OIL AND GAS CLIMATE INITIATIVE

CCUS IN CHINA

The value and opportunities for deployment

A REPORT FROM THE
OIL AND GAS CLIMATE INITIATIVE

SEPTEMBER 2021

FOREWORD

The Oil and Gas Climate Initiative (OGCI) aims to accelerate the industry response to climate change and scale up practical solutions for a net zero future.

Scaling up carbon capture, utilization and storage (CCUS) is an essential tool to achieve both of these goals, and is therefore one of OGCI's top priorities. CCUS opens up opportunities to reduce emissions on a huge scale, make low-carbon products, accelerate the emergence of a hydrogen economy and provide the infrastructure to remove carbon dioxide permanently from the atmosphere.

In 2019, OGCI launched the CCUS KickStarter initiative which focuses on creating CCUS-enabled industrial hubs to leverage economies of scale and drive down costs through accelerated deployment. As part of this work, we are evaluating high-potential hubs around the world and exploring the value and potential of scaling up deployment of CCUS in specific countries. To date, we have focused on the UK, the Netherlands and Saudi Arabia.

This report is based on our analysis and engagement in China, working closely with OGCI member company CNPC, to explore what it would take to create a commercial environment for CCUS in China so that it can be an efficient and large-scale lever to achieve the country's goal of carbon neutrality (also called net zero emissions) by 2060. This work resulted in a detailed white paper written by two leading Chinese academics – Prof Bo Peng (China University of Petroleum Beijing) and Prof Xi Liang (University College London) – with contributions by experts from CNPC, bp and Shell, and feedback from other member companies and key stakeholders. The white paper will be available in Chinese and English on the website of the China University of Petroleum.

This short OGCI report is intended to present the key findings of this work on the potential value and scale of CCUS deployment in China to an international audience.

KEY FINDINGS

- **CCUS will be essential for China to achieve its target of carbon neutrality** by 2060, providing between 1.5 Gt and 2.7 Gt of emissions reductions annually by 2050.

- In addition to climate benefits, CCUS will also create **social and economic benefits**, helping China to maintain economic growth, strengthen its market position in low carbon energy and secure energy supply.

- Deploying CCUS on this scale will require a range of **new policies to commercialize CCS** and help a CCUS industry to emerge. China can draw on early experience in other countries to define appropriate market incentives, subsidies and mandates.

- **CCUS hubs, providing collective transport and storage infrastructure** for carbon dioxide captured from different industrial and power sources, will facilitate China's CCUS scale up. CNPC's China Northwest hub, part of OGCI's hub initiative, aims to lead the way for other hubs to emerge.

- If China can accelerate CCUS deployment at the scale needed to achieve carbon neutrality, it would **catalyze the global CCUS industry**.

CONTENTS

1.

