MEI Seminar Series

Carbon capture in the Asia-Pacific: Progress, policy and the path to net zero

Image: Santos Moomba CCS facility

18 June 2026

THE UNIVERSITY OF MELBOURNE

Melbourne Energy Institute

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CARBON CAPTURE IN THE ASIA-PACIFIC: PROGRESS, POLICY AND THE PATH TO NET ZERO

Launch of 22,000 m^3 low-pressure LCO_2 carrier at HD Hyundai Mipo, Korea – 15 April 2025

DAVID T. KEARNS, PHD
COUNTRY MANAGER, AUSTRALIA & NEW ZEALAND
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Accelerating the deployment of CCS for a net-zero emissions future.

WHO WE ARE
International CCS think tank with offices around the world. Headquarters in Melbourne.

Over 180 members across governments, global corporations, private companies, research bodies and NGOs, all committed to a net-zero future.

WHAT WE DO
Fact-based influential advocacy, catalytic thought leadership, authoritative knowledge sharing.

DAVID T. KEARNS, PHD

David is Country Manager Australia and New Zealand at the Global CCS Institute.

With over 25 years' experience in the energy, industrial and research sectors, David specialises in carbon capture technologies and CCS strategy, policy and deployment. David advises governments, industry and investors globally on CCS and is an advocate for the role of carbon management in achieving net-zero emissions.

He is a specialist in CO_2 capture and transport technologies and was previously Principal of CCS Technologies at the Institute. He holds PhD and BE degrees in Chemical Engineering and a Bachelor of Commerce in Management. He is a Fellow of the Australian Institute of Energy.

SECTION 1 — WHY CCS MATTERS

The Net Zero Challenge in Asia-Pacific

Industrial growth, energy demand and hard-to-abate emissions

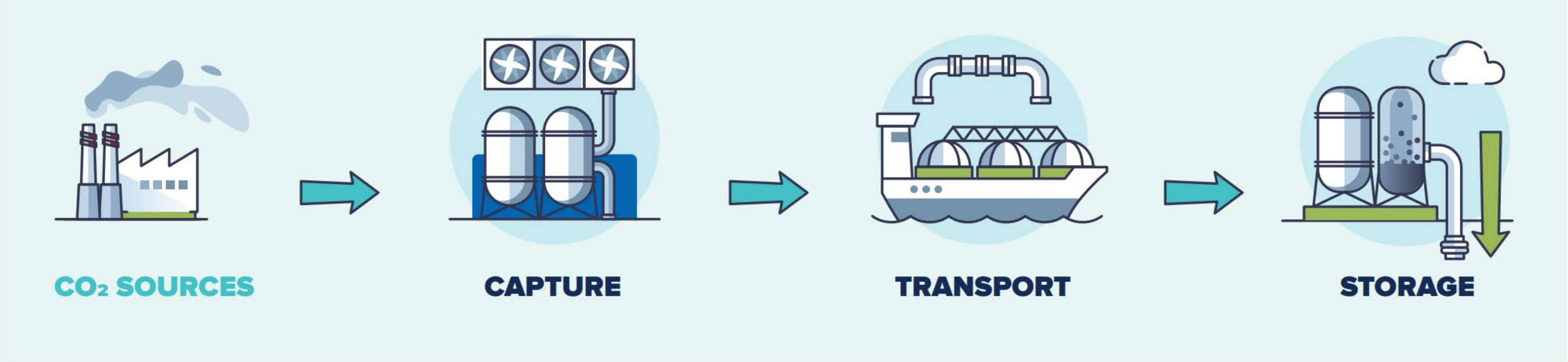
The Asia-Pacific region is at the centre of global emissions growth - ~32 Gt CO_2-e per year (Global total ~53 excl. LULUCF)

Industry remains difficult to decarbonise – cement, steel, chemicals. Over 8 GT per annum across region (4.9 from combustion, 3.3 from process CO_2)

Net zero pathways become *substantially* harder, slower and more expensive without CCS.

(numbers from EDGAR, UNEP, ESCAP in 2024)

Country	Scale of emissions	Difficulty to abate	Why
China	Very high	Very high	Massive coal power fleet; the world's largest steel, cement and chemicals sectors
India	Very high	High	Growing coal demand, industrialisation, rising energy demand
Indonesia	High	Very high	Coal power, metals processing, cement, industrial growth
Japan	Moderate	High	Heavy industry, limited domestic renewable resources, hydrogen dependence for decarb pathways
South Korea	Moderate	High	Steel, petrochemicals, refining
Australia	Moderate	High	LNG, mining, alumina, steel, cement, long-distance transport
Vietnam	Rising rapidly	High	Coal-heavy industrial expansion
Malaysia	Moderate	High	LNG, refining, petrochemicals
Singapore	Small absolute emissions	Very high intensity in industry	Refining, petrochemicals, aviation hub



WHAT IS CCS?

