

F R O S T & S U L L I V A N



FROST & SULLIVAN OIL & GAS PRACTICE

Navigating a Future Defined by Innovation, Sustainability and
Industry Transformation

May
2025

ENERGY TRANSITION & DECARBONIZATION THE KEY THEMES OF ENERGY & ENVIRONMENT

Top Trends driving our strategy and market coverage for 2023-25



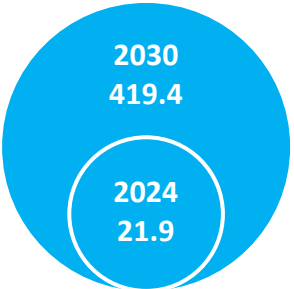
Source: Frost & Sullivan

CCUS IS THE KEY TO UNLOCK THE FULL POTENTIAL OF DECARBONIZATION AND ATTAIN NET – ZERO EMISSION TARGET

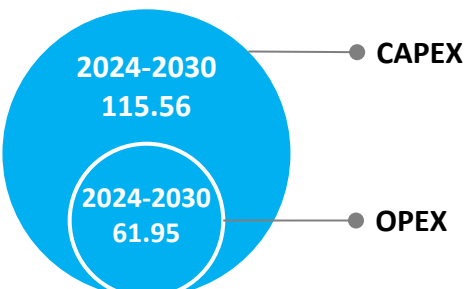
 The Cumulative Market Size For The CCUS Value Chain Including OPEX For Carbon Capture, Transport And Storage From 2023 To 2030 Is Projected To Be 200 To 300 Billion USD. End – to – End Digital Solutions to Measure, Monitor and Manage Carbon Dioxide across the CCUS Value Chain is expected to be 100 – 200 Billion USD.

Carbon Capture Market

Annual Capture Capacity in MTPA

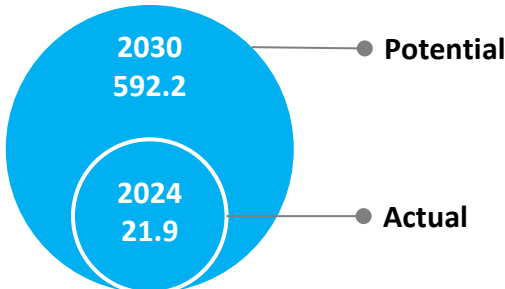


Total CAPEX and OPEX in BUSD

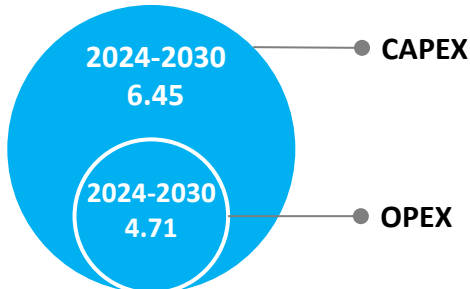


Carbon Transport Market

Annual Transport Capacity in MTPA

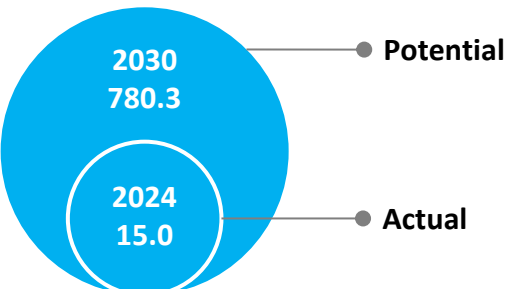


Total CAPEX and OPEX in BUSD

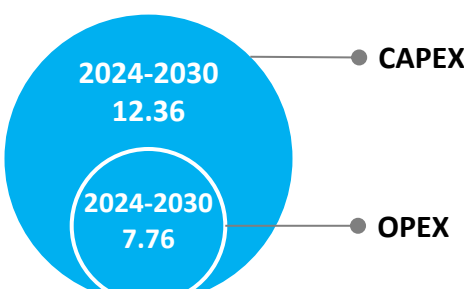


Carbon Storage Market

Annual CO2 Storage in MTPA

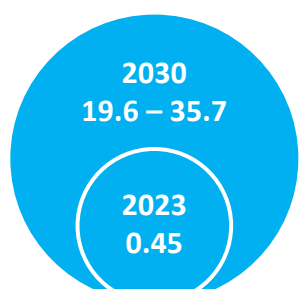
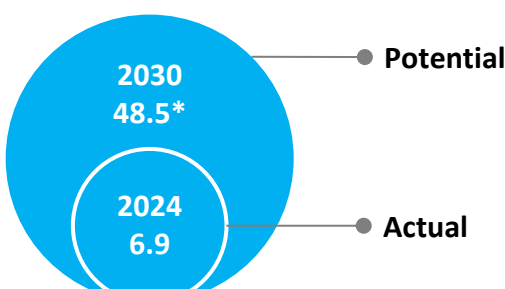