CCUS in a climate-constrained world

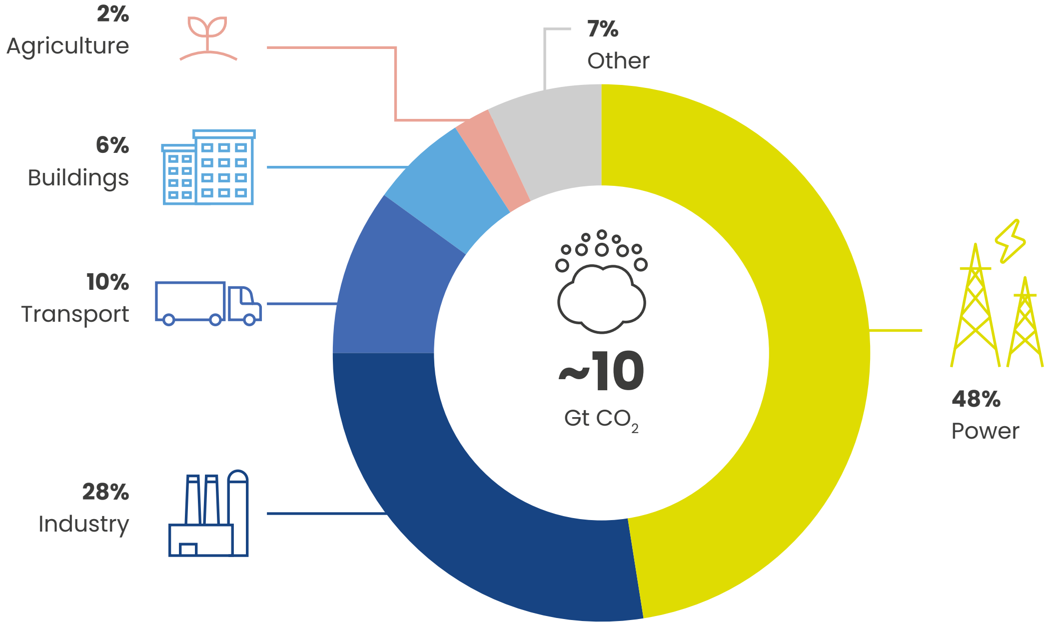
China in the global context

In September 2020, President Jinping Xi announced that China would strive to reach the peak of carbon dioxide emissions before 2030 and achieve carbon neutrality before 2060. Since China is currently the world's largest carbon-emitting country, with emissions more than twice those of the US and three times those of Europe, that will require a significant shift in the pace and scale of transition.

CCUS will be a key component of this effort. CCUS is a significant enabler of the global energy transition since its deployment can support the production of low-carbon electricity and low-carbon hydrogen, as well as providing the necessary infrastructure for negative emissions technologies such as biomass with carbon capture and storage and direct air capture and storage[1].

In China, it could play an even more central role due to the scale of the climate challenge and the speed with which it must be tackled. China has already moved rapidly to develop its renewable energy sector, with installed wind power capacity growing at an annual rate of 20% and installed photovoltaic capacity accounting for 45% of the world's total. Nevertheless, fossil fuels account for more than 80% of the country's primary energy supply, powering its industrial development, and coal remains the country's main energy source. As the only climate mitigation technology that can achieve near-zero emissions while continuing to use some fossil energy, CCUS will be crucial for China to reach carbon neutrality while maintaining economic growth and securing energy supply.

Figure 1: Share of China's energy-related carbon dioxide emissions by sector, 2019



Source: Climate Transparency, Enerdata (percentages add up to 101% due to rounding)

Getting to scale

Getting CCUS to scale is a huge task, however – both globally and in China. The International Energy Agency's latest scenario estimates that over 7 Gt of carbon dioxide will need to be captured by 2050 to achieve net zero, with most of that permanently stored. Currently, some 20 large-scale CCUS projects store around 45 Mt globally per year[2]. According to IEA's net zero scenario, from 2030 onwards, 10 heavy industrial plants need to be equipped with carbon capture technology every month[3] in order to achieve the 2050 target.

1 IPCC, Global Warming of 1.5°C
2 GCCSI, Global Status of CCS 2020
3 IEA, Net Zero by 2050, 2021

A massive scale-up is clearly needed if CCUS is to develop as required to support the aims of the Paris Agreement. The good news is that CCUS is gaining significant momentum internationally. Plans for over 30 commercial facilities have been announced in the past three years, and potential investment in CCUS projects nearing construction has more than doubled since 2017 to US$27 billion[4]. Governments in the US, UK, Norway, the Netherlands, Canada and Australia have recently introduced a range of policy incentives to encourage commercial investment in CCUS.

In China that scale-up will need to be even faster. China is proposing to get from carbon peak to carbon neutrality in just 30 years – significantly shorter than in Europe and North America which have peak to neutrality time spans of about 70 and 50 years, respectively, according to Tsinghua University Low Carbon Economic Research Institute[5].

If China can accelerate CCUS deployment in the power, steel, cement, chemicals, hydrogen and fertilizer sectors as needed to achieve carbon neutrality, it would catalyze the global CCUS industry – bringing down costs while demonstrating its potential, as happened with solar power.

