Arthur D Little

Viewpoint

Unlocking high CO_2 gas fields – Contributing to the carbon economy

Can high CO_2 fields successfully become a new business line for exploration and production operators that embrace an energy transition strategy?

Despite the challenges of the COVID-19 pandemic, gas consumption will be a key driver for the short to medium term as many O&G companies embark on their energy transition roadmaps. In this Viewpoint, we provide an overview of the key opportunities available by unlocking high CO_2 gas fields, the challenges operators face with offshore field developments, and the upcoming innovations involved in building sustainable extraction and utilization of CO_2 into new businesses.

Extraction: The ultimate dilemma for operators

In 2020, global gas demand dropped 4% (Source: IEA) but is expected to rebound in 2021, with demand primarily driven by China and India, supported by the rest of Asia, as governments set pace for sustainable electrification targets. In Europe and North America, we anticipate a rebound in the latter part of 2021, with gradual growth in the industrial sector. With the faster-growing gas markets of the Asia-Pacific region, we will likely see acceleration in gas field development; in particular, an unlocking of high CO_2 gas fields. These contain more than US $2 billion of natural gas in the Southeast Asian offshore blocks of Thailand, Malaysia, Indonesia, and Vietnam alone.

Moreover, CO_2 as a feedstock is anticipated to become a $9 billion market by 2026, growing at 3% per year (CAGR) from 2020. Gas production is expected to grow at about 2% per year through 2040 (Source: BP), driven by the need for cleaner energy fuel to support renewable energy (growing at 6% by 2040) – as we pursue zero carbon targets for the next few decades.

Many unlocked gas fields have varying degrees of contaminants (e.g., CO_2, mercury, and sulfur). While there is much to explore with mercury and sulfur, this Viewpoint focuses on the issues and opportunities associated with high CO_2 gas fields.

Commitments to lowering greenhouse gas emissions and producing sustainably are key reasons prohibiting many operators to produce from high CO_2 gas fields. Levels of CO_2 in these unlocked fields are above 40%, with some being as high as 70% in offshore areas of Thailand and Malaysia (see figure below).

Technologies to extract such highly contaminated gas fields, which can be retrofitted into existing platforms, are not yet fully developed. Moreover, the corrosive nature of CO_2 will require blending, chemical inhibitors, and/or specially coated pipings, adding considerably to the cost of operations and economics of field development.

Case study: Technology benefits in high CO_2 gas fields in SE Asia

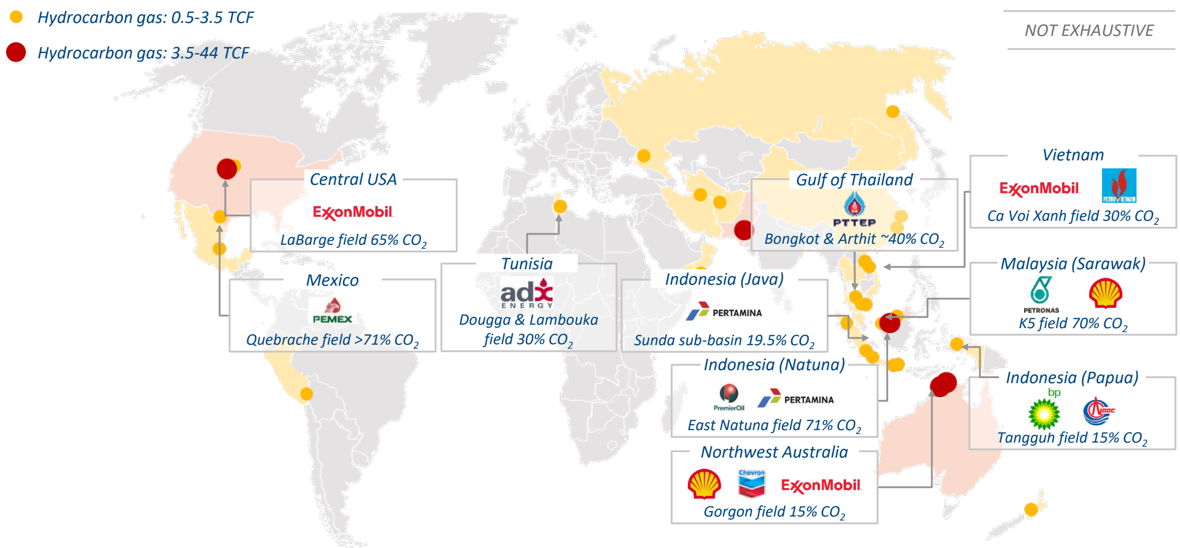
In a recent ADL study for a NOC technology division, we looked at the benefits of technology in high CO_2 gas field development projects to determine areas where technology could reduce cost and improve commercial attractiveness of high CO_2 gas field development.

We highlighted areas of interest from two perspectives:

1. **Maximize revenue.** How much can technology push the ratio of sales gas volume to recoverable gas volume?
2. **Reduce cost.** How could technology improve commercial viability of high CO_2 gas development projects?

