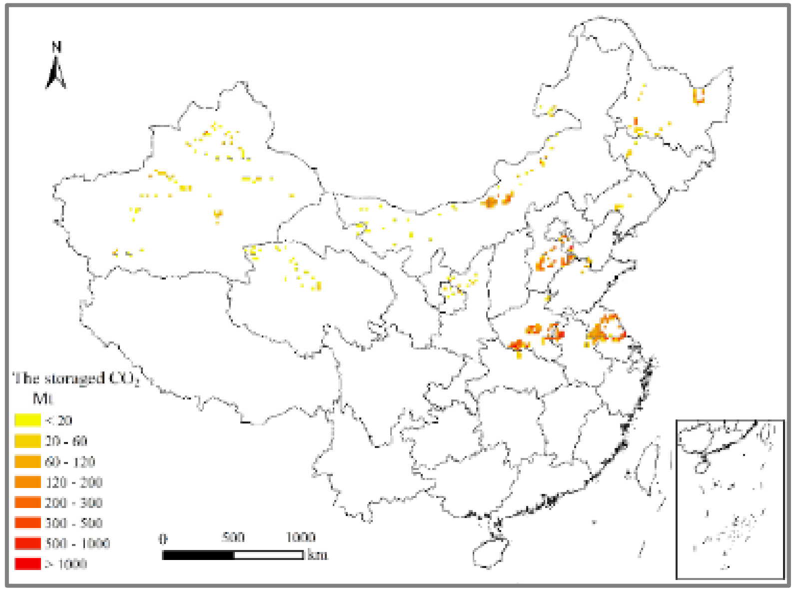
	Coal-fired power plant ($/kWh)	**Steel ($/t)**	**Clinker ($/t)**
Original cost	~0.325	~5500	~450
Cost with CCUS retrofit	~0.525	~6332	~705
Change rate	**↑ ~61%**	**↑ ~15%**	**↑ ~57%**

Challenge 2: CO_2 source and sink mismatch

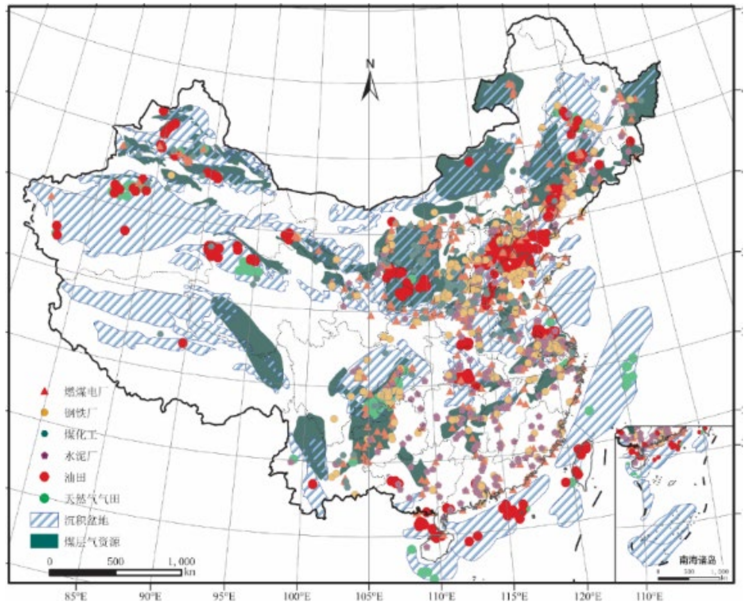
CCUS has great emission reduction potential, but is limited by **source-sink mismatching** in space.