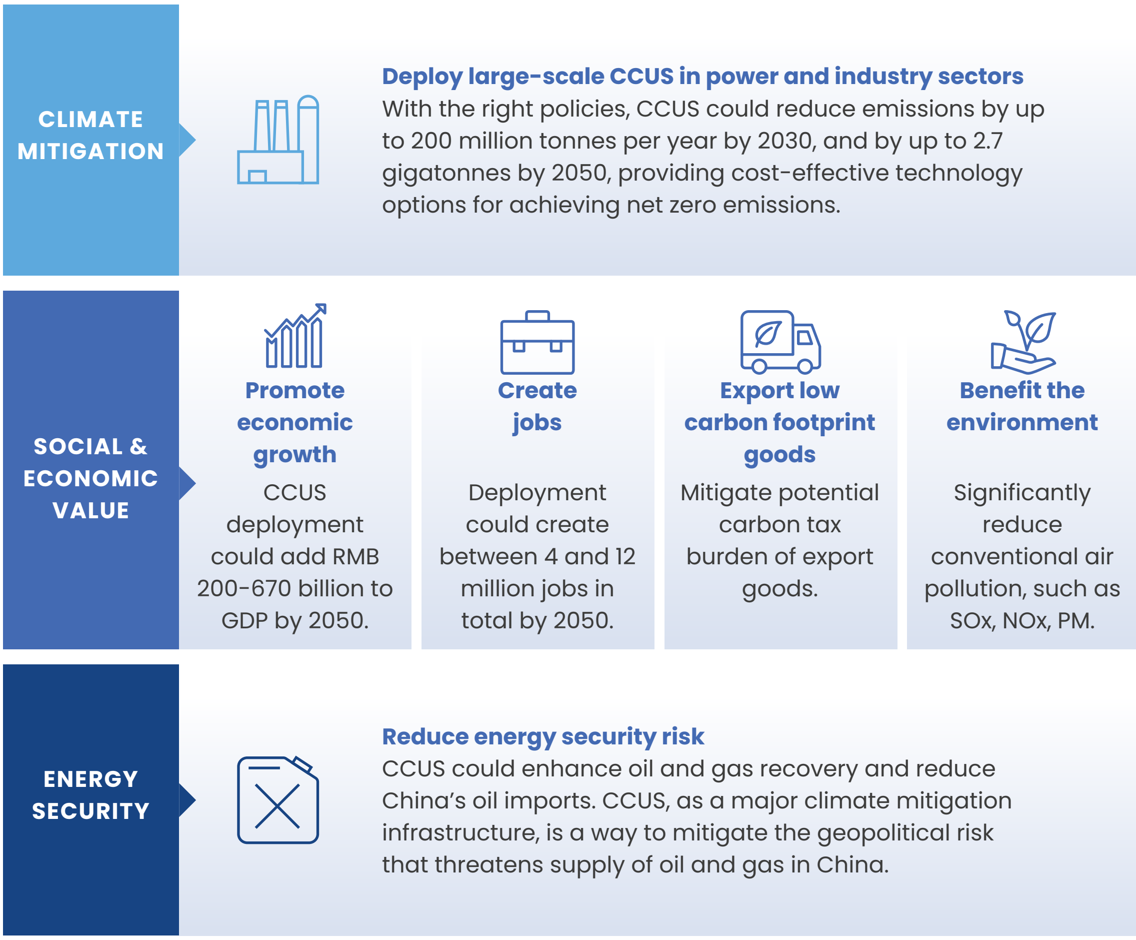
4 International Energy Agency, CCUS in Clean Energy Transitions, 2020
5 2020 CCUS：http://news.sciencenet.cn/sbhtmlnews/2020/11/359041.shtm

2.
The potential value of CCUS in China

CCUS as a broad transition enabler

CCUS will be a crucial technology for China to rapidly reduce absolute emissions from its use of fossil fuels so that they peak before 2030. Such a scale-up would also directly enhance the future competitiveness of Chinese industry – supporting the low-carbon transformation of both the energy sector and high-emission industries. That would preserve and create jobs, stabilize and boost foreign trade, secure energy supply and bring economic value far greater than the the cost of supporting deployment.