Total CAPEX and OPEX in BUSD



Carbon Utilization Market


Annual Utilization Capacity in MTPA Total Utilization Market Potential in BUSD



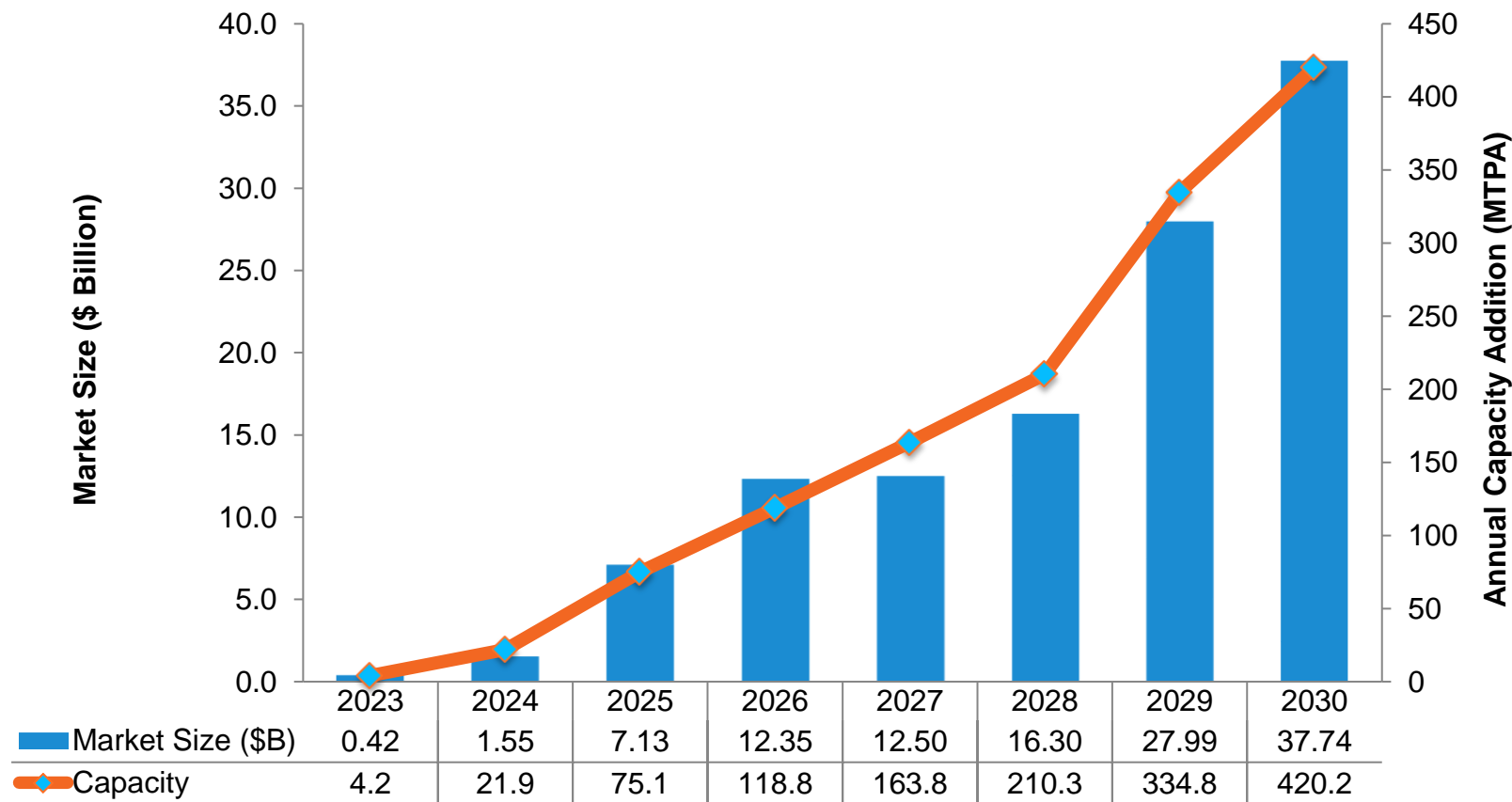
Note: OPEX is calculated for 15 years period

*Including Enhanced Oil Recovery

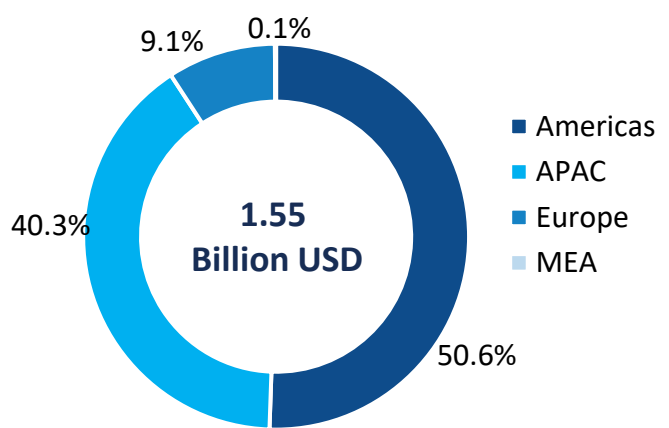
THE CARBON CAPTURE MARKET IS GAINING MOMENTUM WITH INCREASE IN INVESTMENTS AND INDUSTRIES WILLINGNESS TO MEET NET-ZERO TARGET

 The carbon capture market is expected to grow at an CAGR of 39.5% between 2025 and 2030, mainly driven by stringent government regulations, climate change mitigation goals, technological advancements, and economic incentives, all aimed at reducing greenhouse gas emissions and achieving net-zero targets.

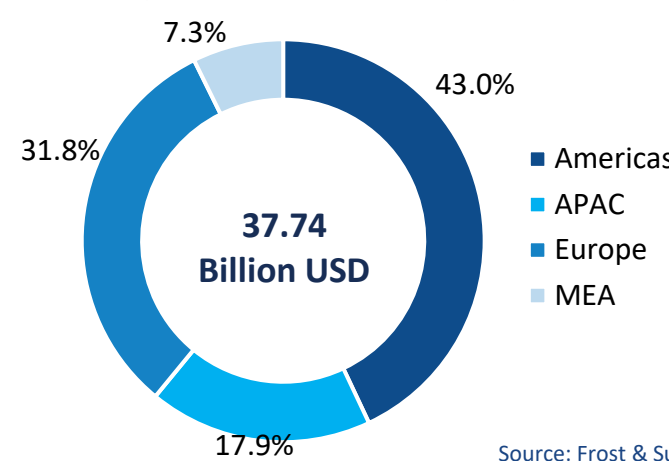
CCUS: Carbon Capture Market Size and Annual Capacity Addition Forecast, Global, 2023-2030