Distribution of CO_2 emission sources in China



Distribution of CO_2 sequestration sites in China (consider injection capacity)



CO_2 source and sink matching process

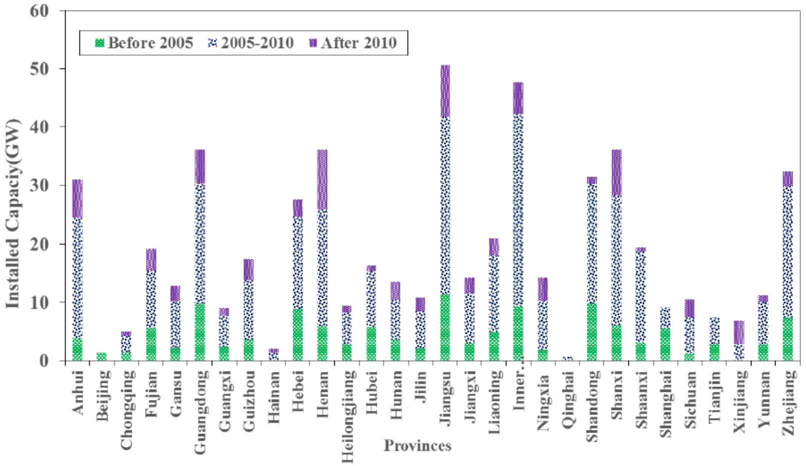
CO_2 sources and sinks are not well-matched

Source: Bureau of Surveys, 2020.

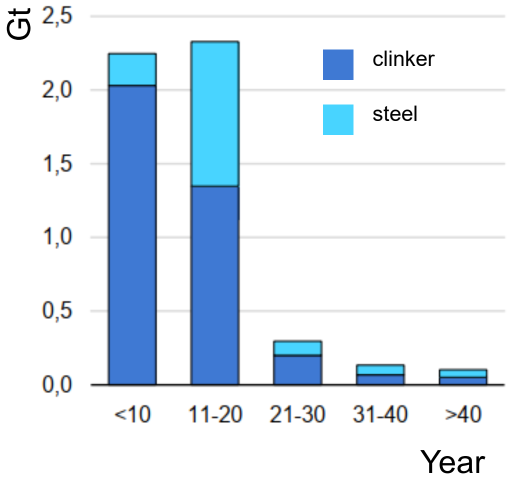
Challenge 3: Urgency of CCUS deployment

The development of CCUS technology faces the risk of **technology lock-in** in time.

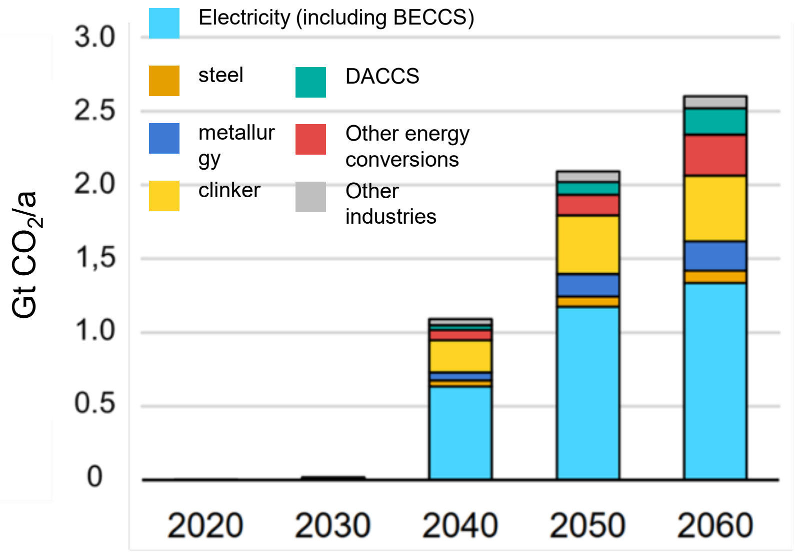
- The future energy infrastructure will require a large number of CCUS facilities. 40% of China's active coal-fired power plants, 55% of cement plants and 15% of steel plants are less than 10 years old and have a long remaining service life. If they are forced to decommission, **a large number of assets will be stranded**.
- **After 2030, the demand for CCUS technology will rapidly increase**. Proactive planning for technology R&D is needed to support the power, industrial, and fuel transformation sectors in increasing their emission reductions to approximately 2.6 billion tons by 2060.



China's active coal-fired power plants



Average age of major heavy industrial assets in China



CCUS deployment expectations by sectors

Source: IEA, 2021.