Figure 2: Key values unlocked for China by CCUS



Source: Bo Peng and Xi Liang et al, The Value of CCUS in China, 2021

Climate mitigation

China's energy-related carbon emissions have grown alongside its rapid economic development, rising from 5.5 Gt CO_2/year in 2005 to 10 Gt in 2019. If growth continues along the same trajectory, emissions would reach 11.6 Gt in 2030, with power generation and industrial production accounting for more than 70% of the total.

If CCUS is supported by focused policy measures and developed at scale in the coal chemical, thermal power, steel and other high-emitting industries, studies suggest it could capture and store between 1.5 Gt and 2.7 Gt per year by 2050[6]. That represents roughly a quarter (between 16% and 28%) of China's annual energy-related carbon emissions in 2018.

6 Asian Development Bank, Roadmap for Carbon Capture and Storage Deployment and Development in the People's Republic of China (and subsequent discussions around ADB's upcoming update), Ministry of Science and Technology CCUS Roadmap, 科学技术部社会发展科技司和中国21世纪议程管理中心. 2019. 中国碳捕集利用与封存技术发展路线图(2019), plus IEA global scenarios

Economic value

Analysis based on IEA and Asian Development Bank (ADB) investment scenarios[7] show the potential economic impact that CCUS industrial investment could have on key emitting sectors in China. These estimates suggest that, by 2030, CCUS could create additional value, equivalent to between 0.2% and 0.6% of China's 2019 GDP. At this stage, CCUS would be in the early phase and would require significant public investment in the demonstration of CCUS in large-scale but low-concentration sources such as steel and chemicals.

In the following years, as CCUS moves into operation, the GDP impact of CCUS projects would increase progressively and could add up to between RMB 200 and RMB 670 billion. Export markets are expected to provide significant opportunities for China's CCUS industrial chain, specifically in engineering services, equipment, and materials.

There is also a significant opportunity cost if China does not simultaneously accelerate the deployment of CCUS demonstration projects designed to mature technology. While Chinese industries would be able to provide materials (such as steel and cement) and equipment with lower profit margins, it may miss the high value-added links of the emerging international CCUS market – areas such as preliminary engineering consulting and design, general contracting, process package licensing, operations and management consulting.

Jobs

CCUS industrial investment creates jobs both directly (during construction and in operation) and indirectly through the chain reaction of upgrading existing industries. As an extension of traditional energy and industrial industries, CCUS has less impact on production process adjustments than other deep decarbonization technologies, and can avoid the social impact of work migration.

According to analysis based on key heavy industries, the deployment of CCUS is expected to create between 90,000 and 200,000 direct jobs by 2030. With the development of the CCUS industry, domestic jobs will continue to increase, bringing an indirect employment effect of 2 to 4 times. It is estimated that by 2050, between 4.0 and 11.6 million jobs could be created. That is equivalent to between 1% and 3% of China's urban employed population in 2019.

The main industries driven by CCUS are mining, metal manufacturing, other service industries, machinery industry, and transportation amongst other sectors. However, the wide application of CCUS will promote infrastructure, technology development, financial services and other industries, creating job opportunities while bringing high value-added innovation.

Low-carbon exports

As countries try to decarbonize their heavy industry while ensuring it remains globally competitive, there will be a greater focus on using unilateral carbon border taxes[8] or other instruments to reduce carbon leakage – the shift of emitting company operations to less regulated jurisdictions. The EU, for example, plans to impose a Carbon Border Adjustment (CBA) mechanism on key emission industries by 2023, putting a price on imports such as steel, cement, fertilizers and aluminium depending on their carbon footprint.

7 Bo Peng and Xi Liang et al, China CCUS White Paper: The value and opportunities for deployment, 2021
8 OECD. 2020. Carbon border adjustment: a powerful tool if paired with a just energy transition. https://oecd-development-matters.org/2020/10/27/carbon-border-adjustment-a-powerful-tool-if-paired-with-a-just-energy-transition/

The use of CCUS technology to reduce the embedded emissions in China's export products could alleviate the negative impact of these instruments on exports. Indeed, since Chinese exporters to the EU might face the choice of paying carbon taxes or introducing CCUS into their industries[9], it could encourage export-oriented industries to take the lead in launching CCUS projects to improve product competitiveness.

