S&P Global
Commodity Insights

On the path of scalability: CCUS in the accelerated energy transition

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Disclaimer

S&P Global addresses a range of questions regarding CCUS

Where is CCUS activity happening?
What fields are involved?

Who are the participants in this project?
What does the project comprise of?

What infrastructure is in place?
Where are the large industrial emitters?

What are the subsurface properties for a given depleted reservoir?
What common geological elements are required for a CCUS project?

**What depleted fields could be potential storage candidates?
Which basins have known saline aquifers?**

**What dry structures are nearby?
What is the seal & how extensive is it?**

**How many gas processing plants are there in the region?
What CO_2 volumes are captured?**

How many EOR candidate fields fall within 50km of these plants and what's the EOR potential?

Which solutions from SPG Commodity Insights address these key question and help to de-risk?

What are the trends for technology and innovation in CCUS?

How is the regulatory, policy and fiscal environment evolving in key countries?

What are the current and forecasted costs for a varied portfolio of projects by type and size?

How are the CCUS strategies differing between peer groups?

We have been working with E&P firms for over 60 years, supplying insights, datasets, and analytics tools to geoscientists, strategists, market analysts, and engineers to assess, benchmark, manage performance and de-risk investment.

Products highlights for ANP's CCUS Data Management seminar:

1

Upstream Transformation / CCUS Insight Subscription Service

Explore detailed cost, technology, supply chain and subsurface assessments crucial to project planning and execution

- **CCUS Project Database**: Monitor CCUS project status, including technology, cost and service company data. 820+ projects globally catalogued to date.
- **CCUS Policy Tracker**: Monitor CCUS regulations developments,
- **CCUS Cost Indices and Cost Estimator**: Current and forecasted costs for a varied portfolio of projects by project type and size
- **Research**: Detailed insights on CCUS developments

2

EDM for Energy

Efficient data management is a pivotal driver in accelerating carbon capture. Organizing and effectively managing data is critical, not just in streamlining processes, but also in saving substantial funds otherwise wasted. These savings could be redirected toward vital CCUS initiatives, propelling efforts in combating carbon emissions.

Upstream Transformation | Subscription Service overview

Integrated Insights

Company

Compare company low carbon strategies and actions, assess their ability to execute, identify emerging corporate best practices

- **Company Low-Carbon Action Tracker**: Monitor events that deliver upstream companies' energy transition strategies and benchmark activity
- **Company Low-Carbon Strategy Profiles**: Analysis of company strategies and potential challenges
- **Research**: Detailed insights on actions

Technology & Innovation

Analyze company technology development strategies and activities to meet the evolving needs of an industry in transition

- **Technology Trends**: Document and anticipate shifts in industry technology sourcing strategies, focus areas, and adoption rates
- **Technology Tracker**: Monitor technology development and deployment activities (e.g., internal R&D, partnerships, corporate VC) in the low carbon, digitalization and core upstream domains
- **Research**: Proprietary frameworks and data sets, company profiles, and technology deployment case studies

Carbon Capture, Utilization & Storage

Explore detailed cost, technology, supply chain and subsurface assessments crucial to project planning and execution

- **CCUS Project Database**: Monitor CCUS project status, including technology, cost and service company data
- **CCUS Policy Tracker**: Monitor CCUS regulations
- **CCUS Cost Indices**: Current and forecasted costs for a varied portfolio of projects by project type and size
- **Research**: Detailed insights on CCUS developments

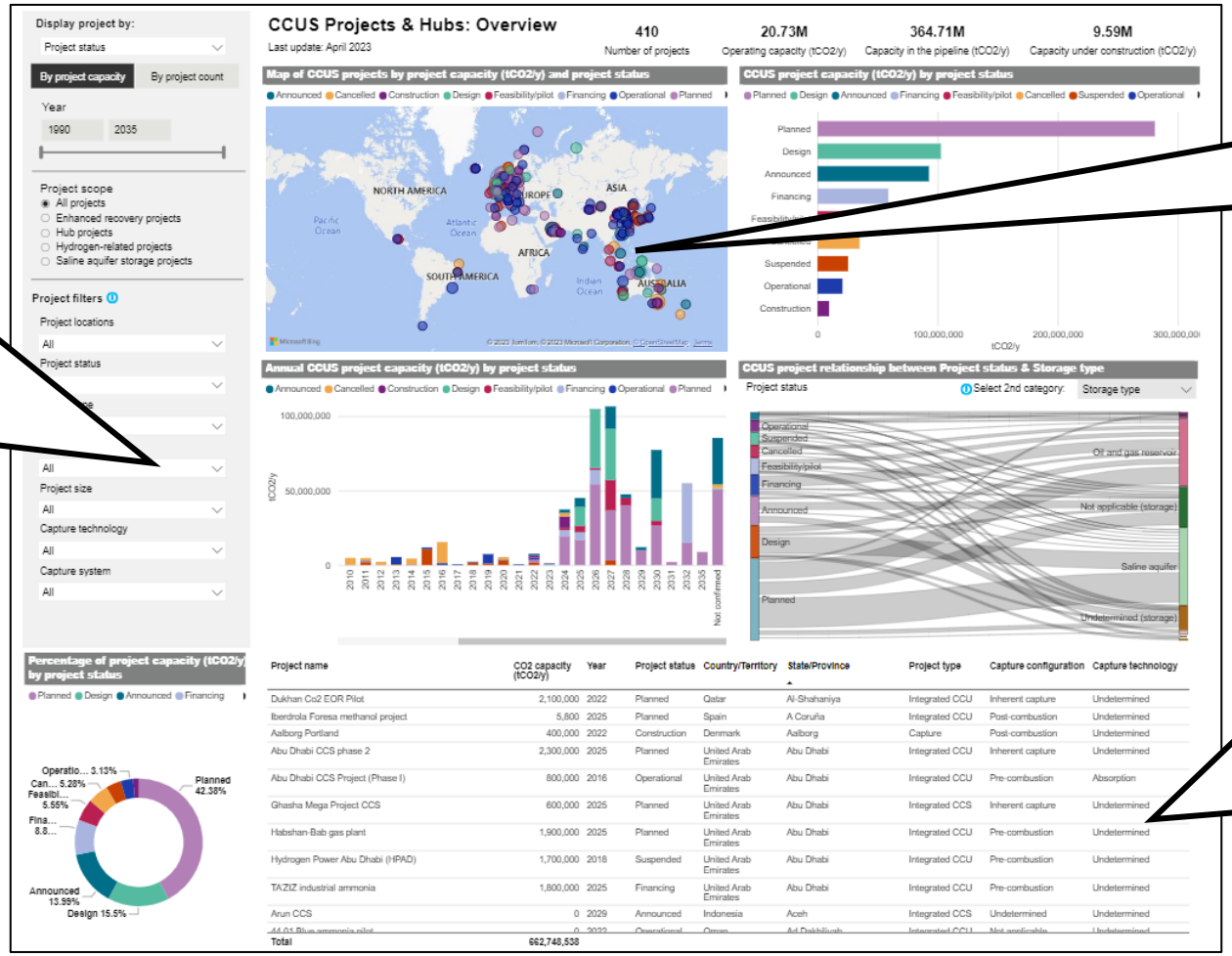
Government

Monitor regulatory changes and incentives that will impact project economics, compliance, technology deployment, market access, and policymaking in other jurisdictions

- **Government Low-Carbon Action Tracker**: Monitor emerging government mandates related to upstream transformation on a country and state/provincial level, and benchmark policy durability and stringency
- **Research**: Detailed insights on future policy directions & developments

A foundational component of the CCUS offering is its dynamic CCUS project database & dashboard now available on our web portal Connect

CCUS projects & hubs: Overview web page



Data sourced via:

- Public sources (press releases, research papers, conferences, gov't publications)
- SPGI proprietary databases (EDIN-subsurface, midstream facility/pipeline), ICONA
- Verified versus competitor databases (e.g., Global CCS Institute)
- 207 data points (SPGI) x 17 (IEA)

Comprehensive industry database

- ~820 projects counted in our database vs 573 (IEA) vs Global CCS Institute

Extensive data fields

- Project name, location, status, …
- Capture capacity, technology, …
- Contractor and supplier information
- Transport distance and type (e.g., vessel)
- Reported costs

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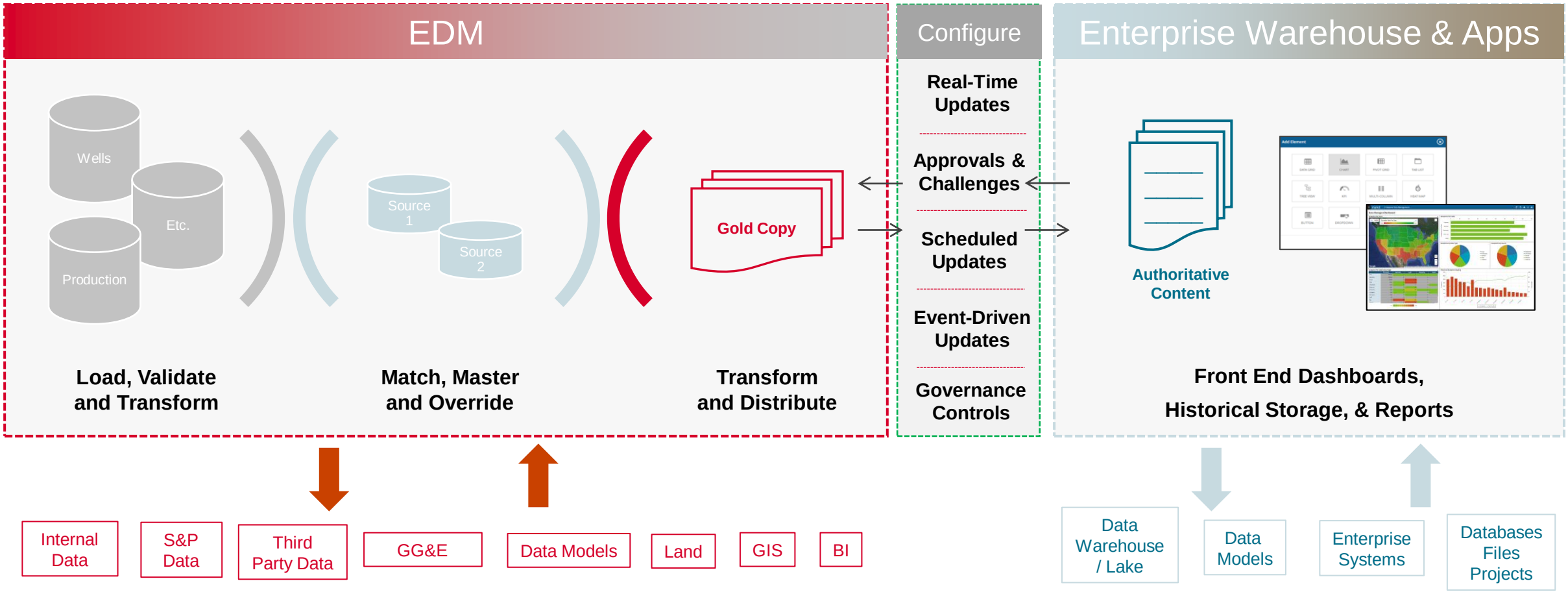
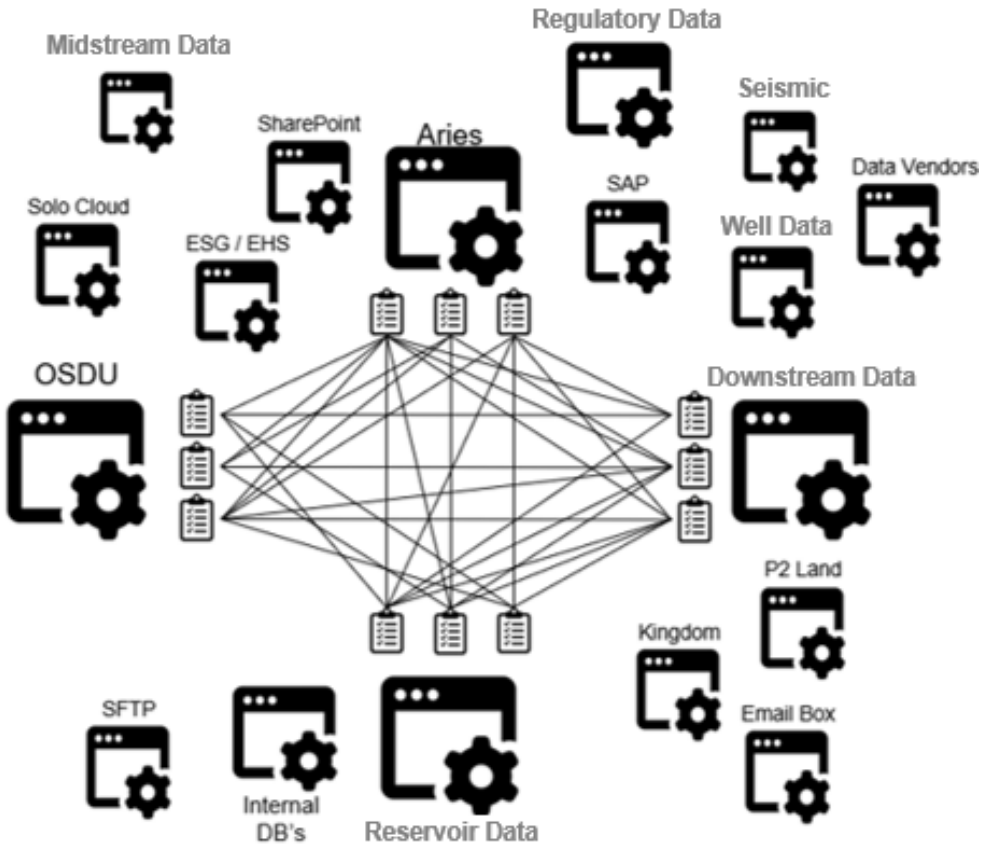
EDM for Energy | How it Works