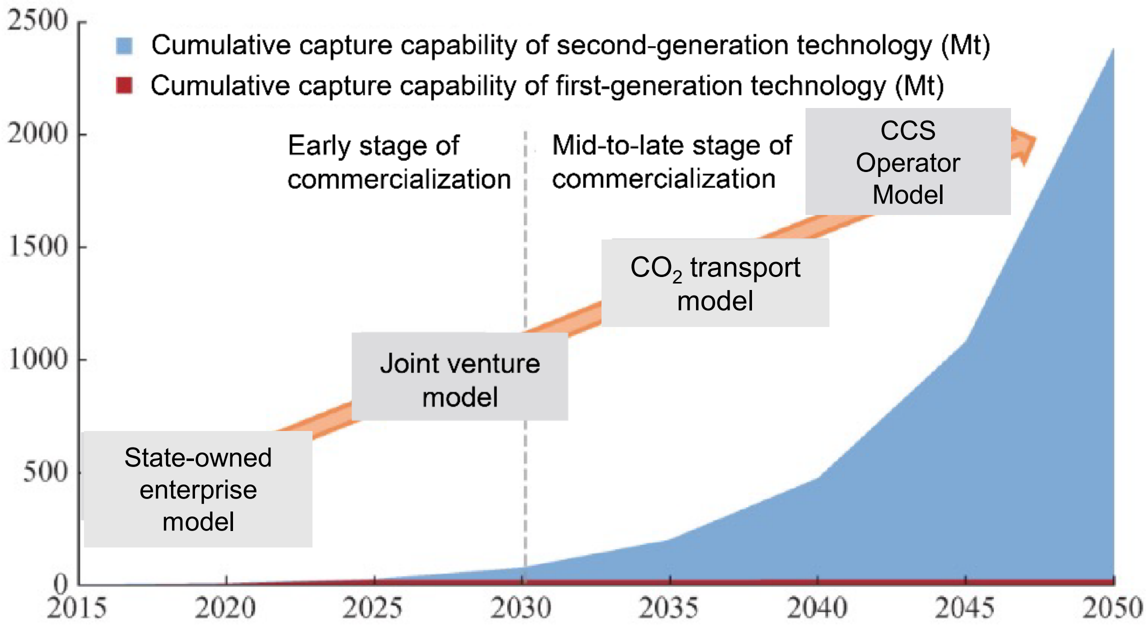
Challenge 4: Lack of commercial models

CCUS projects lack **stable revenue streams**, making it difficult for companies to make investment decisions.

The allocation of **development rights, responsibilities, and benefits** for CCUS projects remains unclear, resulting in a lack of long-term operational motivation for companies.

Currently, **state-owned enterprises** should take a leading role in the initial establishment of CCUS commercial models.

- Some large state-owned enterprises have developed the capability to conduct full-process CCUS demonstrations, including CO_2 capture, transportation, utilization, and storage. This is conducive to establishing mechanisms for the allocation of rights, responsibilities, and benefits for long-term CCUS projects and accelerating investment decisions.
- Once a sustainable commercial model is formed through the state-owned enterprise approach, a joint operation model with multiple enterprises can be explored.



Development planning for each business model at different CCUS technology stages

Challenge 5: Insufficient incentive policies

While international CCUS policy frameworks are relatively mature and robust, with strong operational components, China's CCUS policies focus more on macro-level design and need further enhancement in operational practicality.

International organizations and developed countries are accelerating technology deployment **through financial subsidies, specialized fiscal and tax policies, mandatory regulations, and carbon pricing mechanisms**. China's related incentive policies need further development.