Air pollution

CCUS can have a synergistic effect on other environmental pollutants, such as sulfides, nitrogen oxides and airborne particulate matter depending on where and how it is deployed.

The combination of pre-combustion capture and advanced natural gas power generation technology, for example, can greatly reduce traditional air pollutant emissions. Similarly, oxy-combustion technology not only achieves carbon dioxide capture[10], but also helps to reduce other emissions.

If CCUS is used in coal power plants, this capability must be built into the project planning. For example, a pretreatment unit can be installed before the main capture facility to greatly reduce sulfur content and particulate matter in the flue gas[11]. If CCUS is carried out without a pretreatment unit, the negative impact on pollution will rise since it will require additional energy consumption to operate the capture equipment[12].

Energy security

China is the world's largest importer of oil and natural gas, and the safe supply of oil and gas is easily affected by geopolitical relations, which in turn affect the stability and development of domestic industrial production. CCUS can support China's energy security in two key ways. First, it can help to boost domestic oil production through re-injecting carbon dioxide into oil fields to enhance oil recovery. Secondly, China's deployment of CCUS will bring significant emissions reductions to the world and so help to strengthen international cooperation and stabilize foreign trade.

9 European Commission, 2020. Carbon Border Adjustment Mechanism: Inception Impact Assessment.
10 Dunyu Liu, et al. 2016. CO_2 quality control in Oxy-fuel technology for CCS: SO2 removal by the caustic scrubber in Calliede Oxy-fuel Project. International Journal of Greenhouse Gas Control. 2016(51): 207-217.
11 National Energy Technology Laboratory, 2010. Life Cycle Analysis: Existing Pulverized Coal (EXPC) Power Plant. Report Number DOE/NETL-403-110809. Morgantown, WV: NETL.
12 Viebahn Peter, et al. Comparison of carbon capture and storage with renewable energy technologies regarding structural, economic, and ecological aspects in Germany, International Journal of Greenhouse Gas Control. 2007, 1(1):121-133.)

3.

Unlocking the potential value

Experience to date

China has completed 35 CCUS projects, but most are on a demonstration-scale and largely implemented by state-owned enterprises under the government's guidance, rather than as a commercial project.

One large-scale CCUS project is already in operation at CNPC's Jilin oilfield, five are due to start operation in 2021, and 10 are currently under consideration or in development, including China's first CCUS hub, part of OGCI's KickStarter initiative and three other CNPC-led hubs[13]. Together, these projects have the capacity to capture and store over 19 million tonnes of carbon dioxide per year.

Figure 3: Large integrated CCUS projects, completed and under development, in China

	NAME	SCALE Mt	OPERATION	INDUSTRY
1	CNPC Jilin Project	0.6	2018	Natural gas processing
2	CHNE Jingie	0.1	2021	Power generation
3	CNOOC Enping	0.1	2021	Natural gas processing
4	Sinopec Qilu Project	0.4	2021	Chemical production
5	Yanchang Integrated Project	0.4	2021	Chemical production
6	Sinopec Huadang Project	0.5	2021	Chemical production
7	CHNE Taizhou	0.5	2025	Power generation
8	China Northwest Hub	1.5	2025	Multiple
9	CRP Haifeng Project	1.0	2030	Power generation
10	Huaneng IGCC Project Phase III	2.0	2030	Power generation
11	Shenhua Ningxia Project	2.0	2030	Coal-to-liquids
12	Sinopec Shengli Project	1.0	2030	Power generation
13	CNPC Daqing	3.0	2030	Multiple
14	CNPC Changqing	3.0	2030	Multiple
15	CNPC Dagang	1.0	2030	Multiple
16	Shenzhen Energy	0.5	2030	Power generation

Bo Peng and Xi Liang et al, China CCUS White Paper. The value and opportunities for deployment, 2021 GCCSI, OGCI

Led by large energy enterprises, these projects and pilots have provided valuable experience in the integrated design, construction and operation of CCUS. Carbon capture demonstration units are using a variety of capture technologies from pre-combustion, post-combustion and oxy-combustion of coal-fired power plants, post-combustion capture technologies for gas-fired power plants, and post-combustion exhaust capture technology for cement kilns. Meanwhile, the first carbon capture technology testing platform in Asia was established at the China Resources Power Haifeng power plant in Guangdong province[14].