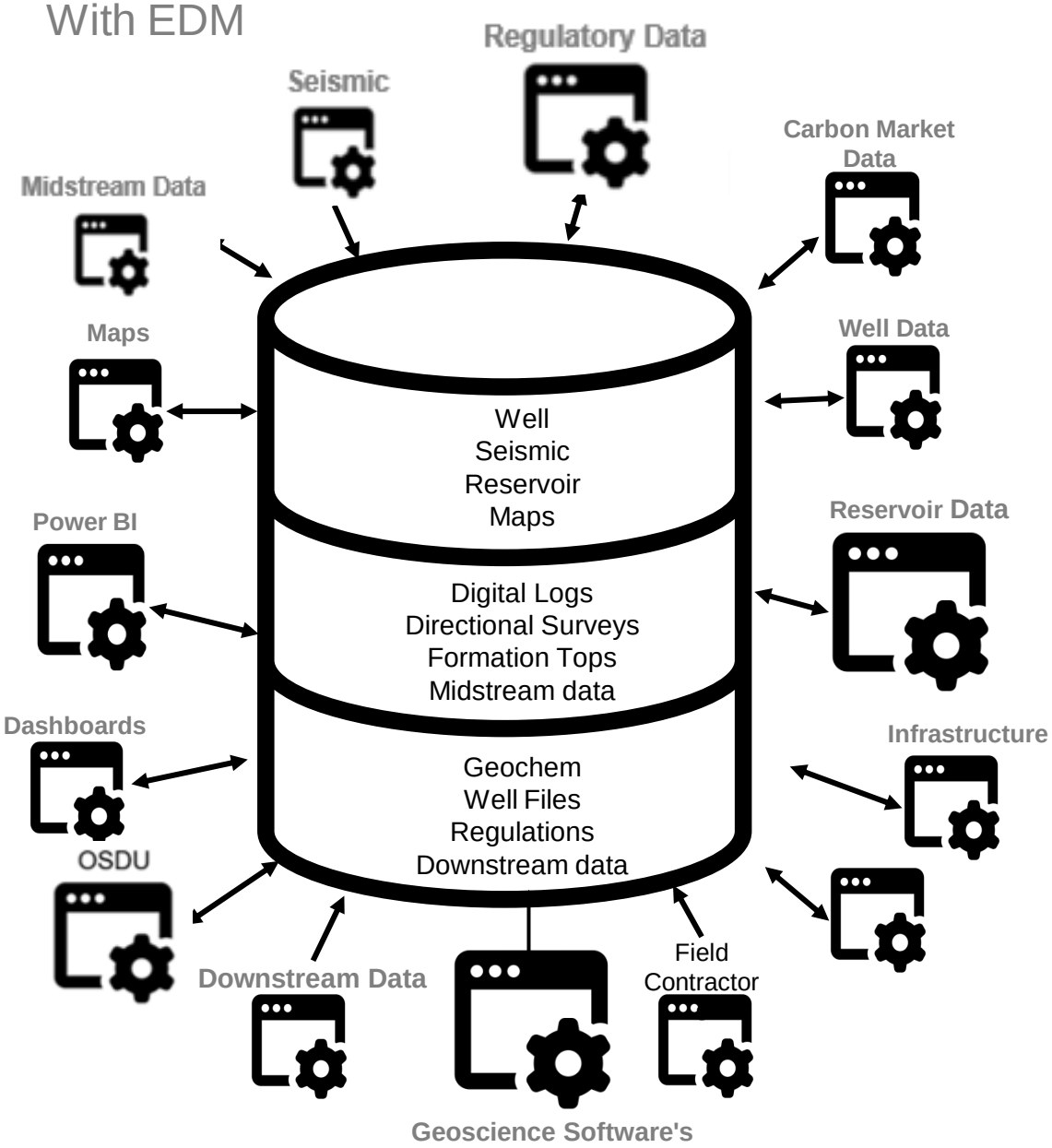
Robust data integration, management, and workflows to support business operations and reporting



Before EDM



With EDM



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Agenda

1. **CCUS as a transition strategy**: The crucial role of CCUS in lowering carbon intensity has increasingly been recognized by the governments and the oil and gas industry

1. **CCUS project trends**: Global new CCUS projects are taking off in the coming decade; can they all be achieved?

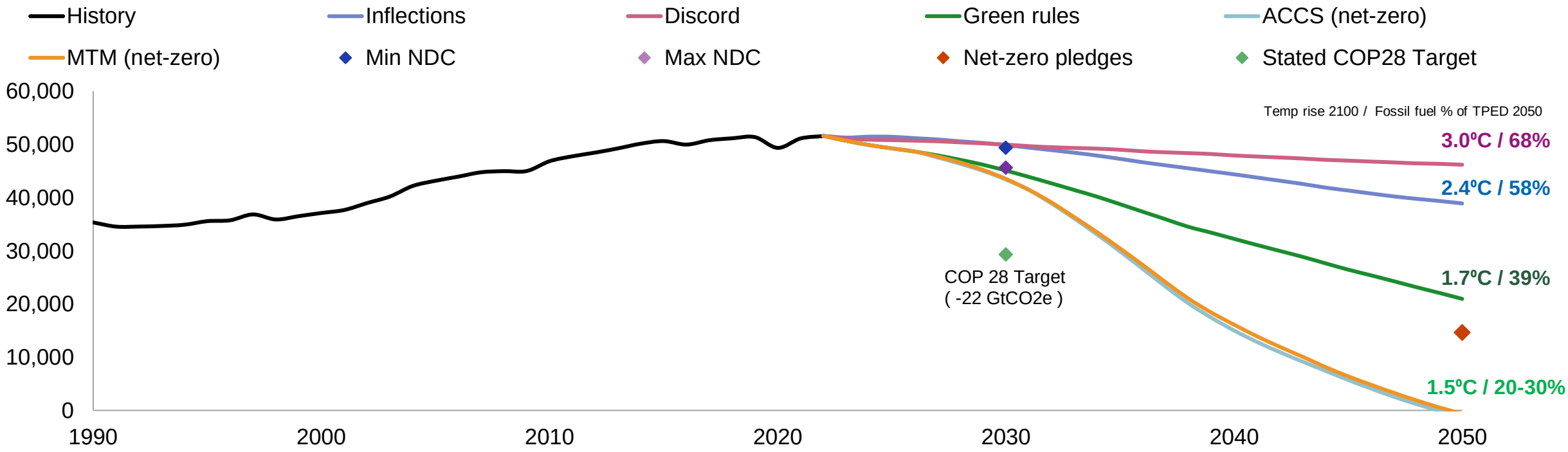
2. **Hub developments**: Hub capacity dominates the capture capacity addition; can the new business model enable sustainable growth in future?

3. **Lessons from past cancellations**: Between 2013–22, 70% of planned capacity was cancelled or suspended. Will history repeat itself?

4. **CCUS in Brazil**: Opportunities for large CCUS projects and hubs being planned in Latam, testing the industries and regulators to eventually switch from pilots to deployments.

To achieve Net Zero the world must reinvent its energy systems and redress climate change at a scale never attempted in history. COP28 will seek a target for 2030 that will challenge global ambitions.