Based on the economics of a greenfield SE Asian offshore gas field, the client required a 50% CAPEX reduction to raise the IRR to 10%. Combined with the challenge of achieving short-to-medium-term execution, ADL proposed initiatives to both maximize revenue and reduce cost through incremental technology development (17% CAPEX reduction) and novel technology development and other elements of project economics (84% CAPEX reduction).

Distribution of natural gas reserves with 15%-80% CO_2 concentration



Source: ExxonMobil Exploration Company, Offshore Technology, OnePetro, various news sources

While offshore greenfield developments and onshore assets may be much easier to design, development costs are generally high. Thus, development proves to be uneconomical for many operators in the current and foreseeable future, as gas prices remain low. Moreover, while some nations have adopted tax credits for carbon (e.g., Europe, Australia, and the US), other resource-rich nations are still grappling with this concept.

Although regulators and the industry benefit by adopting a net zero roadmap, costs will continue to hinder field developments until further advancements in technology, especially for offshore fields. Solutions to reduce costs across the carbon capture and utilization (CCU)/carbon capture and storage (CCS) value chain have yet to be plausible for offshore high CO_2 gas fields:

- **Extraction/separation of high CO_2 from gas fields.** Commercial CO_2 separation technologies are expensive and lack durability. And there is a tradeoff between building a new platform to cater to the separation unit or to retrofit to the existing platform. Both have considerable costs, challenges, as well as benefits.
- **Transportation.** Whether via pipelines or shipping enabled by cryogenic distillation technologies, the economics of CO_2 transport may not pay off, depending on distance to shore/customer. Booster compression and corrosion resistant alloys/chemicals will be required for pipeline protection or buying/leasing a customized LPG/LNG vessel when pipelines are not possible. Alternatively, a floating LNG may be considered, comprising a CO_2 separation unit.
- **Conversion or storage.** While some fields have a geological capability to store CO_2 or the option to use it for enhanced oil recovery (EOR), other fields do not; converting CO_2 will be key in creating a plausible carbon economy.

The existence of local gas resources that could supply the growing regional demands has placed many R&D teams in a race to develop the technology for CO_2 extraction and conversion to a viable byproduct. The key will be offsetting costs of extraction.

Transportation: Access to CO_2 market

CO_2 extracted from natural gas fields must then be delivered to the customer location for conversion into product. Today, there are two options to transport offshore CO_2 onshore:

1. **Pipelines** – gaseous form from supply point to customer location.
2. **Shipping** – liquified form using marine vessels.

The most common transportation mode for various gases, including CO_2, are pipelines; however, they are more suitable for short distances due to costs governed by distance. Shipping costs are less affected by distance, making ships generally better for long-distance transport. Shipped CO_2 is typically compressed using technologies such as cryogenic distillation and supersonic separators. According to an Intergovernmental Panel on Climate Change (IPCC) comparison of the cost of CO_2 transport by ship and pipeline of the same quantity, ship transport is relatively expensive for shorter distances due to fixed costs of liquefication. Thus, a combination of the two transportation options through the development of CO_2 transport clusters, hubs, and networks would create a cost-effective CO_2 transport system and enable better access to CO_2 customers. For large-scale transport infrastructure, long-range and central planning can lead to significantly reduced long-term costs.

Conversion: The CO_2 business opportunities

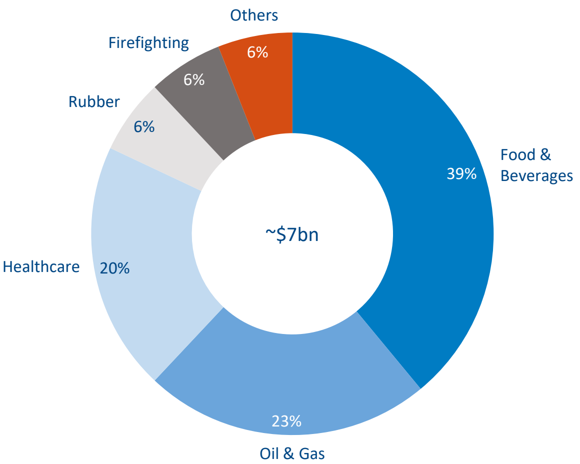
The potential demand for CO_2 is worth approximately $7 billion with annual growth of 3%, leading to a $9 billion market by 2026. While CO_2 demand for fertilizer is mostly constant, CO_2 demand for EOR is increasing rapidly, with an expected growth of 20% CAGR by 2024. However, CO_2-EOR methods may not be applied to all fields, precluding options for considering the removal and use of CO_2.

One exception is the Permian fields of Occidental Petroleum (Oxy). Taking steps toward net zero carbon emissions by 2050, Oxy has committed to increase its use of CO_2-EOR as a major source of long-term revenue. This approach is in contrast with many other major O&G companies that have been in pursuit of renewable energy. Oxy currently stores about 20 million tonnes of CO_2 per year in geologic formations through its various EOR operations. In the short term, Oxy's net zero plan will be based on having the world's largest direct-air-capture facility in the Permian Basin (expected to capture 1 million tonnes of CO_2 per year, operationalizing in 2022). Although this facility is currently operating onshore, advances in technology may take offshore developments to the next level, further reducing carbon footprints.