13 https://www.ogci.com/action-and-engagement/removing-carbon-dioxide-ccus/our-kickstarter-hubs/
14 http://www.cnenergynews.cn/zhuanti/2020/09/15/detail_2020091576974.html

Policy options

The carbon neutrality target provides a strong policy background for the development of CCUS. Over the past few years, China has focused on feasibility studies, demonstration projects and engineering tests. It has published more than 30 policies, development plans or roadmaps in place supporting the technological development of CCUS. To use CCUS industrialization as a tool to reach carbon neutrality, however, the government now needs to focus on financing and commercialization models for industrial-scale projects.

COUNTRIES TAKING CONCRETE POLICY MEASURES TO COMMERCIALIZE CCUS DEPLOYMENT

- The **US** has a federal production tax credit, known as 45Q, that rewards companies on a per ton basis for anthropogenic carbon dioxide securely stored geologically in approved reservoirs and aquifers. California has implemented a Low Carbon Fuel Standard that creates demand for CCUS-enabled fuel products. This has been adopted in Washington, British Columbia and Oregon, and is being considered in 14 other states.
- **Norway's** is investing directly in the Longship/Northern Lights large-scale full chain CCUS hub, supporting both capture from industrial facilities and collective transport and storage infrastructure, in an effort to support the emergence of a commercial CCUS industry globally. Operations are expected to start in 2024.
- The **Netherlands** government has approved subsidies to emitters in the Rotterdam/Porthos hub to bridge the gap between the EU Emissions Trading System price and the cost of capture, as part of its strategy to reduce industrial emissions by 2030.
- The **UK** is developing a package of policies – including a regulated asset fee, contracts for difference and capital co-funding – to support emitting sectors as well as transport and storage operators in a number of CCUS hubs, including Net Zero Teesside.
- Policy enablers for CCUS projects in **Canada** include the federal Strategic Innovation Fund and Clean Fuel Standards, alongside provincial efforts including Alberta's Technology Innovation and Emissions Reduction regulation that covers industrial greenhouse gas emissions through an emissions trading system.
- **Germany** announced in 2021 a subsidy programme aimed at supporting the country's raw material industry in developing technologies for CCUS.
- **Australia** expanded in 2020 the remits of the Clean Energy Finance Corporation and the Australian Renewable Energy Agency to include CCUS. In addition, they launched in 2021 a Carbon Capture Use and Storage Development Fund for pilot or pre-commercial projects aimed at reducing emissions.

That requires clear policy objectives, building on the Ministry of Science and Technology's CCUS development plan from the 12th Five-Year Plan and setting clear and ambitious CCUS-enabled industrialization goals in the framework of the 14th Five-Year Plan.

Using CCUS as a tool for achieving carbon neutrality will also require the introduction of active short-term policy incentives – from subsidies and carbon market mechanisms to tax credits and mandates to promote the development of a safe and viable CCUS industry and enhance social and economic value as industry transforms. China has extensive experience in the development of policies to incentivize the large-scale deployment of renewables. As it formulates fiscal and taxation policies to support the technological development of CCUS, China can draw on that experience as well as on international experience in shaping packages of market-based mechanisms to kickstart the scale-up of CCUS.

Regulatory systems

In conjunction with providing national policy support, China also needs to develop a regulatory and licensing system, ensuring that projects are designed, deployed, implemented and operated in a safe manner. By doing so, it reduces investors' risk by providing predictability and ensures that the public retains trust and confidence in the safety and effectiveness of CCUS. Lack of clear and coordinated CCUS regulations remains one of the main barriers to CCUS deployment internationally.