Total GHG emissions in S&P Global Commodity Insights global scenarios, national NDC targets, and net-zero pledges ($MtCO_2e$)



Data compiled October 2, 2023.
Source: S&P Global Commodity Insights

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In S&P Global's long-term net-zero scenarios, at least 1.2 $MMtCO_2$ of CCS capacity are required globally by 2050, when combined with other decarbonization measures

S&P Global net-zero scenarios description

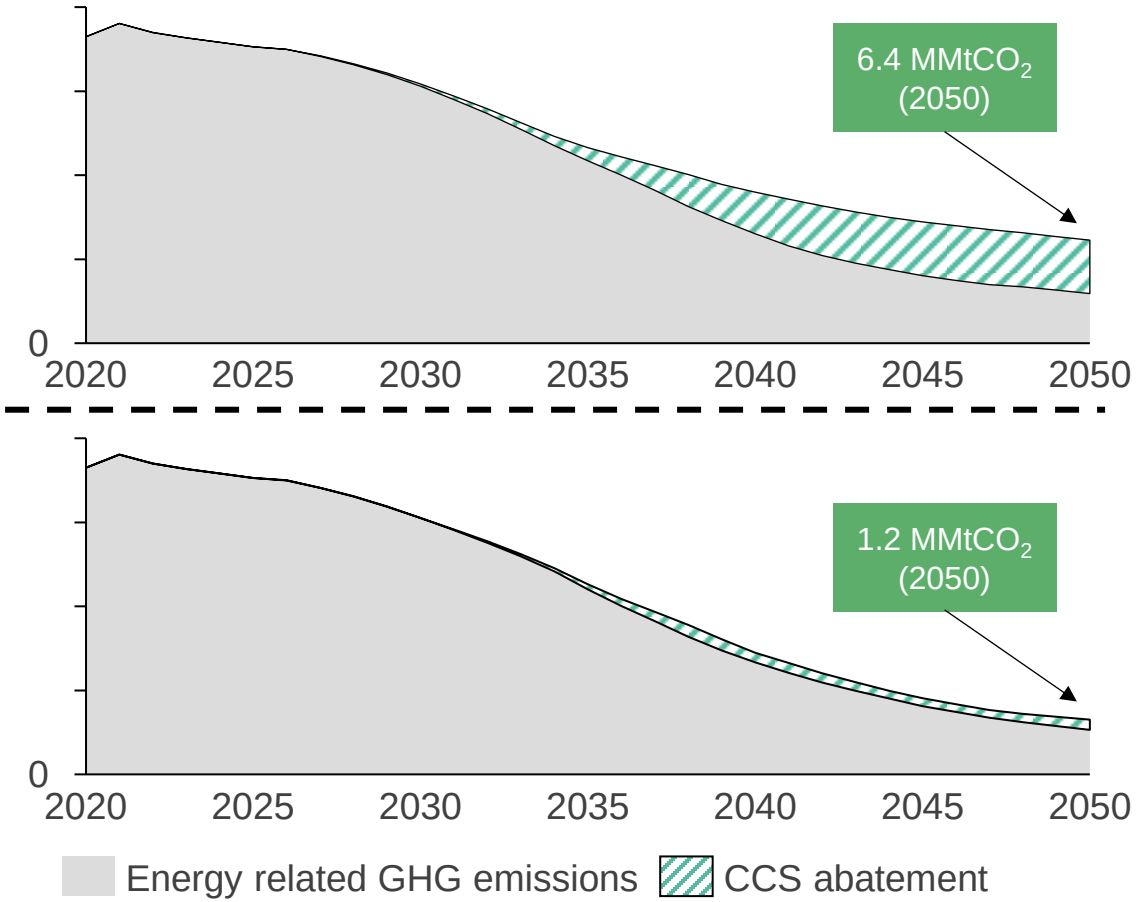
The net-zero cases are constructed backward, starting with a predetermined end point of global net-zero emissions by 2050.

Accelerated CCS (ACCS) → Widespread use of CCS to offset emissions from energy and hard-to-abate industrial sectors such as steel and cement. By 2050, 6.4 billion metric tons of energy-related carbon dioxide are sequestered, equal to 18% of 2021 energy related carbon dioxide (CO_2) emissions.

Multitech Mitigation (MTM) → Supply diversification, electrification, and renewables dominate as key drivers, as well as a moral imperative to move away from hydrocarbons. Although there is some use of carbon capture, it is seen as an undesirable and expensive enabler of hydrocarbon use that should not be incentivized.

Global energy related GHG emissions net zero scenarios

$MMtCO_2$

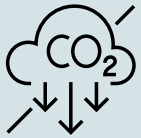


Source: S&P Global

Carbon Capture, Utilization and Sequestration (“CCUS”) is back in focus – but why?

Relevance of CCS worldwide

Essential tool for decarbonizing hard-to-abate industries



- Certain industries such as **cement and steel**, require significant power and heat, not met with current renewables technology
- **CCUS** is the **only** current available solution to make deep emission cuts from **hard-to-abate** industries.

Can tackle emissions from existing energy infrastructure

- The use of CCS allows countries to balance transition with energy security and economic growth with fossil fuels
- CCUS can be retrofitted to existing high-emission industrial facilities.

Effective path to negative-emissions production

- CCUS is an enabler of least-cost low-carbon hydrogen production
- Applying CCS to bioenergy (BECCS) can lead to a carbon negative source of energy

CCS underpins many of the current net-zero pathways

- S&P Global’s ACCS[1] scenario considers 6.4 $MMtCO_2e$ of CCS capacity added to 2050.
- In IEA’s NZE[2] scenario, CCS projects could reduce global CO2 emissions by almost a fifth and reduce the cost of tackling the climate crisis by 70%.

1. Accelerated CCS deployment scenario
2. Net Zero Emissions by 2050 Scenario

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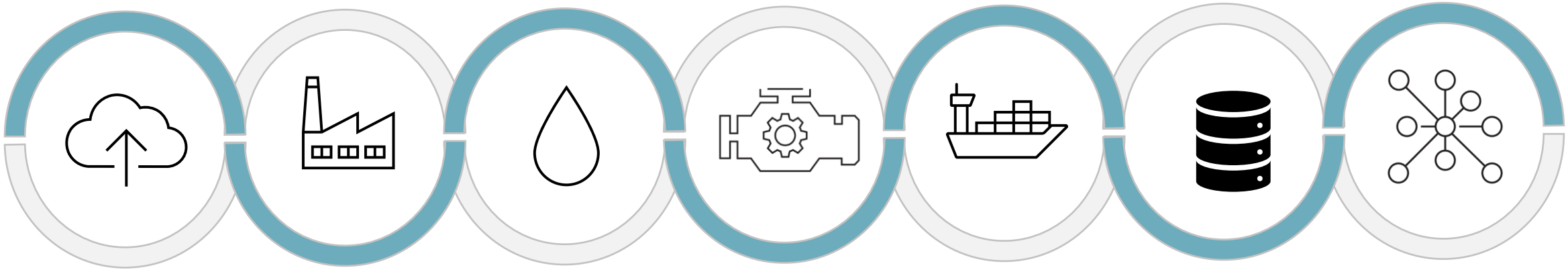
Introduction



Emission	Capture	Liquefication	Compression	Transportation	Storage	Utilization
The burning of hydrocarbon during the industrial production process is the beginning of the CCUS value chain. Most concentrated in energy intensive industries, but also present in most economic activity	The capture of locally produced CO_2, driven by national and international policy has increased the market size and demand of the dedicated facilities via retrofitting or constructing new capture machinery in existing production plants	Liquefication of CO_2 provides several advantages in reducing overall cost of the CCUS value chain, as this process allows the liquified gas to be stored and transported in a much more compact method in comparison to its gas form	Often overlooked yet highly energy intensive part of the CCUS value chain, compression plays a crucial role in all parts of CCUS, from capturing to storage, allowing plants to compress gas into desired pressure for usage	The intermediary process between the capturing and final use of the CO_2 whether it is storage or utilization. The pipeline and/or ship transportation's importance and impact on the value chain has grown with increased demand of CO_2 storage hubs	With increasing plans to further equip plants with CO_2 capture, storage capacity will have to increase in order to close the gap between anticipated demand and the development pace of storage facilities	Offering potential revenue stream, with further development of market required to further incentive CO_2 capture. Around 230 $MMtCO_2$ are used yearly within fertilizer and urea industry, as well as development in CO_2 based synthetic fuels and chemicals.

Data compiled December 2023
CCUS = carbon capture, utilization and storage; $MMtCO_2$ = million metric tons of CO_2.
Source: S&P Global Commodity Insights.

Global trends on CCUS activity

- Prepared for ANP – not for distribution

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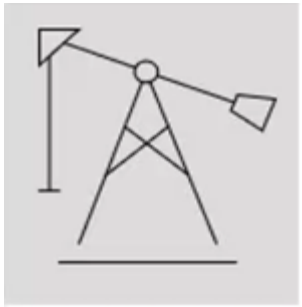
CCUS Industry - recap

How traditional Oil and Gas operations compare to CCUS

Upstream — Finding & extracting oil & gas

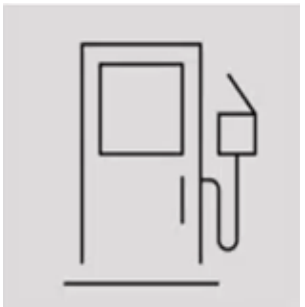


Finding pore space & injecting CO2

Midstream — Transporting & storing oil & gas

Transporting compressed CO2

Downstream — Refining, marketing, & selling oil & gas



Converting infrastructure to capture CO2 and monetizing credits

Carbon Capture → Transportation → Utilization / Storage

CCUS – same data attributes, skillset, analytics, equipment etc (with enhancements and retrofitting)

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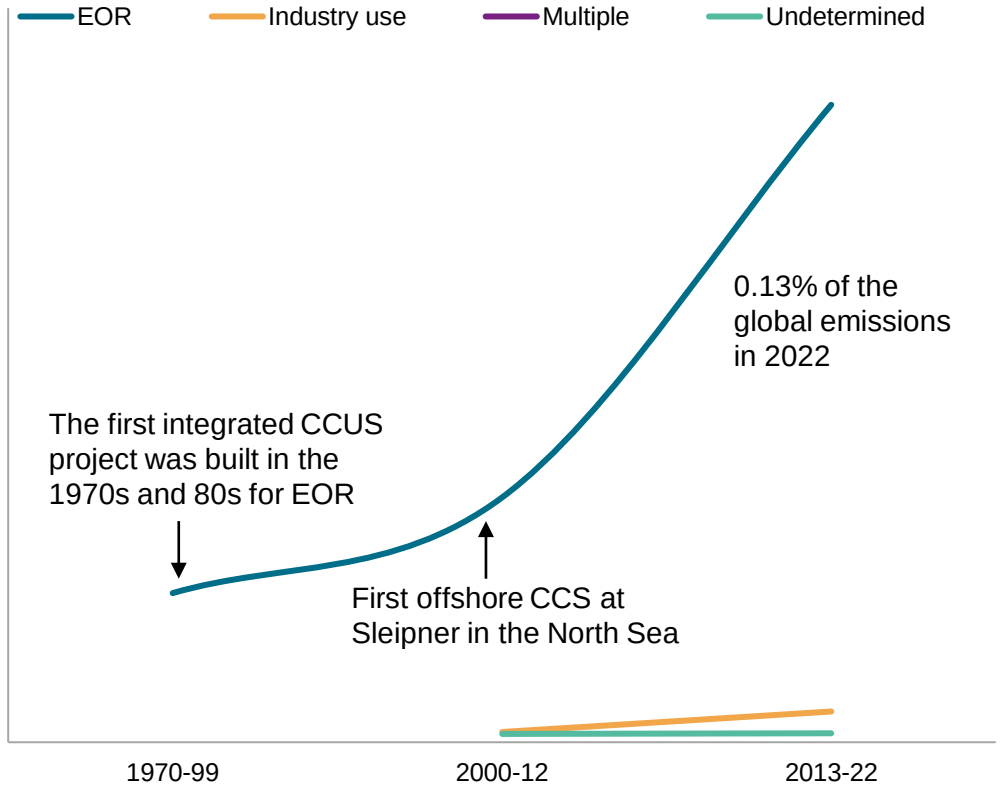
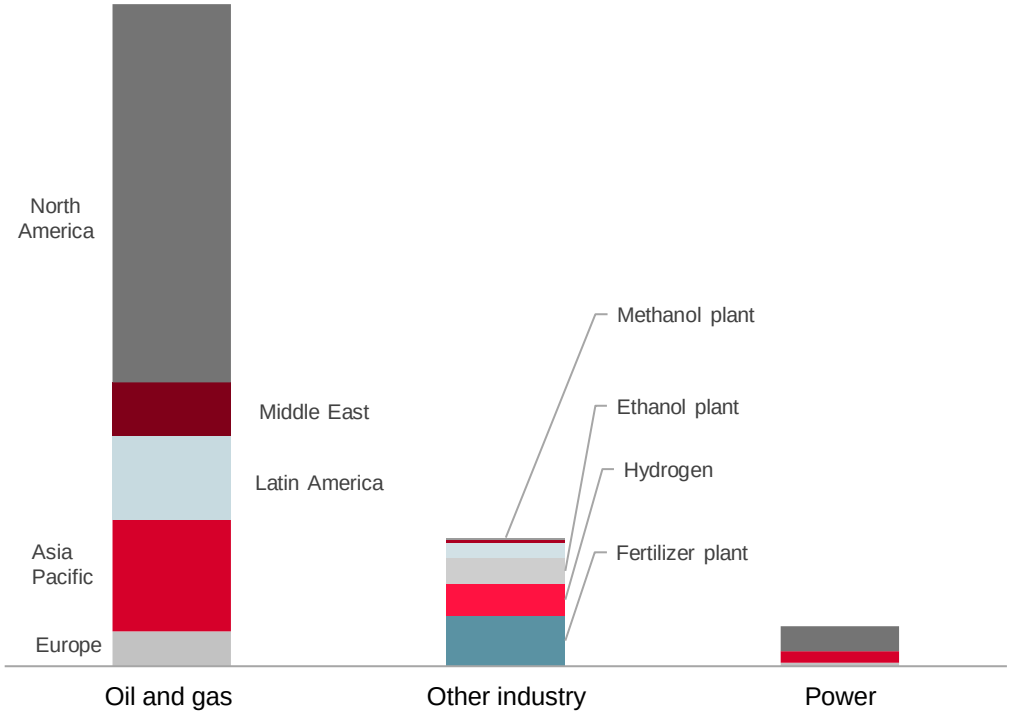
Oil and gas companies are the primary drivers of today's operated CCS facilities, using captured CO2 for EOR