Percentage Revenue Share by Region, 2024




Percentage Revenue Share by Region, 2030

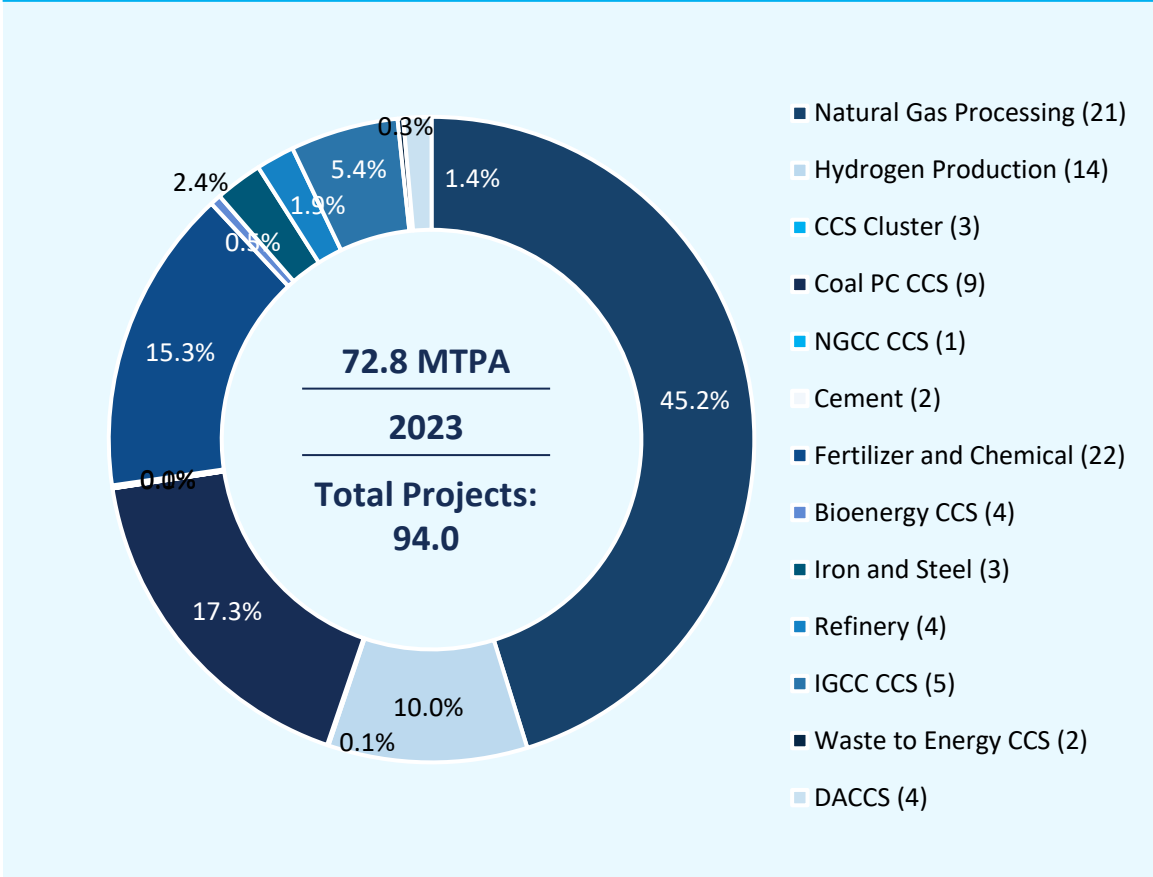


Source: Frost & Sullivan,

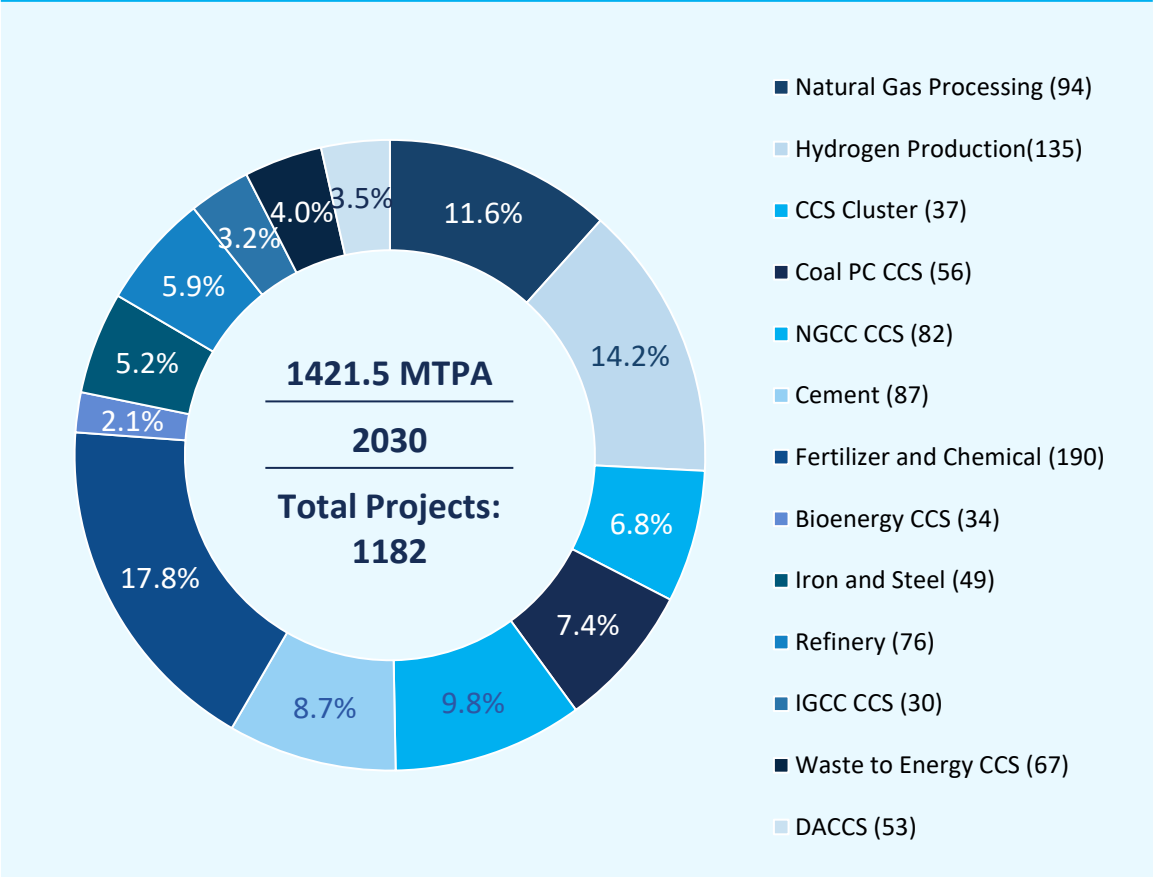
DIVERSE INDUSTRIES INCLUDING HARD-TO-ABATE SECTOR CONTRIBUTE TO THE GROWTH OF CARBON CAPTURE

 Although Oil and Gas Industry is front runner in adopting CCUS, Hard to abate industries such as Cement, Iron and steel, Fertilizers and Chemicals will be the fastest growing market mainly driven by Net-Zero targets, lower alternatives to production process, and regulatory pressure.