China's CCUS supervision and licensing system could build on the existing legal framework, based on environmental protection and environmental impact assessment laws, and the regulations and standards of national and local area management, gradually including all aspects of CCUS into regulations. Alternatively, China could develop a system explicitly targeted at CCUS technology, learning from and adapting the experience of foreign CCUS pioneers to reflect China's national conditions.

CO_2 storage resources

Studies suggest that China has the potential to sequester more than 200 Gt of CO_2 in oil and gas fields, saline aquifers and unrecoverable coal seams[15,16]. **OGCI's CO_2 Storage Resource Catalogue** identifies 10 Gt of discovered potential in 72 sites and over 20 geological basins, both onshore and offshore[17]. Several regions in north and northwest China have a large number of high-quality onshore sequestration sites, while east and southeast China will rely on offshore sequestration sites to reduce emissions.

The resource is easily large enough to provide geological storage for China's carbon dioxide emissions. At the same time, injecting CO_2 has the potential to increase oil recovery by 15-20%[18] and coal bed methane recovery by 10-30%, which has considerable economic benefits and reduces the total amount of oil and gas imports.

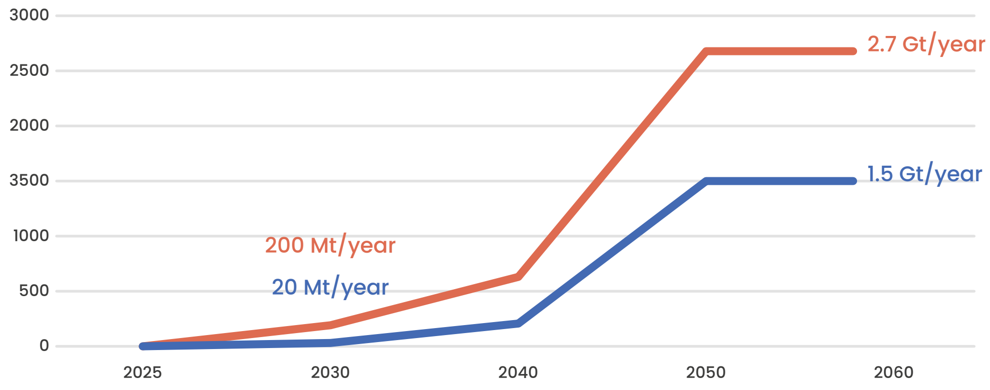
15 科学技术部社会发展科技司和中国21世纪议程管理中心. 2019. 中国碳捕集利用与封存技术发展路线图(2019版).
16 Pacific Northwest National Laboratory. 2009. Establishing China's Potential for Large Scale, Cost Effective Deployment of Carbon Dioxide Capture and Storage [EB/OL].
http://energyenvironment.pnnl.gov/news/pdf/us_china_pnnl_flier.pdf, 2009-10-14/2016-08-07.
17 https://www.ogci.com/co2-storage-resource-catalogue/
18 Global Energy Institute, US Chamber of Commerce, CO_2 enhanced oil recovery, 2012

4.
Commercial development pathways for CCUS in China

Potential CCUS pathways

Drawing on the Ministry of Science and Technology's CCUS roadmap[19], scenarios for China from the Asian Development Bank[20], domestic energy and climate experts, as well as IEA global scenarios and international learnings on enabling policies, the authors of the white paper identified two possible pathways for CCUS deployment in China. Both pathways help to realise carbon neutrality, while supporting industrial transformation and preserving energy security – but rely on different policy models to enable CCUS deployment.

Figure 4: Potential CCUS deployment trajectories in China



Bo Peng and Xi Liang et al, China CCUS White Paper. The value and opportunities for deployment, 2021

The 'necessary' pathway relies on gradually increasing incentives to deploy CCUS.