Primary drivers for CO_2 removal in the past
Installed CO_2 removal and sequestration capacity (MMtpa)



Deployed capture and integrated capacity worldwide by sector
MMt CO2 per year capacity

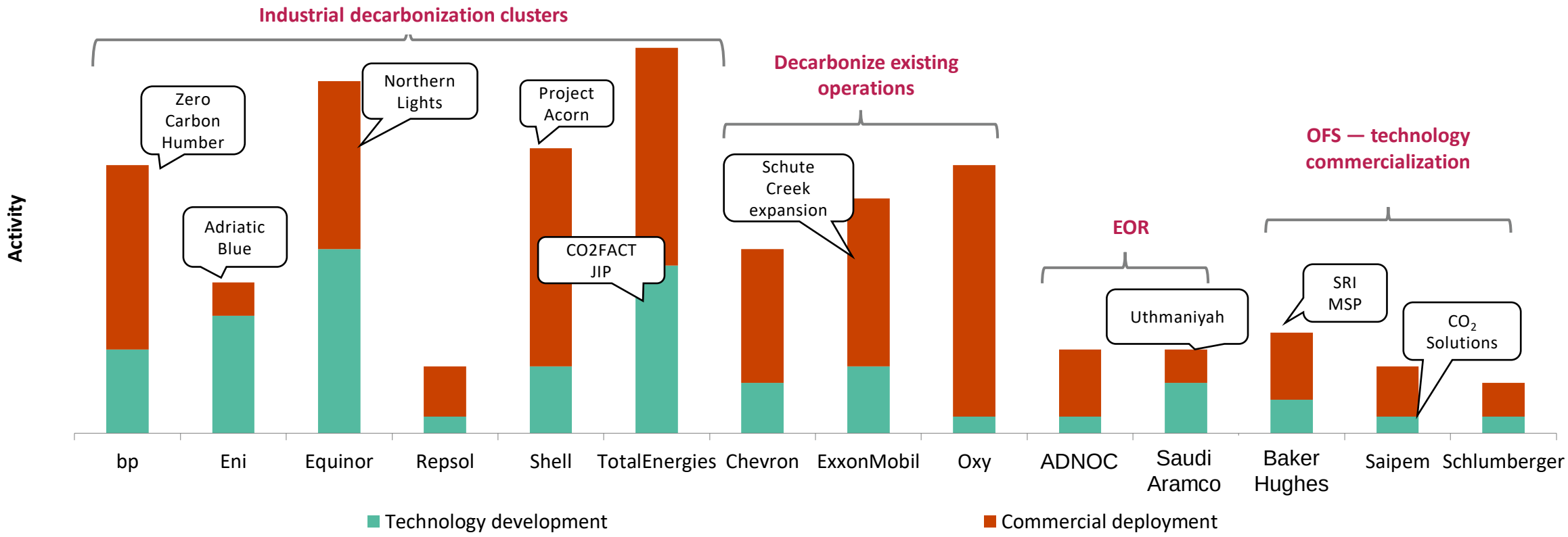


Coupled with improved oil and gas revenue, the O&G industry has the expertise to handle complex and large volumes of carbon capture and storage, which could justify significant investments.

Data compiled July 2023
Source: S&P Global Commodity Insights, Upstream Transformation Service.

CCUS fits in the transition strategy of different company groups

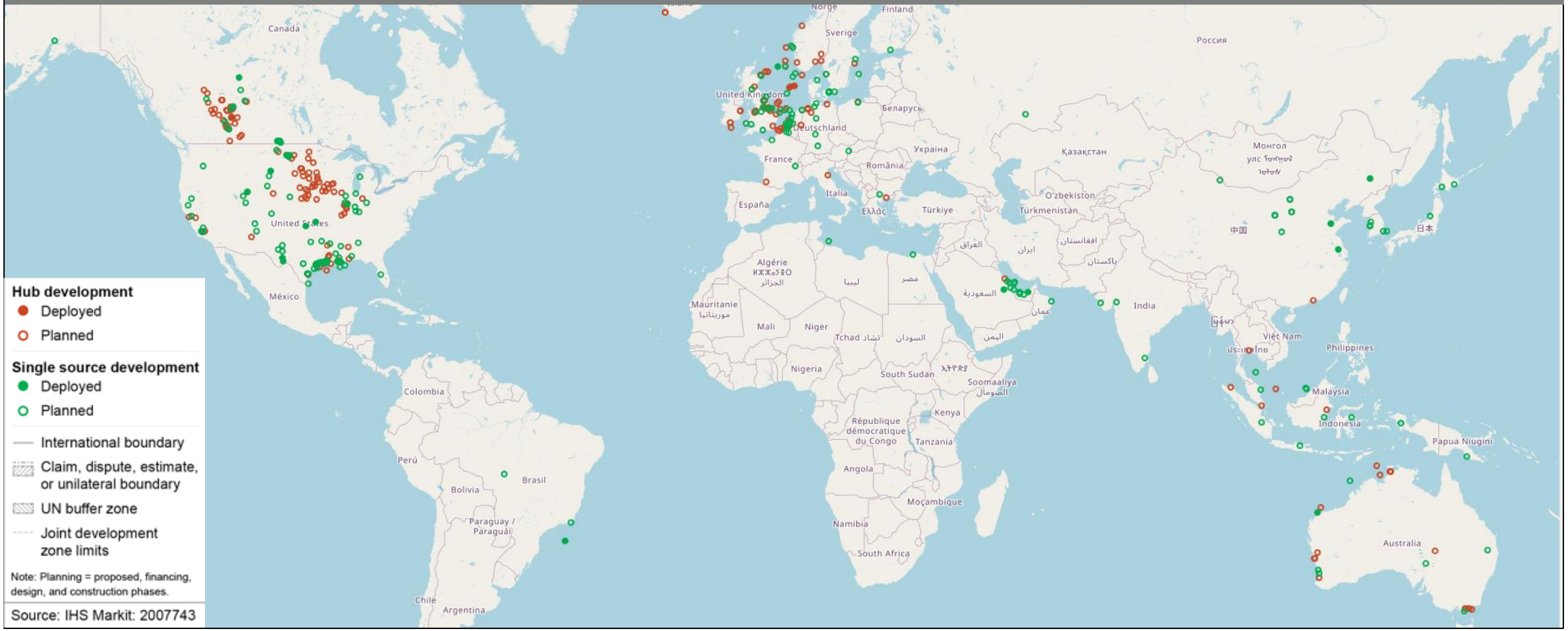
CCUS activity



Notes: Technology development activity includes basic research, feasibility studies, technology development and demonstration. Deployment activity includes first-of-a-kind deployments, large scale (>0.4 MMt CO2 captured/year) developments and hub developments. Excludes OGCI activity
Source: S&P Global Commodity Insights - Upstream Technology and Innovation Service

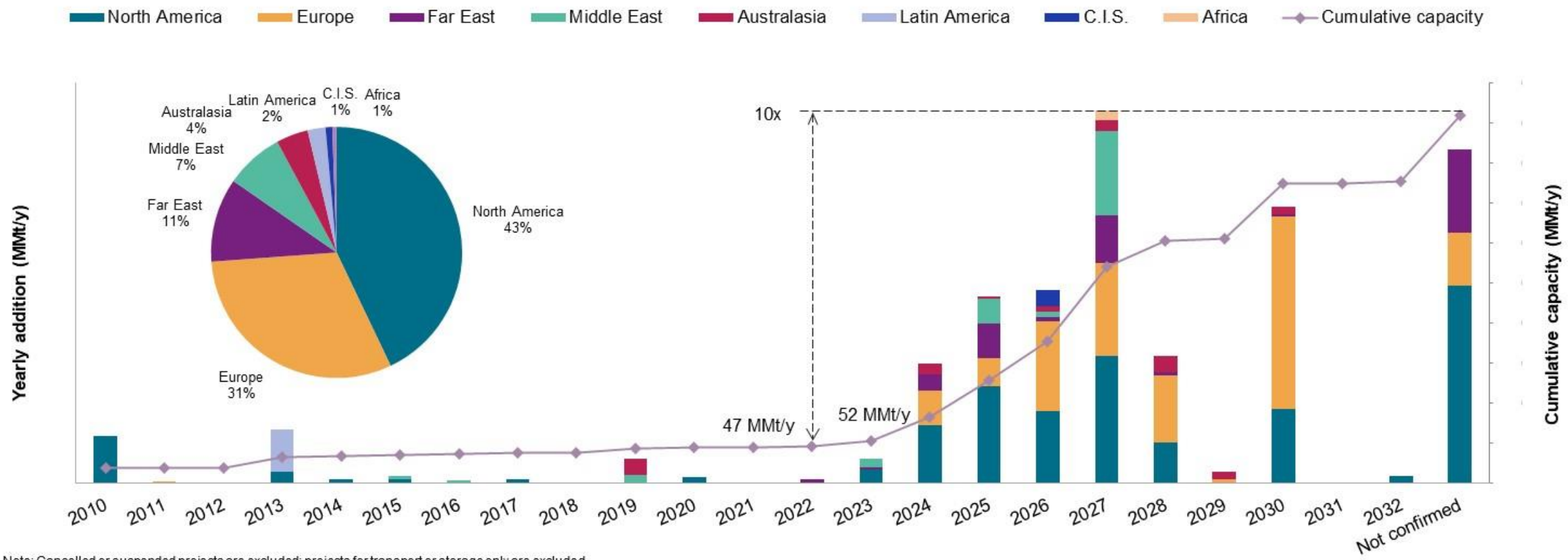
While only a handful of large, integrated CCUS projects are currently operational, CCUS deployment activity is expected to accelerate over the coming decade

Large (>0.4 MMtCO$_2$ captured per year) integrated CCUS projects in operation and planning stages



The capture capacity is projected to increase almost tenfold compared to the 2022 level in the coming decade, led by North America and Europe

CO2 capture capacity annual addition for large projects (>0.4 MMt/y) by project region



Note: Cancelled or suspended projects are excluded; projects for transport or storage only are excluded

Data compiled Jul. 19, 2023.