CCUS: Cumulative Carbon Capture Capacity in million tons per annum (MTPA), Percentage Share by Industry, Global 2023




CCUS: Cumulative Carbon Capture Capacity in MTPA, Percentage Share by Industry, Global 2030

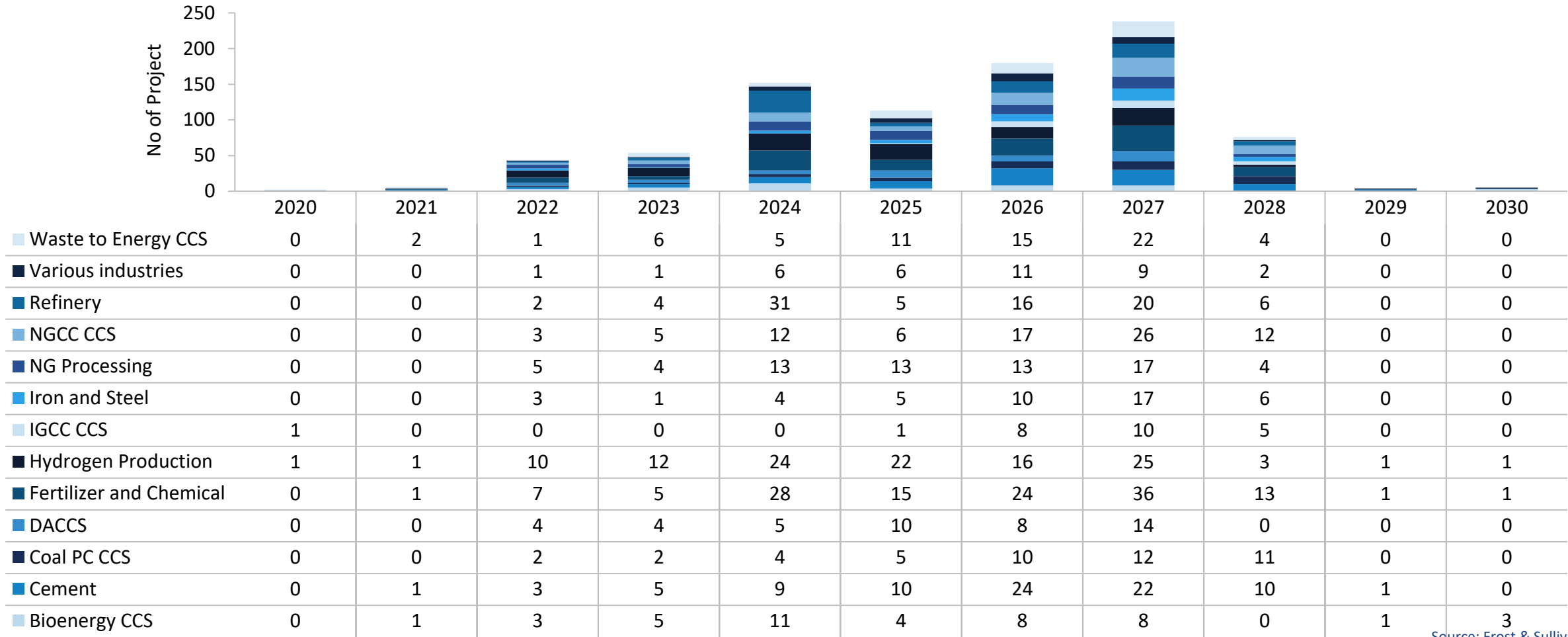


Source: Frost & Sullivan

CARBON CAPTURE, TRANSPORT AND STORAGE PROJECTS ARE GAINING MOMENTUM LEADING TO INCREASE IN FINAL INVESTMENT DECISION (FID)


 Oil and gas industry is the largest developer of CCUS project with more than 200 projects in refinery, hydrogen, chemical and fertilizers to reach FID between 2024 and 2027. Heavy industries such as Iron & Steel and Cement are catching up in terms of project development with 131 projects between 2020 and 2030.