- By 2030, China is capturing 20 Mt of carbon dioxide per year, focusing on high-density source and power.
- By 2050, CCUS accounts for a reduction in carbon dioxide emissions of 1.5 Gt per year by 2050.
- The costs of capture and transportation are reduced by 10-20% by 2030, and by 60-75% by 2060 compared with current costs.
- Greater emphasis is given to the introduction of negative emission technologies, starting with biomass and CCS (BECCS) in 2040, direct air capture with storage in 2050, and widespread use of negative emission technology, including for carbon dioxide utilization, by 2060.

The more ambitious 'ideal' pathway relies on a carbon value mechanism, as well as a range of mandates to deploy CCUS across industry.

- By 2030, China is already capturing 200 Mt of carbon dioxide per year, with deployment in power, steel, cement and petrochemical industries.
- It reaches a total carbon dioxide storage target of 2.7 Gt per year by 2050.
- The costs of capture and transportation are reduced by 10-30% by 2030, and by 70-80% by 2060 compared with current costs.
- Around 2040, China exports its CCUS expertise to other countries, and is able to store carbon dioxide from neighbouring countries by 2060.

19 科学技术部社会发展科技司和中国21世纪议程管理中心. 2019. 中国碳捕集利用与封存技术发展路线图 (2019).
20 Asian Development Bank, Roadmap for Carbon Capture and Storage Deployment and Development in the People's Republic of China, 2015, https://www.adb.org/sites/default/files/publication/175347/roadmap-ccs-prc.pdf

Leveraging CCUS hubs

In scaling up CCUS deployment, China has the potential to build out pipeline and storage infrastructure to create large-scale regional CCUS hubs in a number of major industrial regions, as shown in Figure 6.

CNPC is working on China's first CCUS hub, China NorthWest in the Junggar Basin – one of OGCI's defined KickStarter hubs, alongside Net Zero Teesside, Northern Lights and Porthos/Rotterdam. The KickStarter initiative is designed to facilitate the emergence of low carbon industrial hubs which help accelerate CCUS deployment and bring down costs through collective carbon transport and storage infrastructure.

In the first phase, CNPC plans to capture 1.5 million tonnes of carbon dioxide each year from one of its own facilities by 2025, and to construct the relevant pipelines and system for geological storage and utilization through EOR. In the second phase, which is expected to capture 3 million tonnes of carbon dioxide per year by 2030, the project will capture carbon dioxide from nearby coal-fired power plants, steel mills, cement plants and other high-emission industries, while expanding the transport system.

Figure 5: CNPC's planned CCUS hubs

PLANNED HUBS	STORAGE	LOCATION	SCALE (Mt CO_2 per year)	OPERATION STARTS	POTENTIAL INDUSTRIES
China NW	Junggar Basin	north west	3.0	2025	Chemicals, power, steel, cement
Daqing	Songliao Basin	north east	3.0	By 2030	Chemicals, power, steel, refining, cement, biomass
Changqing	Ordos Basin	north central	3.0	By 2030	Chemicals, power
Dagang	Bohai Bay Basin	north east	1.0	By 2030	Chemicals, power, steel, refining, cement, biomass

Source: Ministry of Science and Technology Roadmap, OGCI

OIL AND GAS CLIMATE INITIATIVE

WHAT IS THE OIL AND GAS CLIMATE INITIATIVE?

The OGCI is a CEO-led initiative that aims to accelerate the industry response to climate change. OGCI member companies explicitly support the Paris Agreement and its aims.
As leaders in the industry, accounting for almost 30% of global operated oil and gas production, we aim to leverage our collective strength and expand the pace and scope of our transitions to a low-carbon future, so helping to achieve net zero emissions as early as possible.

Our members collectively invest over $7B each year in low carbon solutions. OGCI Climate Investments was set up by members to catalyze low carbon ecosystems. This $1B+ fund invests in technologies and projects that accelerate decarbonization in oil and gas, industry and commercial transport.

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OUR MEMBER COMPANIES

aramco, bp, Chevron, CNPC, eni, equinor, ExxonMobil, OXY Occidental, BR PETROBRAS, REPSOL, Shell, TotalEnergies