Source: S&P Global Commodity Insights, CCUS Projects and Hubs database of Upstream Transformation Service

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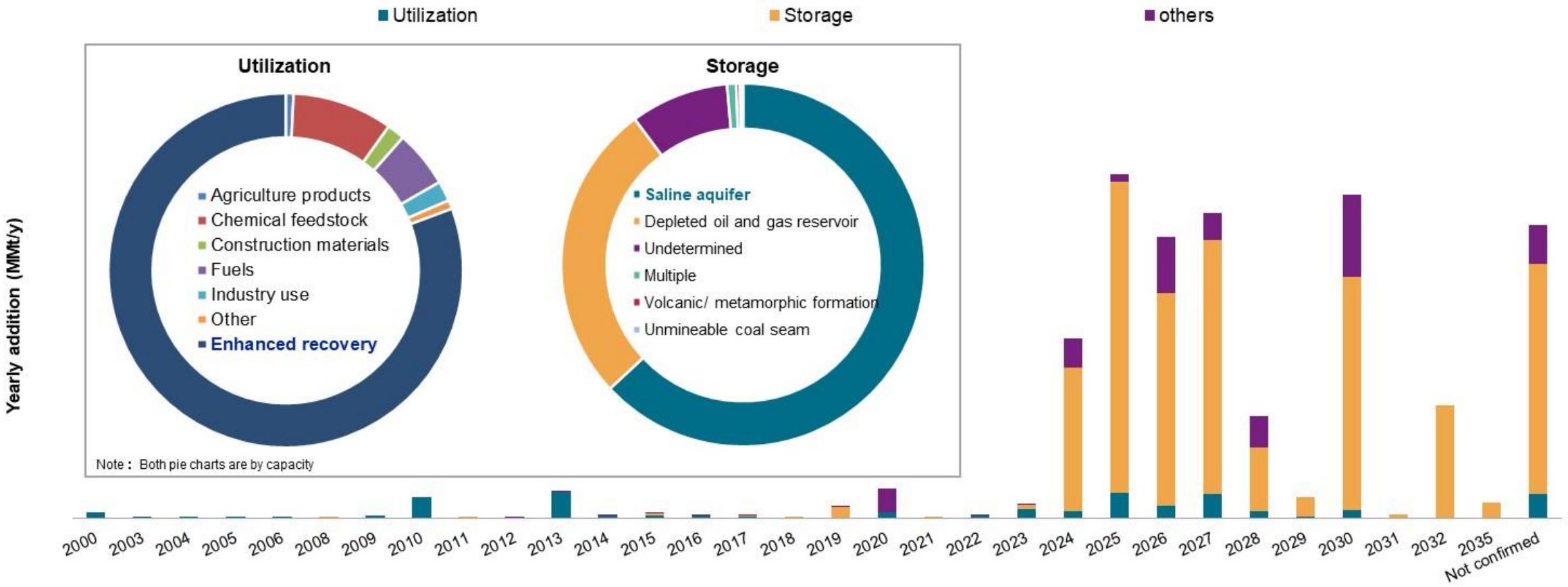
Storage dominates the use of carbon in new projects; enhanced recovery is the main utilization type, while saline aquifer is the main storage type

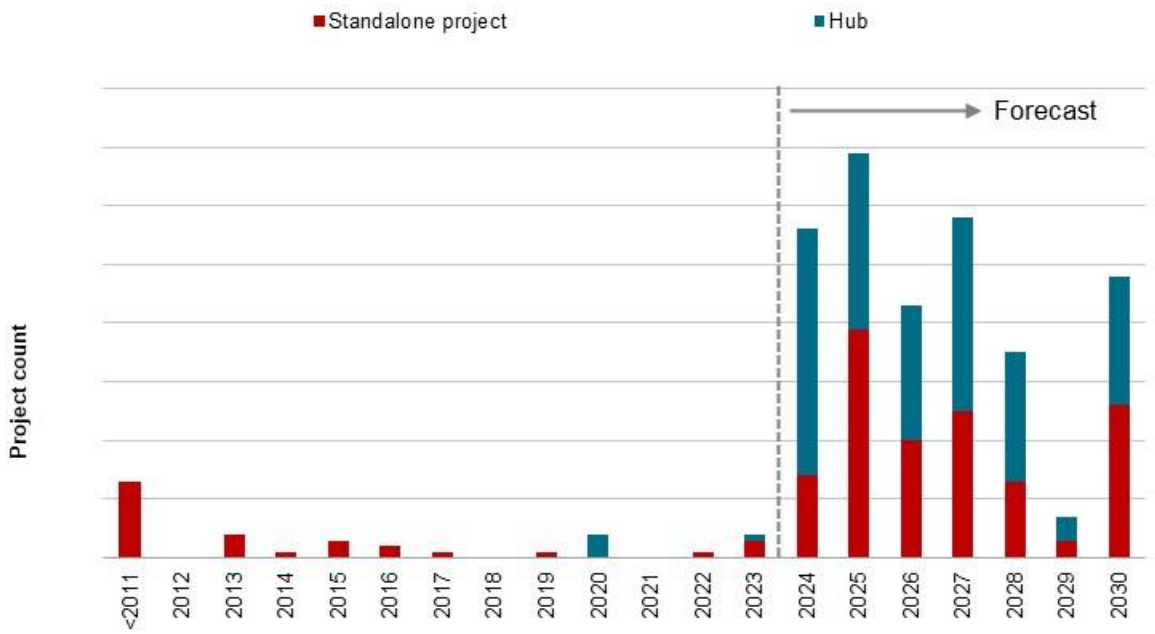
CO2 capture capacity annual addition by carbon use



Note: Cancelled or suspended projects are excluded; projects for transport or storage only are excluded. Other projects are the ones that have not been confirmed for carbon use.
Data compiled Jul. 20, 2023.
Source: S&P Global Commodity Insights, CCUS Projects and Hubs database of Upstream Transformation Service

Hubs will play a prominent role in scaling CCUS in the near-term, providing a potential pathway to transition CCUS from a cost to a business opportunity

Large scale CCUS and hub project deployment

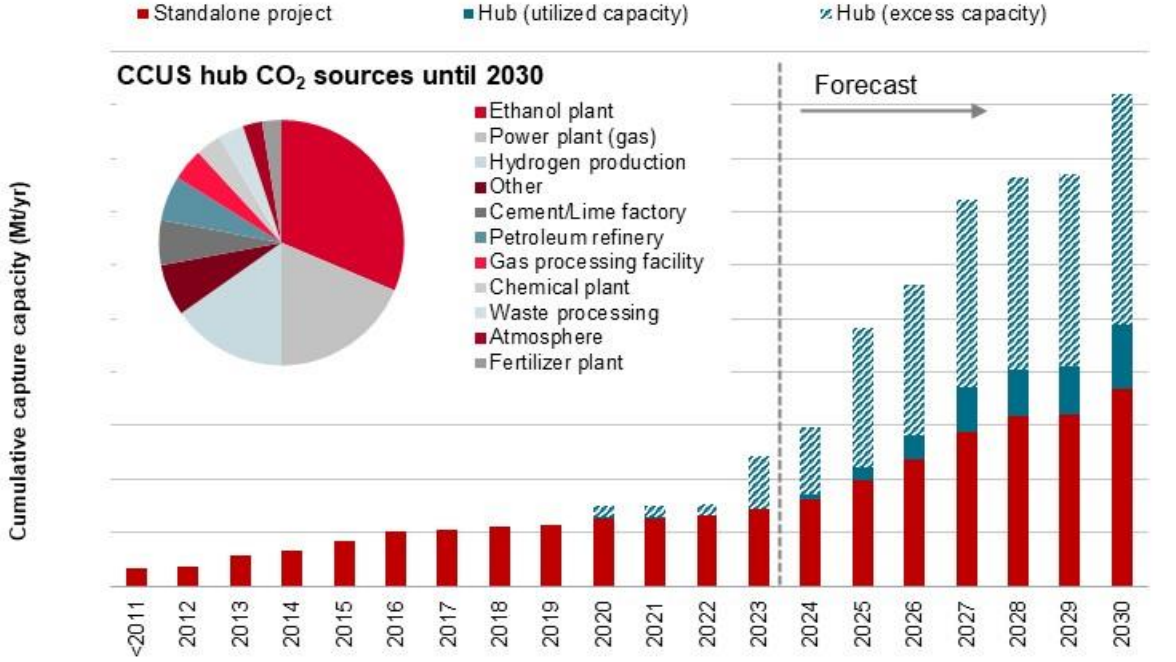


Note: Large scale deployments ≥ 0.4 MMt CO2/year. Capture projects associated with Summit Carbon Solutions Hub, with an revised onstream date of 2026, consolidated into one project. Projects = announced, planned, operating, financing, design and construction phases. CCUS value chain project activity includes capture, storage, transport, transportation and storage, and fully integrated projects.

Data compiled Dec. 13, 2023.

Source: S&P Global Commodity Insights, CCUS Projects and Hubs database of Upstream Transformation Service.

Large scale CCUS and hub project cumulative capacity (Mt/yr)

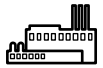


Note: Cancelled or suspended projects are excluded. Hub value chain project activity includes capture, storage, transport, transportation and Data compile Dec. 13, 2023.

Source: S&P Global Commodity Insights, CCUS Projects and Hubs database of Upstream Transformation Service.