CCUS: Carbon Capture, Projects by FID, Global, 2020-2030

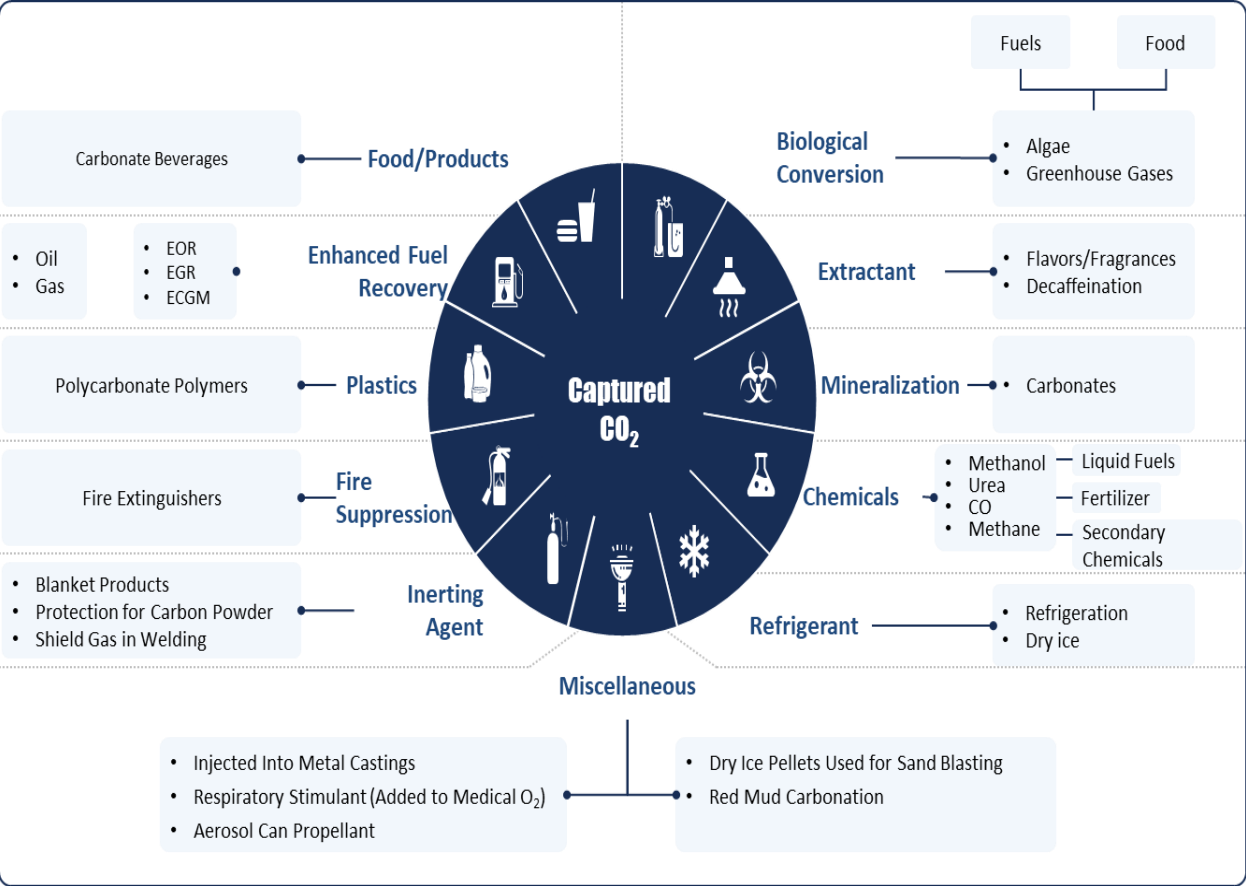


Source: Frost & Sullivan,

Carbon Capture With Utilization A Future Growth Prospect



CCS struggles with high upfront costs and the process itself uses electricity, reducing the electricity available for the wider grid. Ultimately there needs to be a way to offset these costs, and revenues from utilization opportunities could provide that. For customers requiring feedstock for production – e.g. plastics, building materials and fuel producers, captured carbon could be attractive financially and from a sustainability perspective.



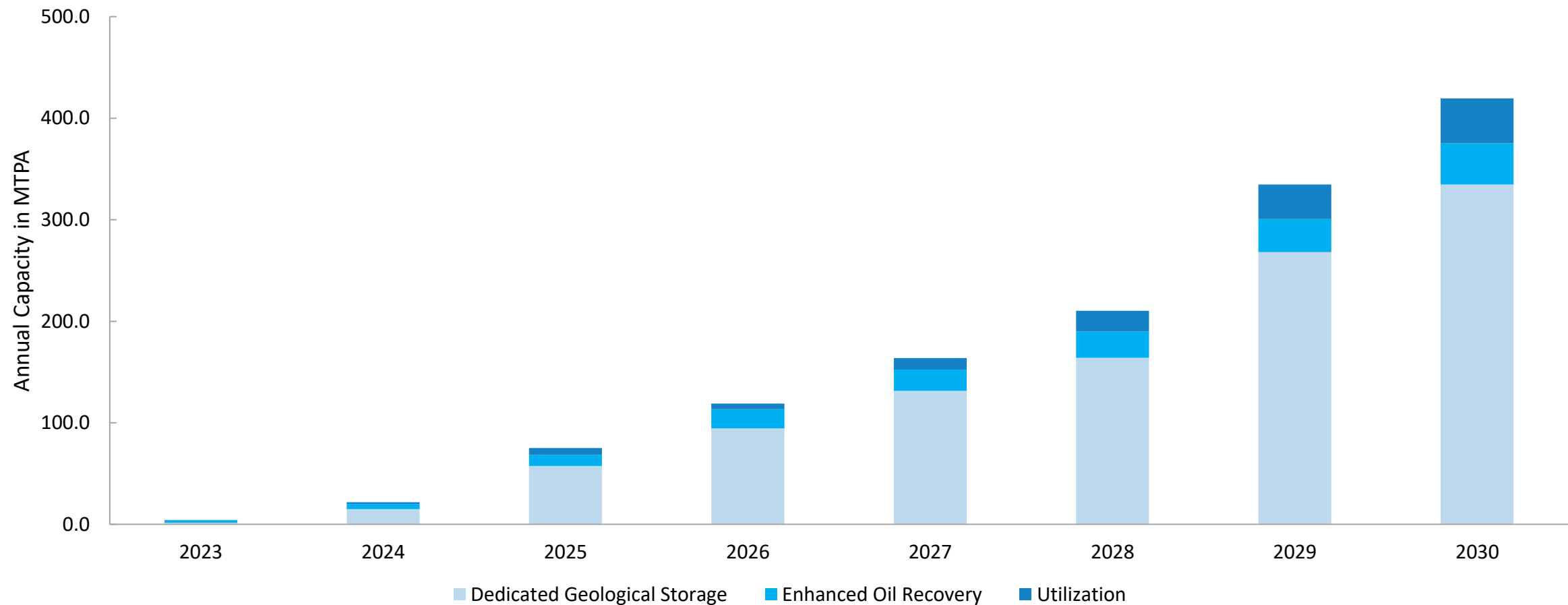
Product	End Product Price \$/t	Product Demand Mt/yr	CO ₂ Use in production tCO ₂ /t	Total CO ₂ Demand for Production, Mt/yr
Aggregate	10	55,000	0.25	13,750
Concrete	100	20,000	0.025	500
Methanol	350	140	1.37	192
Ethanol	475	100	1.91	191
Sodium Carbonate	150	60	0.42	25
Calcium Carbonate	200	10	0.44	4.4
Polymers	1900	24	0.08	1.9