A series of gas processing steps

1) **Capture** – separation and purification of CO_2 from a gas mixture
2) **Compression** / **liquefaction** – reduces the volume of CO_2 to make transport easier/cheaper (often grouped with Transport)
3) **Transport** – most commonly by pipeline, ships also an emerging mode, moderate amounts by other means (trucks, rail)
4) **Storage** – injection for permanent storage into porous rock deep beneath the Earth's surface

The intent is to prevent CO_2 emissions to the atmosphere, reducing the impact on climate change

CCS is emissions management infrastructure for industry.

It is <u>not</u> a single technology. This means regulation, economics, technology decisions are needed over multiple different processes.

WHERE CCS FITS IN CO_2 MANAGEMENT

We emit CO_2 to the atmosphere because it is a *waste* – a material stream for which we cannot find a market and because historically atmospheric dumping was free/cheap.

Some CO_2 can be used as a product and as a raw material for other products, but the volumes produced mean most cannot.

We can conceive of solutions to CO_2 emissions using the *Waste Management Hierarchy* (right).

Reduction: Energy efficiency, non-CO_2 producing energy sources – e.g. renewables, nuclear, biogenic feedstocks/fuels

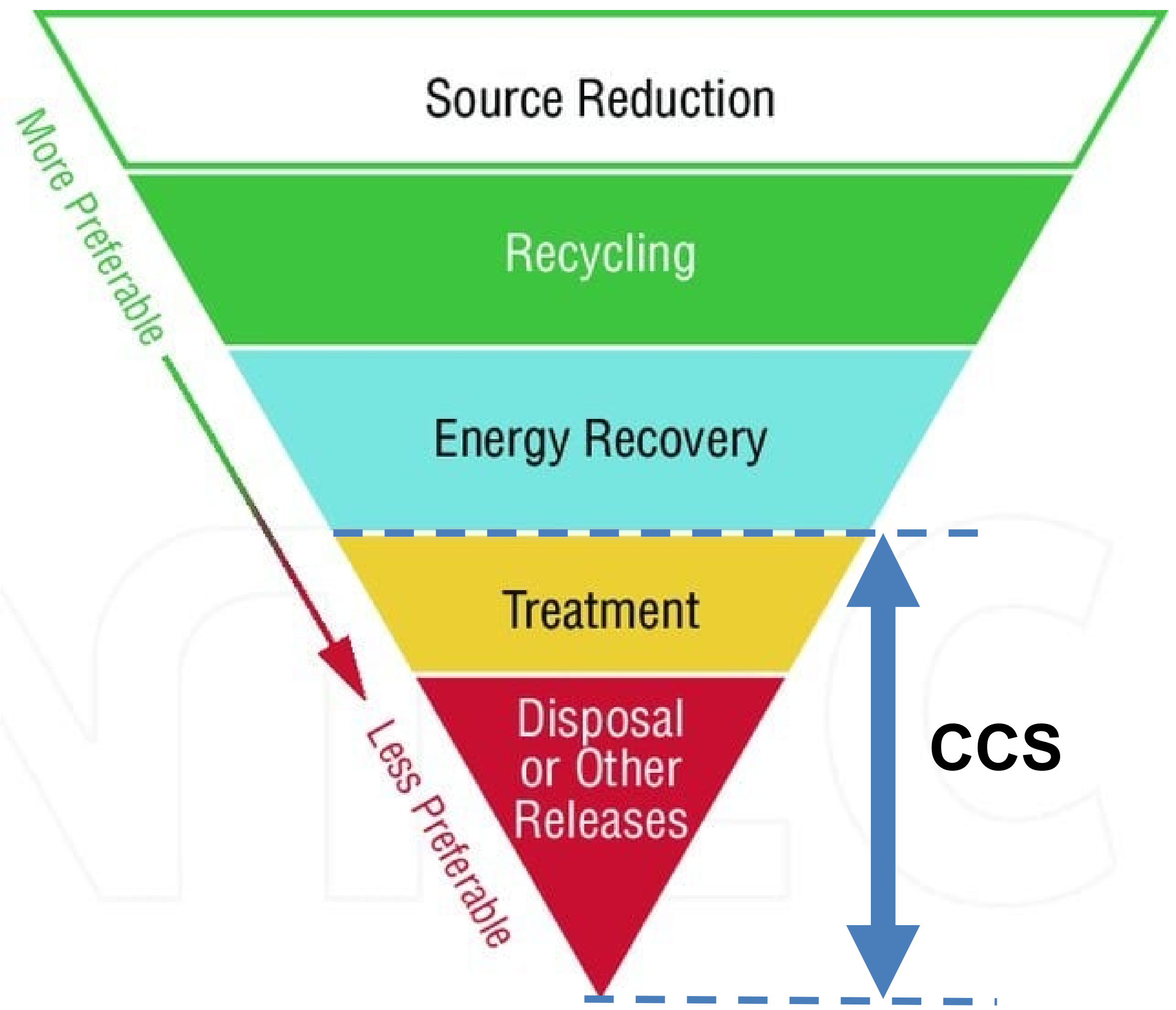
Recycling – utilisation of CO_2 to make synthetic fuels