CCUS incentive polices in America

	2008:45Q First enacted		2018:45Q partially revised		2021:45Q Revised again		2022: Inflation Reduction Act (IRA)	
Rules and regulations	**Tax relief to offset some of the running costs**		**CCUS program is loan-ready to address financing issues** • 12 years of tax credits for various CCUS programs • Eliminate the $75 million tCO_2 subsidy cap		**Addressing CCUS Program Benefit Transmission** • More flexible system for allocating credit eligibility • Credits available for private capital • Allow taxpayers with multiple capture devices to add up to a total application • Credit recovery period reduced from 5 to 3 years		**Taking into account new technologies** • Added provisions for air capture	
Maximum compensate for	EOR utilization 10 $\$/\text{tCO}_2$	Geological sequestration 20 $\$/\text{tCO}_2$	Utilization projects 35 $\$/\text{tCO}_2$	Sequestration project 50 $\$/\text{tCO}_2$	Utilization projects 35 $\$/\text{tCO}_2$	Sequestration project 50 $\$/\text{tCO}_2$	Utilization projects 60 $\$/\text{tCO}_2$ (stationary source) 130 $\$/\text{tCO}_2$ (DAC)	Sequestration project 85 $\$/\text{tCO}_2$ (stationary source) 180 $\$/\text{tCO}_2$ (DAC)

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Principles to consider for future CCUS development

Goal-orientation	"Energy-source-sink" matching can help support the net-zero goal and provide a guarantee for energy security and sustainable development.
Technical feasibility	Standing and breaking simultaneously, integrating consideration of technology maturity, technology lock-in and asset stranding risk. Coupling CCUS and renewable energy to reshape the net-zero industrial process and build negative emission technology systems.
Economic affordability	Adequately understand the impact of CCUS on the total cost of economic and social emission reduction in the near, medium and long term under the carbon neutrality target, and comprehensively consider the stranded cost of assets, incremental cost of technology, and cost of industrial emission reduction.
Just transition	Considering the energy security, strengthening economic momentum, guaranteeing jobs and other comprehensive benefits, to integrate industrial-chain technology, couple cross-industry chain system, and optimize the overall solutions.
Global policy	Policies, technologies and markets interact positively and collaboratively to help the formation of CCUS business models for long-term sustainable operations.

Development goals of CCUS technology

Construction of low-cost, low-energy, safe and reliable CCUS technology system and industrial clusters, providing **technical options for the low-carbon utilization of fossil energy, and technical support for the realization of carbon neutrality goals**, as well as **technical guarantee for energy security, sustainable economic, and social development.**

2030

- Significant increase in the unit size of mature capture technologies;
- Conversion to pipeline transport;
- Existing technologies begin to enter commercial applications with industrialization capability;
- Forward deployment of negative emission technology demonstration projects.

2035

- Low-cost, low-energy capture technologies is mature, and conversion from first-generation to second-generation technologies is completed for deployment in various industries;
- Onshore transport pipeline networks are beginning to be deployed;
- Novel technologies have matured in development and are beginning to be rapidly rolled out to achieve large-scale commercial operation;
- Formation of multiple CO_2 utilization commercialization projects;
- Accelerating the deployment of negative emission technologies.

2050

- Widespread commercial application of second-generation capture technologies;
- Formation of a large-scale land transport pipeline network;
- Achieving large-scale application in the hard-to-abate industrial sector, and several industrial clusters have been built;
- CO_2 chemical, biological, mineralization utilization, and negative emission technologies are fully commercialized.

2060

- Comprehensively forming a new CCUS industry cluster, and realizing the triple objectives of effectively responding to climate change (environmental protection), guaranteeing energy security and stable supply (security), and low economic cost (economy), to achieve deep emission reduction and carbon neutrality goals.

Note: Existing technologies refer to technologies that are currently eligible for industrial demonstration, including first-generation capture technologies and partial utilization and storage technologies. New technologies refer to technologies that are not currently eligible for industrial demonstration, including second-generation capture technologies and partial utilization and storage technologies.

Relevant work undertaken and ongoing

China CCUS technology development roadmap

Published: 2011 and 2019 editions
Ongoing: 2024 edition
Leading the development of CCUS technology and related industries

Assessment reports of CCUS technology

Published: National assessment reports, annual reports, and series book
Tracking the new advances in CCUS technology

CCUS multi-bilateral international cooperation

Continuously deepening: China-US/Europe/Australia bilateral and clean Energy Ministerial (CEM) multilateral CCUS exchanges and cooperation

Thank you!