Source: Frost & Sullivan

END FATE OF THE CAPTURE CARBON – STORAGE, ENHANCED OIL RECOVERY AND UTILIZATION

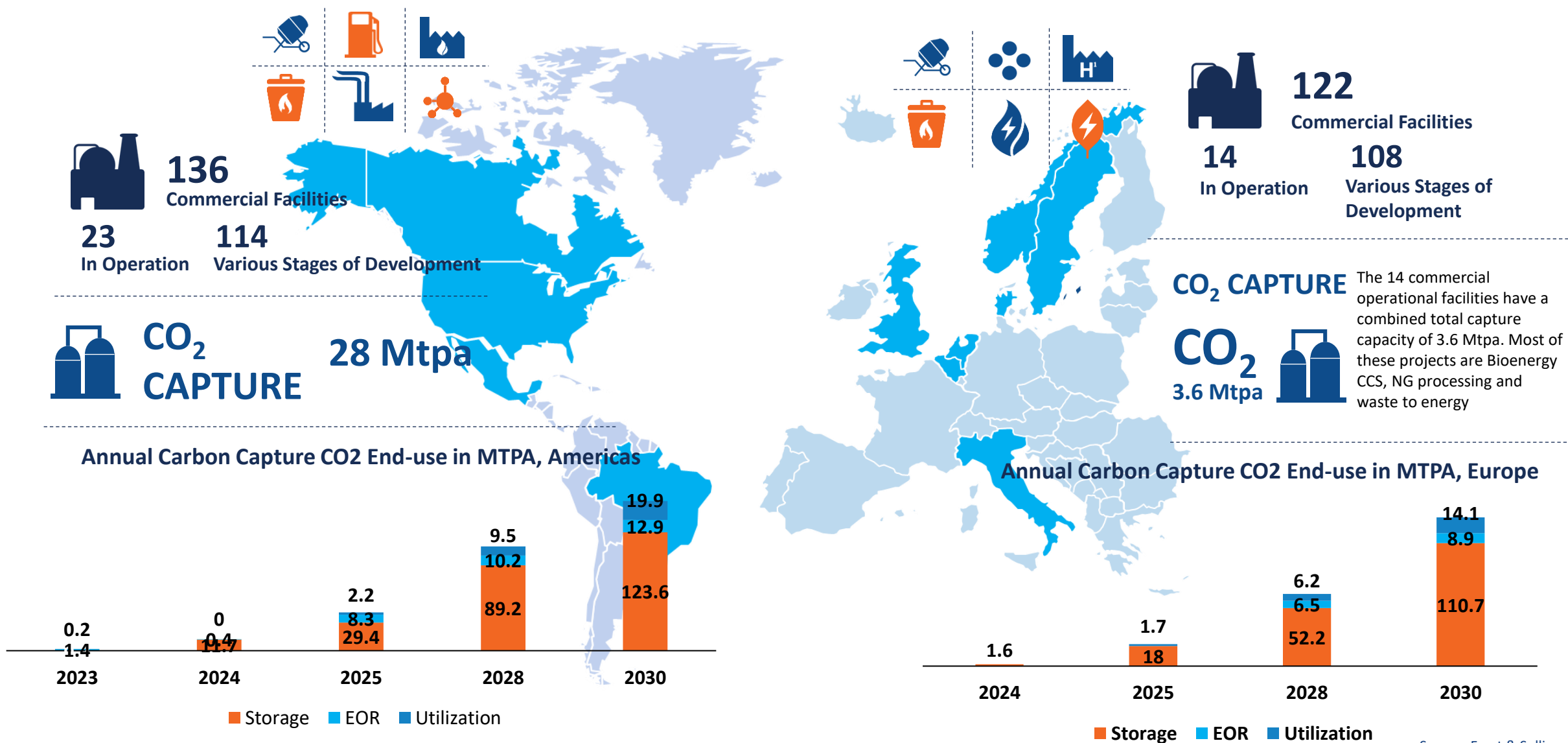
 Carbon capture and storage is currently considered to be the most viable option driven by vast amount of storage options available across the globe. Moreover, EOR is highly dependent on oil price and it subject to price volatility, while utilization market is still at a nascent stage of development.