While regulation is a critical factor, corporate capabilities and infrastructure assets play also a key role in determining the success of **CCS Hubs**

Framework for hub development conditions

	 **CO2 Emitters**	 **Transport**	 **Storage**

Policy and Regulation	• **Stable regulatory environment** that incentivizes CO_2 capture:
	  • **Carrots**: Tax credits, CfD, direct payments, infra grants and loans
	  • **Sticks:** ETS caps, carbon tax
		▪ Regulatory structures for rates and land access
		▪ Pipeline transport safety and quality standards
		▪ Cross-jurisdiction transport custody and liability standards
			Policies to promote reasonable balance of **storage security** with risk of leakage:
			▪ Risk-based monitoring requirements
			▪ Timely permitting process
			▪ Post-closure **liability transfer**

Assets / Infrastructure	▪ Existence of **anchor emitter(s)** ▪ Nearby industrial sources that can be aggregated to reach scale ▪ Proprietary capture technology	▪ Transportation right-of-ways ▪ **Existing infrastructure** capacity to transport CO2 ▪ Market access to decarbonized products (e.g. hydrogen pipelines)	▪ Large and contiguous **pore space holdings** ▪ Subsurface data (e.g., seismic, logs) ▪ Repurposing of existing oil and gas, equipment, wells and reservoirs
Company Capabilities	▪ Gas treatment process operations ▪ Major projects execution ▪ Process technology development ▪ Competitive landscape	▪ **Business development acumen** ▪ Operational excellence ▪ Complex network optimization ▪ Regulatory and stakeholder engagement	▪ Subsurface characterization and uncertainty quantification ▪ Required authorizations and land access ▪ CO2 offtake agreements for EOR or sequestration

Source: S&P Global - Upstream Transformation Service Note: **Bold** = critical component

Lessons Learned from past cancellations

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Social and regulatory barriers are creating delays and uncertainties in investments

Perceived risks

- Major local or regional accidents create negative impact on public perception.
- Carbon leakage from pipeline and storage (2020 Mississippi rupture of pipeline)
- Environmental impact on land and ground water
- Carbon disposal and the integrity of subsurface structure.
- Perception that carbon injection could lead to more seismic activity (Japan)

Some of the arguments that are imposing project delays

- Public knowledge about CCS are insufficient— often with misconceptions
- CCS perceived as temporary solution that only support use of fossil fuels.
- Lack of long-term regulation for CCS implementation
- Lack of clear safety controls and measures
- Special provisions and liabilities arrangements to parties that will be affected

- ✓ **Not in my background reaction** – Residents are worried about the idea of using relatively untested technology to pump carbon dioxide under their streets with the misconception idea that it's similar to a balloon inflation into the ground
- ✓ **The Heartland Greenway case:** On October 20, 2023, Navigator CO2 Ventures cancelled it's CO2 pipeline that would have spanned five US states– with heavy resistance from local communities due to its perceived lack of consideration of local land rights and environmental concerns, which led to pressure on state-level officials.
- ✓ **The Louisiana case**: the core of the public debate is the proposed blue hydrogen project with 95% of the associated emissions sequestered under Lake Maurepas— creating delays.
- ✓ **Summit Carbon Solutions:** A similar multistate project by Summit Carbon has also encountered state-level permit challenges in North Dakota, South Dakota and Iowa, and has delayed its original startup timeline from 2024 to 2026.
- ✓ **Wolf Carbon Solutions** :Another large CO2 pipeline project by Wolf Carbon has encountered less resistance as it spans just two states, but opponents– emboldened by Navigator's Heartland cancelled project –have indicated they would soon ramp up the pressure.
- ✓ **Prolonged delays** and/or cancellations of CO2 pipeline projects could also begin to have a financial impact, potentially preventing project developers from enjoying the full tax incentives from IRA, many of which are time-bound (ending in 2033).

Data compiled November 2023.
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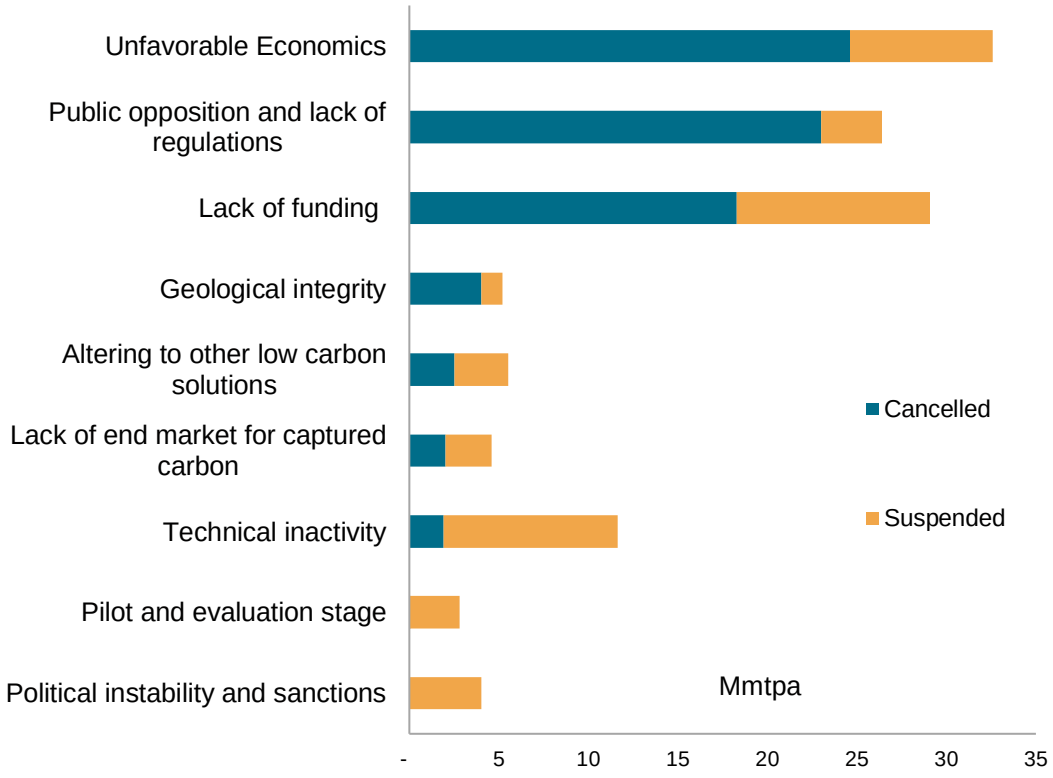
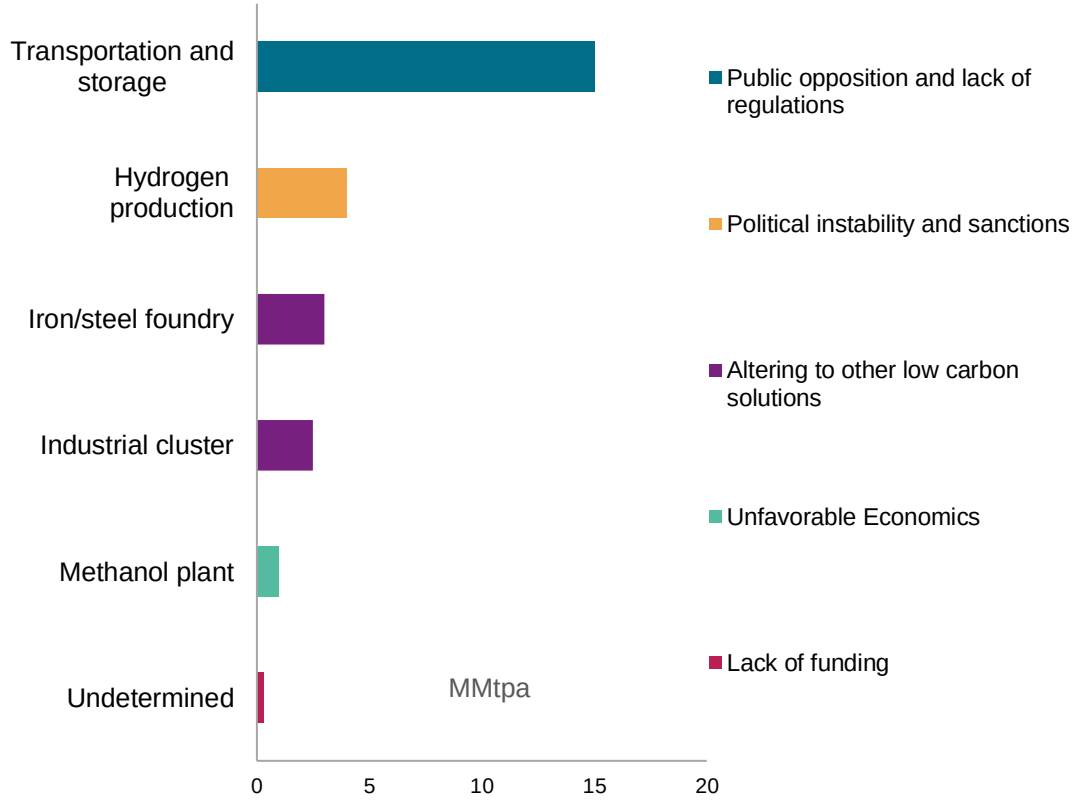
Barriers | Challenges and sited reasons for cancellation or suspension since 2013

52% of reported cases faced financial problems or delays, leading to cost escalation and unfavourable project economics during the past decade.

Project economics and regulations are the most reported reasons for cancellation or suspension since 2013



Projects aimed to be developed by 2030 facing hurdles at various fronts



Data compiled November 2023.
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Brazil CCS Hub Opportunities