In terms of storage, not all developments have the luxury of depleted reservoirs in which to store CO_2, as do those in the North Sea, nor the ability to support the costs involved in CCS. In our research, we have seen a 16% reduction in CCS activity over the last eight years, with a clear pivot toward CCU.

Use cases for CO_2 conversion or utilization are increasingly being developed (e.g., fuel production and building materials). Other growth areas include increasing existing novel CCU applications in food and beverages and healthcare. In total, approximately 84.2 million tonnes of CO_2 were consumed by industry applications in 2019, with food and beverage applications accumulating the share of 32.8 million tonnes of CO_2 (see figure below).

Global CO_2 market by application



Source: Grand View Research, Arthur D. Little analysis

To capture this market, many O&G operators are developing research into converting their CO_2 waste into viable products, including methanol production, syngas production, formic acid production, concrete production, aggregates, carbon nanotubes, biofuels, food additives, and various polymers. Though still in various stages of technology maturity, carbon conversion will continue to gain interest as the regulatory push for a greener economy, internal use of carbon credits, implementation of an emissions trading system, and a wider community sentiment turns toward carbon use circularity.

What will success look like?

Market research has shown that the carbon-based products industry has the potential to utilize about 15% of annual global CO_2 emissions by 2030. Four key challenges remain:

1. **Regulatory stimulus.** CCU growth has been slow due to absence of action/low intervention by government on climate change, public skepticism, increasing costs, and advances in other options.
2. **Storage over utilization.** Players often form strategic partnerships predominantly focused on CCS rather than CCU because of storage's technical readiness.
3. **Underdeveloped "premiums."** For market-based carbon materials use cases (e.g., carbon cement, steel, and chemicals), premiums are somewhat underdeveloped, impacting the cost of conversion; larger-sized contracts could help establish this market.
4. **Technology readiness.** Although CCU is technically possible in a lab, commercial feasibility is far from proven. It is expected to be many years before companies come close to both retrofitting offshore platforms to extract >40% CO_2 (carbon capture) and converting it into viable and valued products (carbon utilization).

Firms must work closely with governments and regulators to proliferate CCU/CCS impetus through appropriate regulations, incentives, and carbon price rationalization schemes. Given the current uncertainty, a fully supportive ecosystem and/or a strong vertically integrated O&G company might be considered a success. This may provide a closer solution to the economic hurdles that continue to plague both the development of high CO_2 gas fields and the benefits possible in supplying much-needed gas for the rapidly growing and emerging Asia market while sustainably creating high-value products.

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Case study: Technology selection to unlocking high CO_2 gas fields

For a client with a total remaining recoverable gas reserves of >1 trillion cubic feet, currently unlocked due to high CO_2 contamination, ADL evaluated best available technologies and future options to retrofit existing platforms. We reviewed each technology for CO_2 removal based on the following six features, tailored to the client's current field development constraints:

1. **Inlet concentration** – indicate technology capability to process high CO_2 concentration.
2. **Outlet concentration** – assess technology capability to remove the desired substance, indicated by substance concentration at the outlet.
3. **Compactness** – evaluate applicability of the technology to be operated on offshore region.
4. **Cost-effectiveness** – measure financial benefit/ advantage gained using a technology.
5. **Capacity** – measure volume of a technology/system to process/contain CO_2.
6. **Commercially proven** – measure commercial reliability of a technology.

Together with a decision tree (including actions capabilities, partnerships, IP transfer, and timeline), the best available technology was chosen, and a roadmap was developed. To enhance the business case, we provided a roadmap to CCU options where a few strategic opportunities were developed to capture carbon-based products and build the ecosystem across the CCU value chain.

Contacts

Austria
virag.bela@adlittle.com

Belgium
baes.kurt@adlittle.com

China
song.ninghua@adlittle.com

Czech Republic
vylupek.lukas@adlittle.com

France
klossa.amaury@adlittle.com

Germany
kruse.michael@adlittle.com

India
maitra.barnik@adlittle.com

Italy
caldani.saverio@adlittle.com

Japan
harada.yusuke@adlittle.com

Korea
lee.kevin@adlittle.com

Latin America
guzman.rodolfo@adlittle.com

Middle East
merhaba.adnan@adlittle.com

The Netherlands
eikelenboom.martijn@adlittle.com

Norway
thurmann-moe.lars@adlittle.com

Poland
baranowski.piotr@adlittle.com

Russian Federation
lubuzh.pavel@adlittle.com

Singapore
ito.yuma@adlittle.com

Spain
gonzalez.juan@adlittle.com

Sweden
thurmann-moe.lars@adlittle.com

Switzerland
kruse.michael@adlittle.com

Turkey
baban.coskun@adlittle.com

UK
white.nick@adlittle.com

USA
goodnight.chuck@adlittle.com

Authors: Trung Ghi and Prakarsa Mulyo

Acknowledgements: Ben Thuriaux, Philip Webster, Felix Wu

Arthur D. Little

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