CCUS: CO2 End-useAnnual Capacity Addition Forecast, Global, 2023-2030



Source: Frost & Sullivan,

Carbon Capture, Utilization and Storage Regional Trends and Analysis

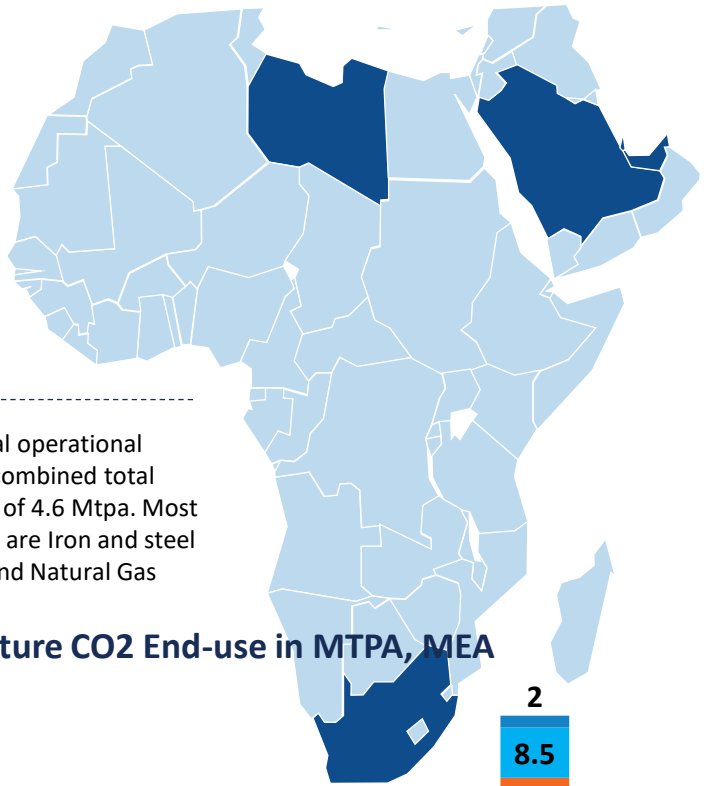


Source: Frost & Sullivan

Carbon Capture, Utilization and Storage Regional Trends and Analysis



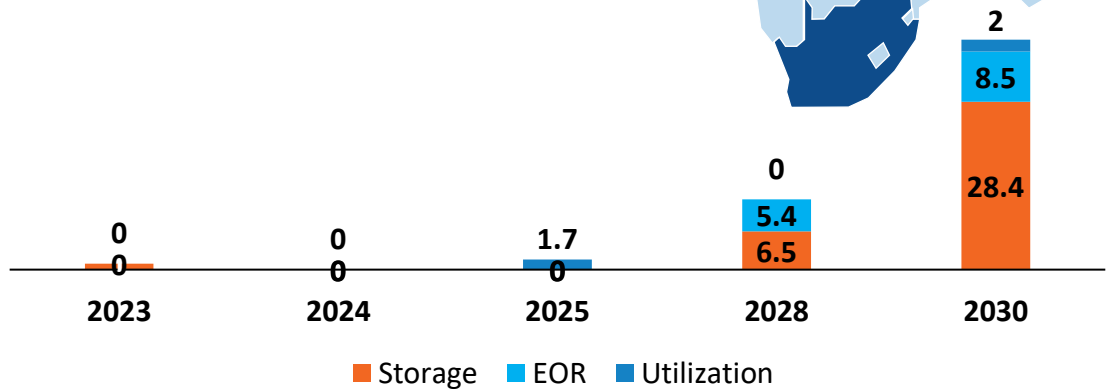
15 Commercial Facilities
5 In Operation
10 Various Stages of Development



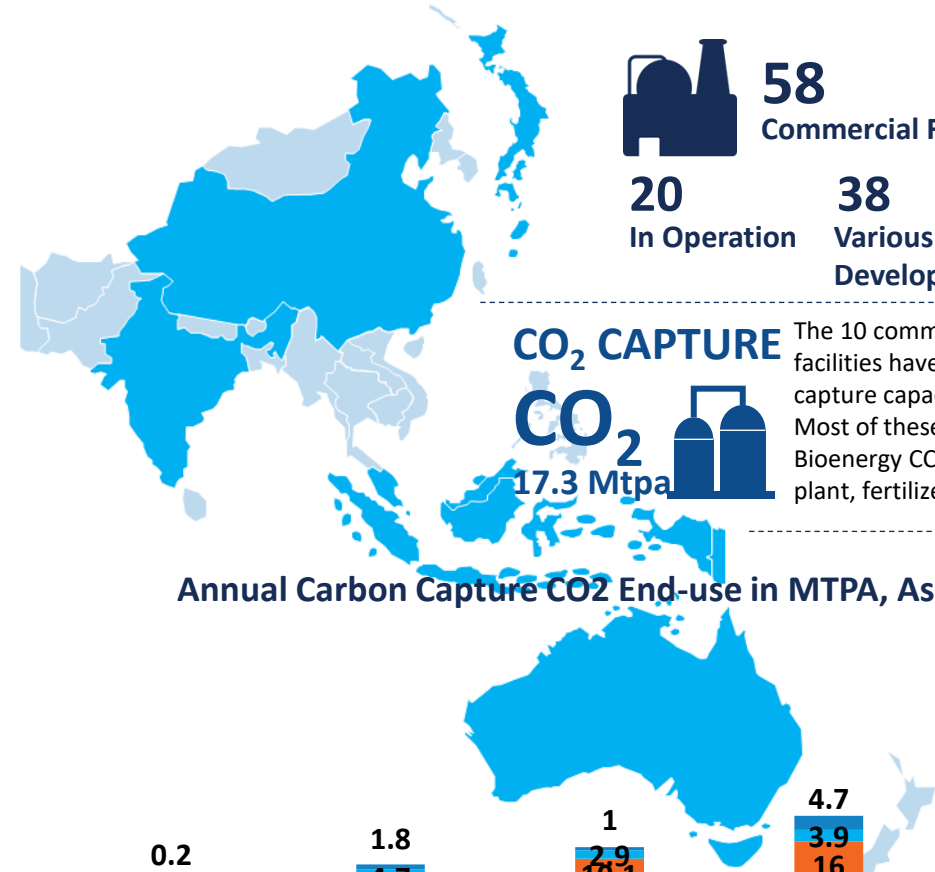
CO₂ CAPTURE
CO₂
4.6 Mtpa

The 5 commercial operational facilities have a combined total capture capacity of 4.6 Mtpa. Most of these projects are Iron and steel manufacturing and Natural Gas processing.

Annual Carbon Capture CO2 End-use in MTPA, MEA



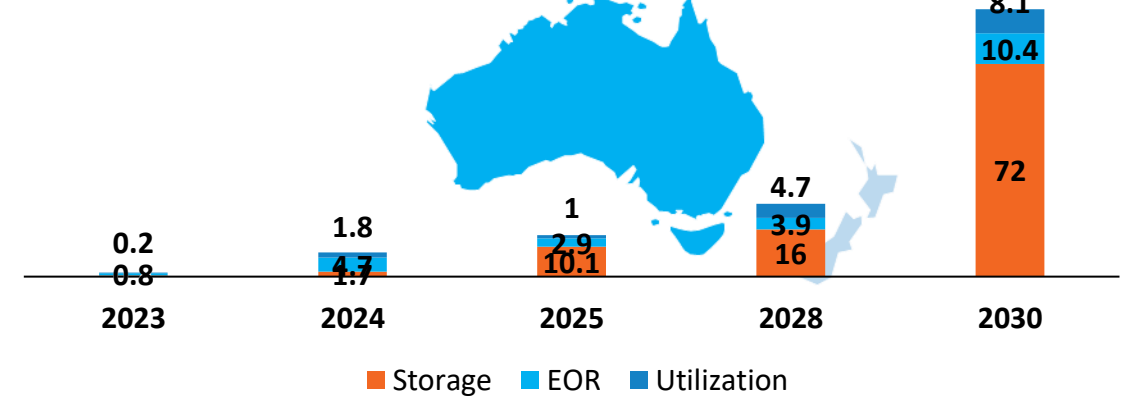
58 Commercial Facilities
20 In Operation
38 Various Stages of Development