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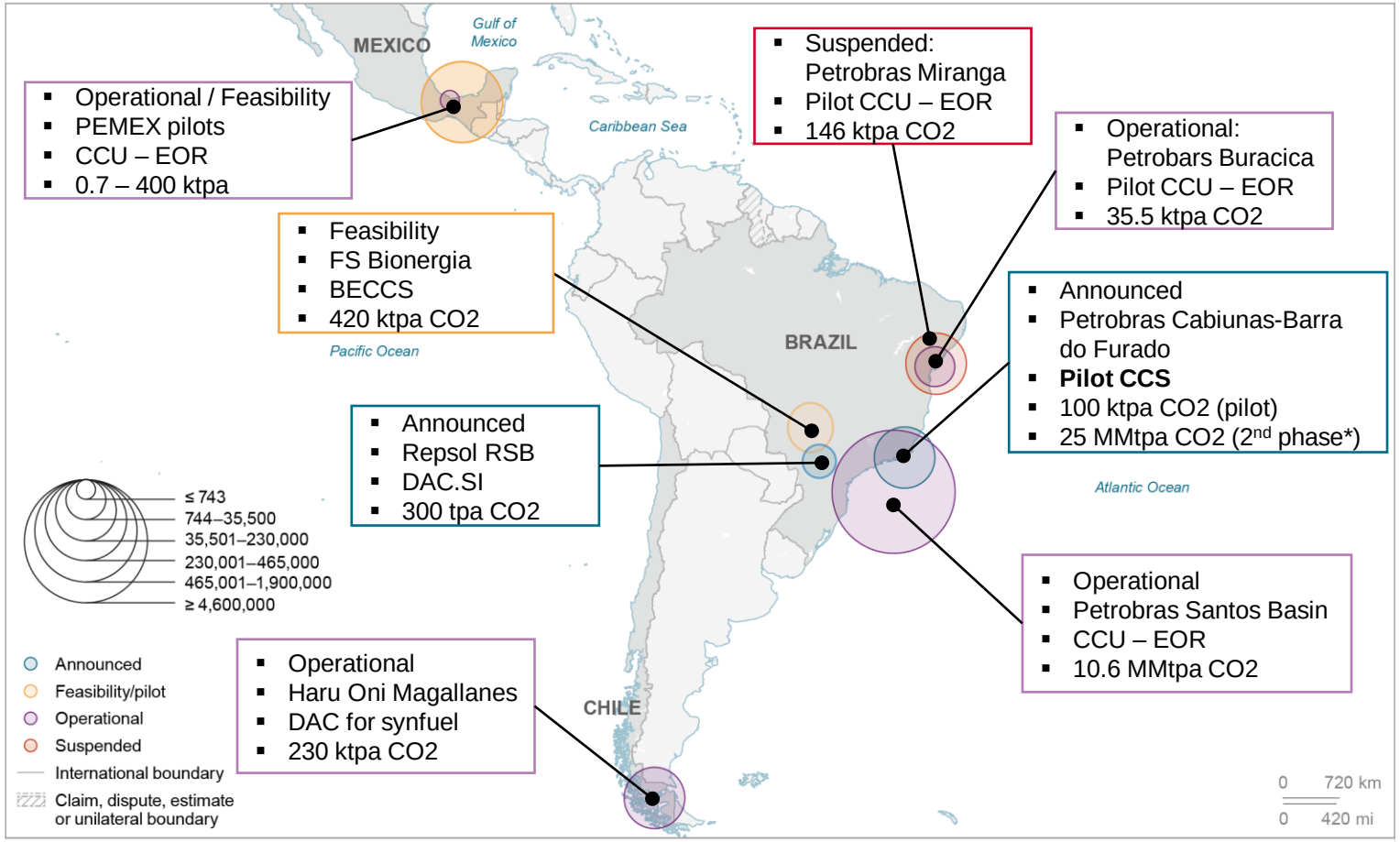
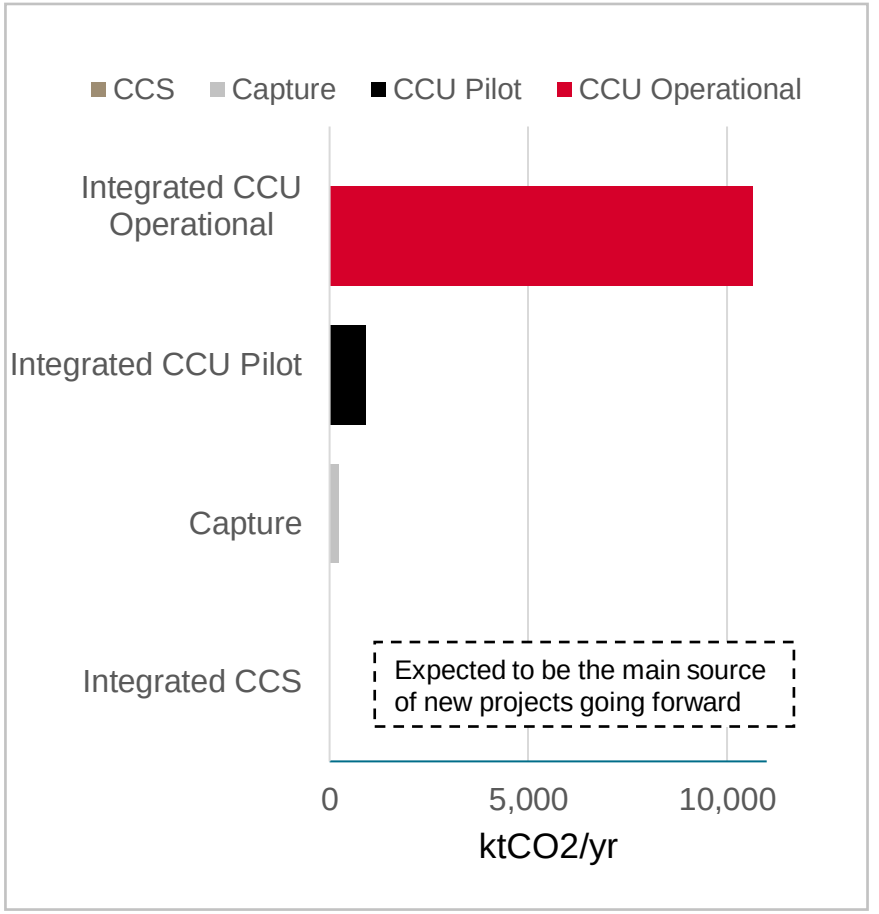
CCUS existing projects in Latam are mostly CO2-EOR related

Latam CCUS projects



Data compiled May 29, 2023.
Source: S&P Global Commodity Insights upstream E&P content (EDIN): 2009698.

Latam installed capacity by type (ktCO2/yr)



*Among its options for transporting CO2, Petrobras is looking at **repurposing existing** pipelines, given the proximity of the Campos and Santos basins to hubs of hard-to-abate industries such as the Cubatao complex, Sao Paulo state, but **new pipelines** are also under study

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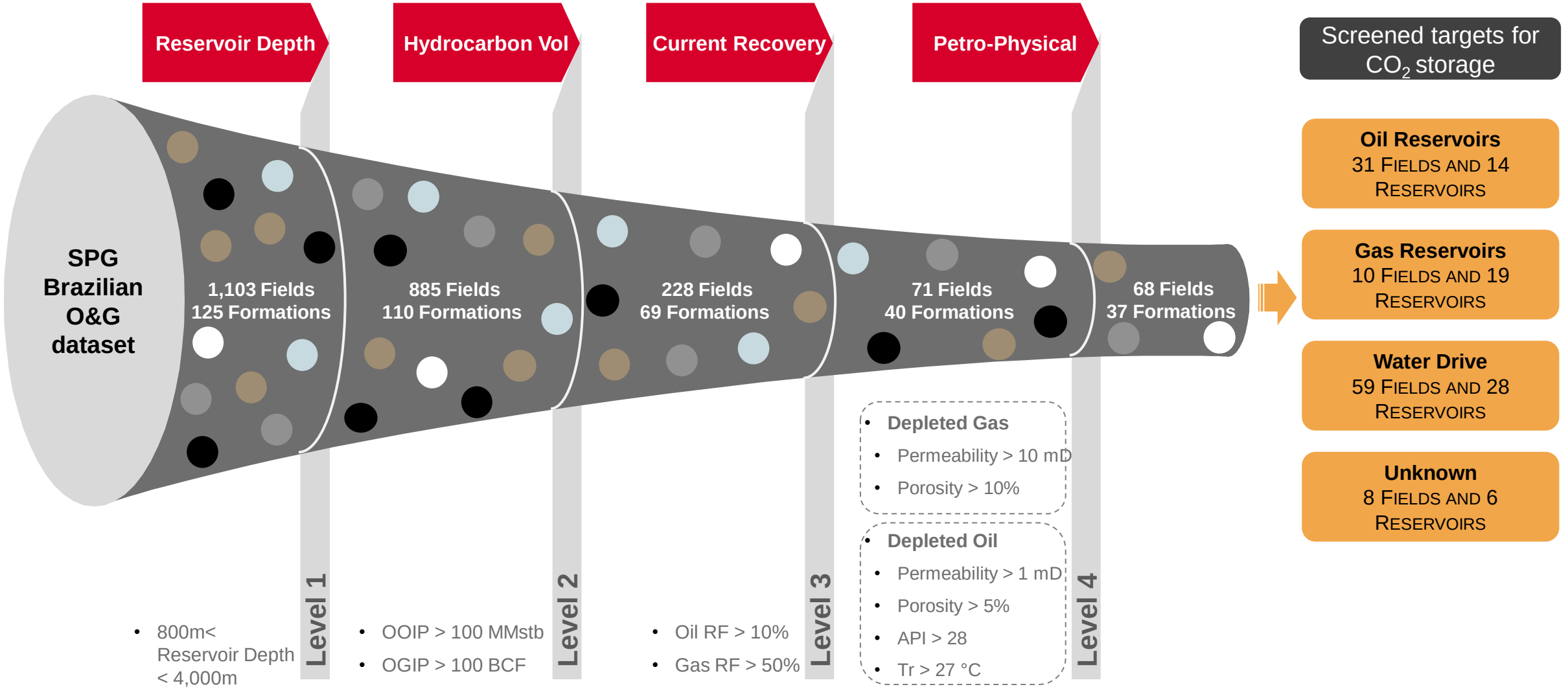
Note: CTSatc, Diamante et others R&D partnership project being developed for CO2 capture for synthetic zeolite application on feritilizers. 3 year Pilot plant with 2 tCO2/day

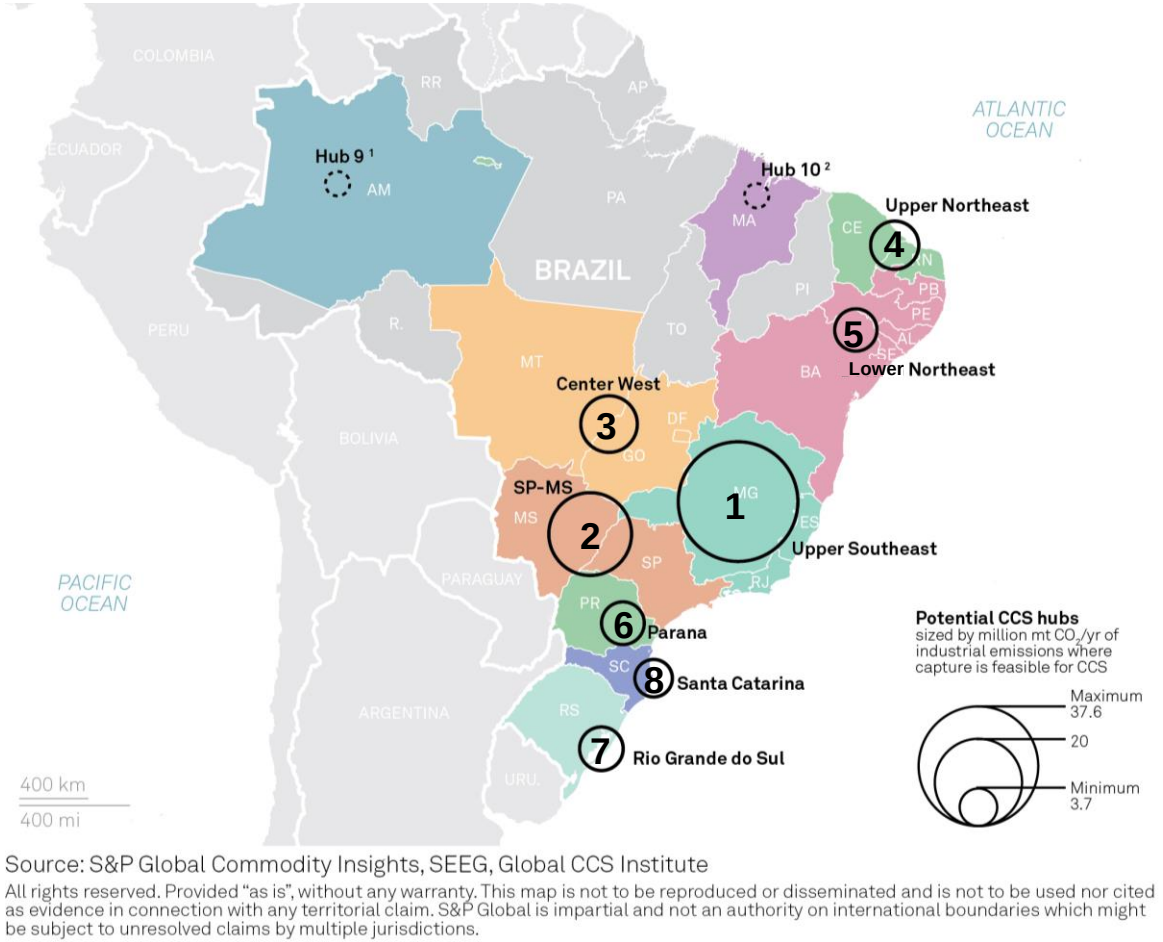
Starting with ~1,100 O&G fields from **S&P Global's EDIN E&P database,** our screening process narrowed down the results to 68 fields for CO_2 storage potential



Note: The selected fields are at different stages of production maturity and are chosen due to the availability of data
Source: S&P Global