CO₂ CAPTURE
CO₂
17.3 Mtpa

The 10 commercial operational facilities have a combined total capture capacity of 12 Mtpa. Most of these projects are Bioenergy CCS, Coal Power plant, fertilizers, NG processing

Annual Carbon Capture CO2 End-use in MTPA, Asia Pacific



Source: Frost & Sullivan

TRENDS AND CHALLENGES IN CARBON CAPTURE, UTILIZATION, AND STORAGE (CCUS)

The CCUS market is undergoing rapid evolution with innovative trends like Direct Air Capture and advanced materials, but faces risks like high costs and regulatory challenges, necessitating continuous innovation and strategic partnerships.

TRENDS

CCUS Hubs: The creation of CCUS hubs, where multiple facilities share infrastructure for CO₂ capture, transport, and storage, is gaining traction. This approach can reduce costs and risks associated with individual projects.

Integrated Value Chains: Businesses are integrating carbon capture with other processes, such as converting captured CO₂ into useful products like fuels, chemicals, or building materials. This creates additional revenue streams and enhances the economic viability of carbon capture projects.

Policy and Incentives: Stronger investment incentives and climate targets are driving new momentum behind CCUS. For example, the U.S. Inflation Reduction Act has increased tax credits for captured CO₂, making many projects economically viable.

Public-Private Partnerships: Governments and private companies are partnering to fund and develop carbon capture projects. These partnerships often involve shared investment and risk, leveraging public funding to attract private capital.

Subscription Models: Some technology providers are exploring subscription-based models where companies pay for carbon capture as a service. This model can lower the initial investment barrier for companies looking to reduce their carbon footprint.

RISKS

High Costs: Implementing CCUS technology is expensive, involving significant upfront investment for capture, transport, and storage infrastructure.

Storage Risks: There are uncertainties regarding the long-term storage of CO₂. Potential risks include leakage from storage sites, which could negate the benefits of capturing the CO₂ in the first place.

Transportation Risks: Transporting CO₂, especially in liquid form, requires high-pressure pipelines, which can be prone to leaks and ruptures.

Policy and Incentives: Government supporting fossil fuel over energy transition can lead to push back in net-zero targets thereby deaccelerating technologies such as CCUS.

Market Volatility: The market for CCUS equipment is still developing, leading to fluctuations in demand. This volatility can affect the financial stability of manufacturers and suppliers.




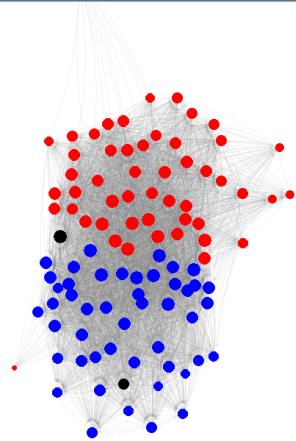


Supply Chain Disruptions: The complexity of the CCUS supply chain can lead to disruptions. Delays in the delivery of critical components can halt project progress.

Environmental Impact: CCUS aims to decrease CO₂ emissions, but its process may have environmental impacts.

Key CCUS Growth Opportunity Areas

CO₂

Key to higher deployment is to have a range of solution offerings to cater to the diverse sub-set of customer industries.

DAC and Negative Emissions Tech.	CCUS as a Service Business Models	Modular CCUS	CCUS Clusters/Hubs	Upcycling & Utilization of Captured Carbon	Digital Technology in CCUS
					
<ul style="list-style-type: none"> • Going Beyond NetZero • Bioenergy and Direct Air Capture are key technologies • Higher carbon pricing key element in economic viability 	<ul style="list-style-type: none"> • Integrated value proposition with client paying per tonne of CO2 removal • Carbon neutrality as a service 	<ul style="list-style-type: none"> • Standardized plant structure to minimize costs • Remote and automated operations 	<ul style="list-style-type: none"> • Shared infrastructure and transportation costs enable higher deployments 	<ul style="list-style-type: none"> • Upcycling into plastics, building materials fuels etc. • Generating revenues or environmental benefits to offset carbon capture costs 	<ul style="list-style-type: none"> • Help in managing the CCUS assets effectively • Process optimization to improve capture efficiency

Source: Frost & Sullivan

CCUS Company Landscape ... Diverse Ecosystem of Players

Carbon Capture Solutions



CCUS Digital Solutions



Utilization & Upcycling



Project Backers



Source: Frost & Sullivan

Key Takeaways

1

Carbon capture market is largest and the fastest growing segment across the CCUS value-chain. **Investing in carbon capture projects which has a Return on Investment (ROI) between 10% to 20% of project lifecycle will be a good value proposition.** Americas and Europe are the main regions to focus in short to mid-term with long-term focus on MENA and Asia Pacific.

2

In short to mid term, CCUS will find a wider application in hard – to – abate industries such as cement, iron and steel, fertilizers and chemical production by retrofitting the existing plants. **To have a larger implication in the decarbonization strategy, investing on negative emission technologies like BECCS and DACCS will support long-term growth.**

3

Like any other industrial technologies, CCUS is heavily dependent on economies of scale, while this might be favorable in large – scale deployment with large tonnage of CO₂, not all sector emit large quantity of CO₂. **Modularization is key for such reduced economies of scale which can bring down the cost by building standardized plant and mass production techniques.**

4

Carbon Capture is energy intensive process, accounting for 25 to 30% of the OPEX. **90% of the industry players believe energy consumption is the one of the biggest challenge in scaling carbon capture projects.** Developing energy efficient processes and equipment will help bring down the cost of capture significantly and help in faster deployment.

5

As demand for green products increases utilizing captured CO₂ can significantly improve the economics of carbon capture projects. Instead of merely storing CO₂, converting it into valuable products such as fuels, chemicals, building materials can create new revenue streams, making carbon capture more financially attractive.

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