Industrial facilities in the Southeast where there is a strong presence of iron/steel and ethanol plants would be best placed to store CO_2 emissions in depleted Campos basin reservoirs

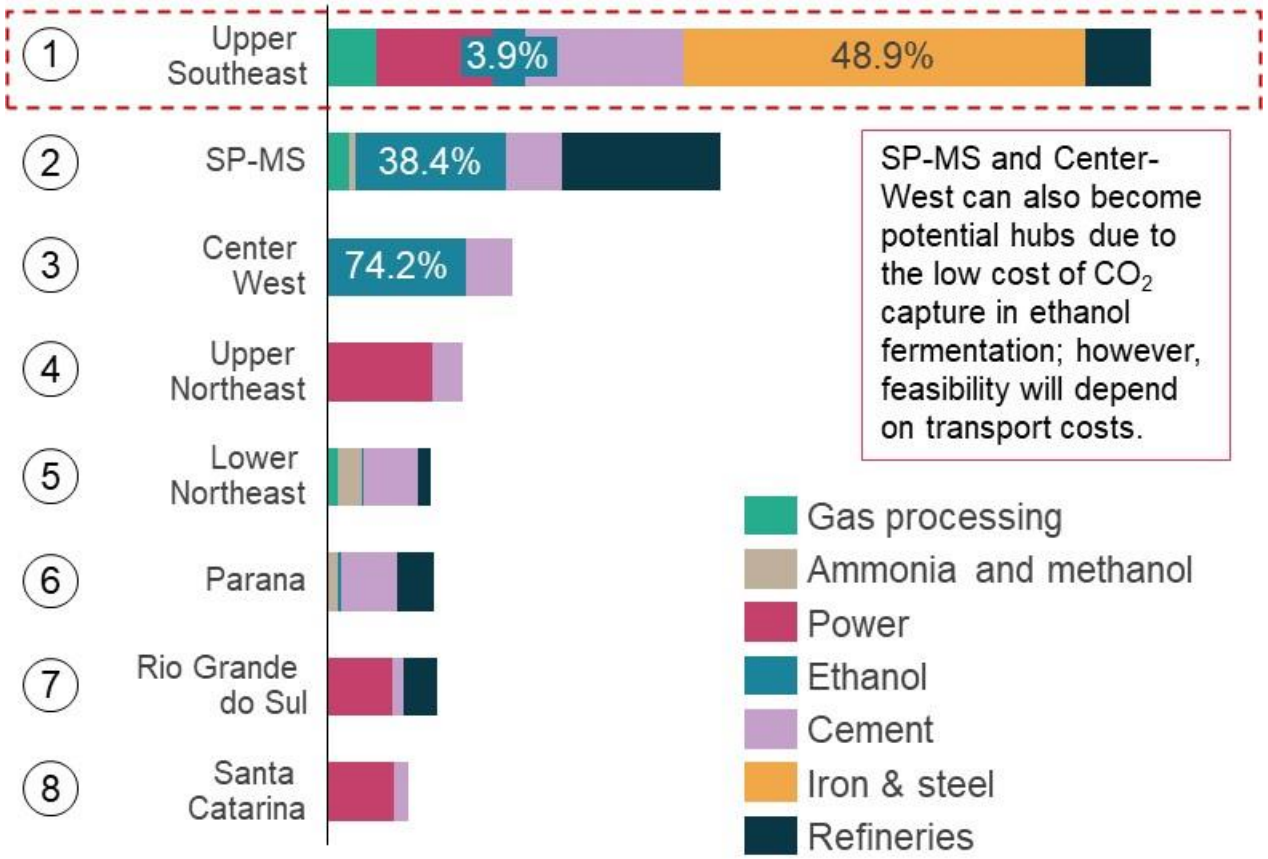
Industrial emission hubs evaluated



Source: S&P Global Commodity Insights, SEEG, Global CCS Institute

Industrial sectors identified for potential CCS hubs[1,2]

Million $mtCO_2/yr$ of industrial emissions where CCS is competitive



1. Abatement potential was estimated based on 2021 reported emissions, which were broken down to the facility level; methanol facilities with potential capture capacity of less than 10,000 $mtCO_2$/year and facilities from remaining sectors with potential capture capacity of less than 100,000 $mtCO_2$/year were not considered. Capture cost assumptions were based on estimate ranges from Global CCS Institute, then allocated to each facility according to the scale, normalized according to the utilization rate for the refineries and power sectors, adjusted to Brazilian costs by adding 65% import tax on the equipment portion on the total CAPEX and adjusting the WACC to 14%WACC. For storage costs, we developed CO_2 projects representative of the main potential locations identified in the storage screening and evaluated the average costs using a cashflow discounted at a 14% rate. Transportation costs were estimated for each state by using a discounted cashflow model in an interactive way in which the costs varied according to the amount of carbon transported in the grid. We also excluded facilities in which the total CCS cost surpasses US$200/$mtCO_2$. 2. Hub 9 has 1.1 $MMtCO_2$ gas processing abatement potential and is not included due to the low likelihood of hub deployment. Hub 10 does not show abatement potential at proposed cost.

Source: SEEG; Global CCS Institute; S&P Global.

S&P Global Commodity Insights

A strong coordination with clear policies, a carbon market and financial incentives are required to deploy CCUS at scale in Brazil

Main barriers and enablers facing CCUS advancement in Brazil

Main Barriers:

- Lack of legal certainty on **regulatory framework** addressing the risks for investors, especially on the storage liabilities.
- Clear policies and **price signals** have been a *sine qua non* condition for early movers
- **Costs** remains largely prohibitive and cost reductions are still uncertain. Developing technologies to reduce costs and improve capture efficiency
- Difficult **access to financing**. Investments will need to rely on NOCs, National Development Bank, World Bank etc
- Limited and **aging infrastructure** for CO2 transportation
- Lack of CO2 storage potential mapping: need granular sink-source matching for hub development, including saline formations.
- **Social license** – improve communication and public awareness of benefits and risks of the CCUS, especially in sensitive areas

Existing Enablers:

- Advantage of depleted oil reservoirs throughout the region, allied with **extensive O&G operations** and supply chain expertise
- Hard to abate industries **concentrated** in main capital cities, mostly in the SE region
- Mobilization of legislators to be early movers in the region, sector public-private **coordination**
- Large **biofuels** activity enabling negative emissions through BECCS, and high support for development of blue H2.
- CCS adds competitivity to the **iron & steel and ethanol exports** via CBAM and LCFS. Brazil is the second-largest emitter of CBAM-covered emissions.
- Voluntary carbon market (e.g. RenovaBio): Companies can offset their emissions through CCS and sell the carbon credits
- Public support for funding **R&D**

Final Key Takeaways

Continued stakeholder pressure to decarbonize has accelerated interest in CCUS – Fossil fuels will continue to play a critical role in the global economy and hence to tackle the emissions, the deployment of CCUS is essential.

Increasing government support (e.g., US Inflation Reduction Act, Emissions Reduction Alberta Carbon Capture Kickstart program) are accelerating the deployment of large CCUS projects.

Cost reduction remains the focus for making CCUS into a viable business. Near term, innovations in project execution and operational efficiency (e.g., modularization, standardization) are expected to deliver 15–30% cost reduction

CCUS hubs are expected to play a critical role in developing this carbon management industry – a pathway for the oil and gas industry to transition CCUS for both own emissions and other industries.

Incentives, carbon prices and clear regulatory policy are just some of the areas that need much more attention – while the **intent to invest in CCS exists in Brazil**, the underlying foundations for investment are still **unclear**.

Thank you

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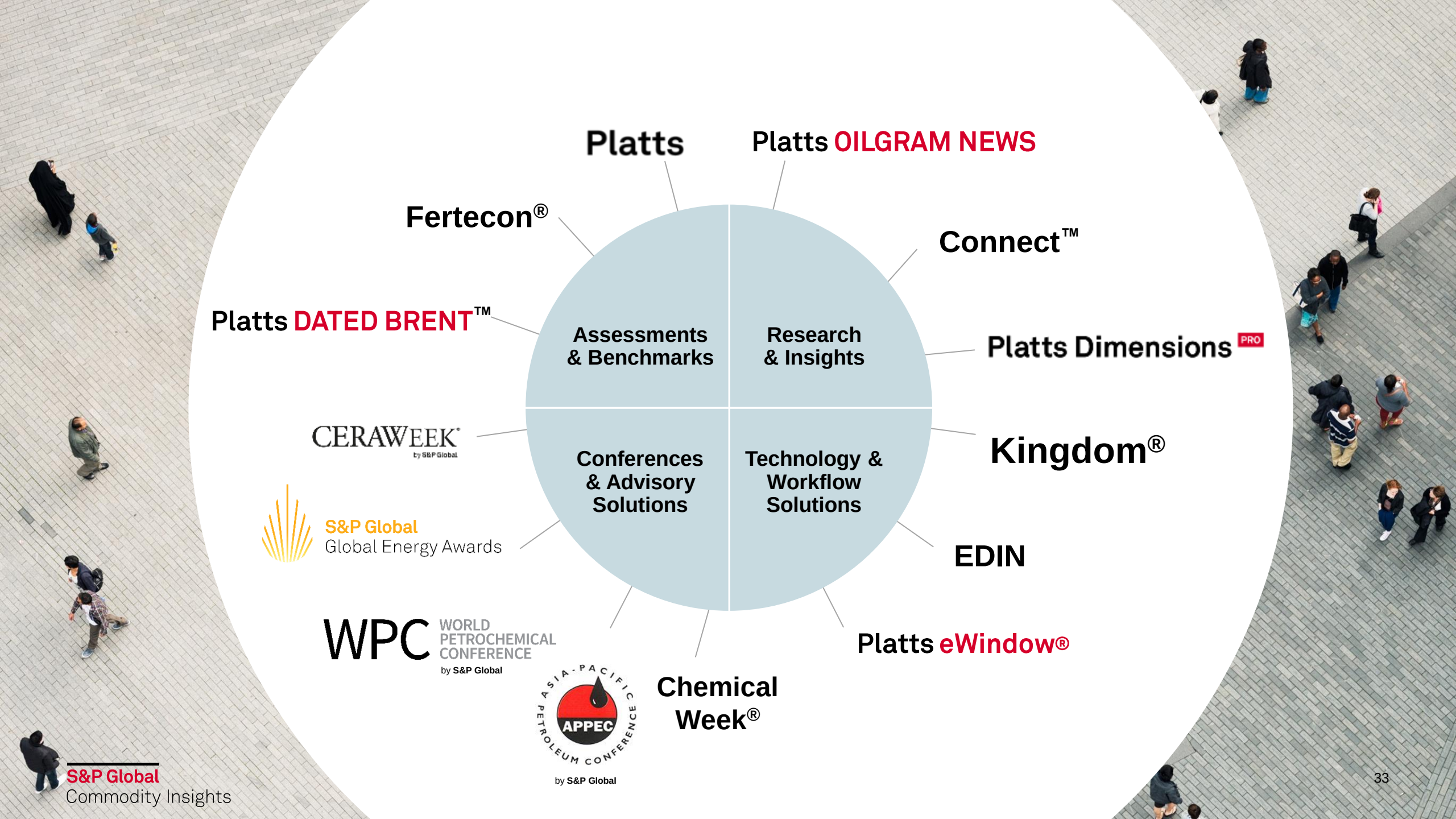
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