Energy recovery – less relevant for most CO_2 sources

Treatment – CO_2 capture, release other gases to atmosphere

Disposal – Transport and storage of CO_2 for long-term storage away from the atmosphere (geological storage, also conversion to carbonate materials)

Efficient and effective CO_2 management requires <u>all</u> these solutions. CCS is part of a broad suite of decarbonisation measures needed. More effective together than as individual options



Waste management hierarchy (Sandra Duque Gaona, 2018)

WHY SOME EMISSIONS CANNOT SIMPLY BE ELECTRIFIED

Cement – clinker produces CO_2 chemically with Calcium Oxide (~65-70% of mass of cement).

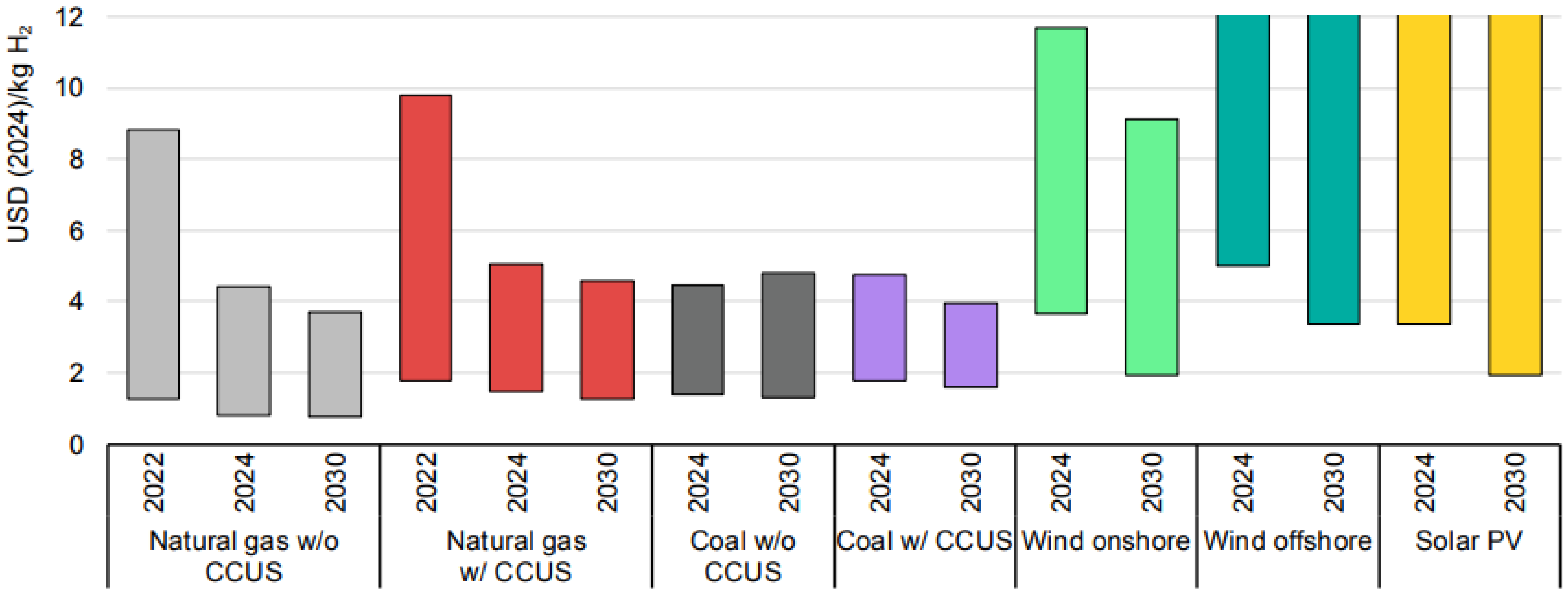
Iron & steel – Blast furnaces represent majority of global production. Hydrogen-based ironmaking is emerging but remains expensive and unsuitable for retrofitting large installed base of existing furnaces.

Natural gas production – reservoir CO_2 (that emerges with raw natural gas) can only be abated by CCS.

Power generation – in some locations (e.g. China) renewables have been insufficient to keep up with rising electricity demand. Fossil fuels will continue to be used and will require CCS for large-scale abatement.

Hydrogen – essential for chemicals production (fertiliser, explosives, hydrogen peroxide, oil refining/hydrotreating, methanol). Production of low-carbon H_2 with CCS significantly lower cost than electrolysis based hydrogen, and does not call on at-capacity electrical grids.

CO_2 capture on cement manufacturing facility. Brevik CCS project, Norway (source: Heidelberg Materials)



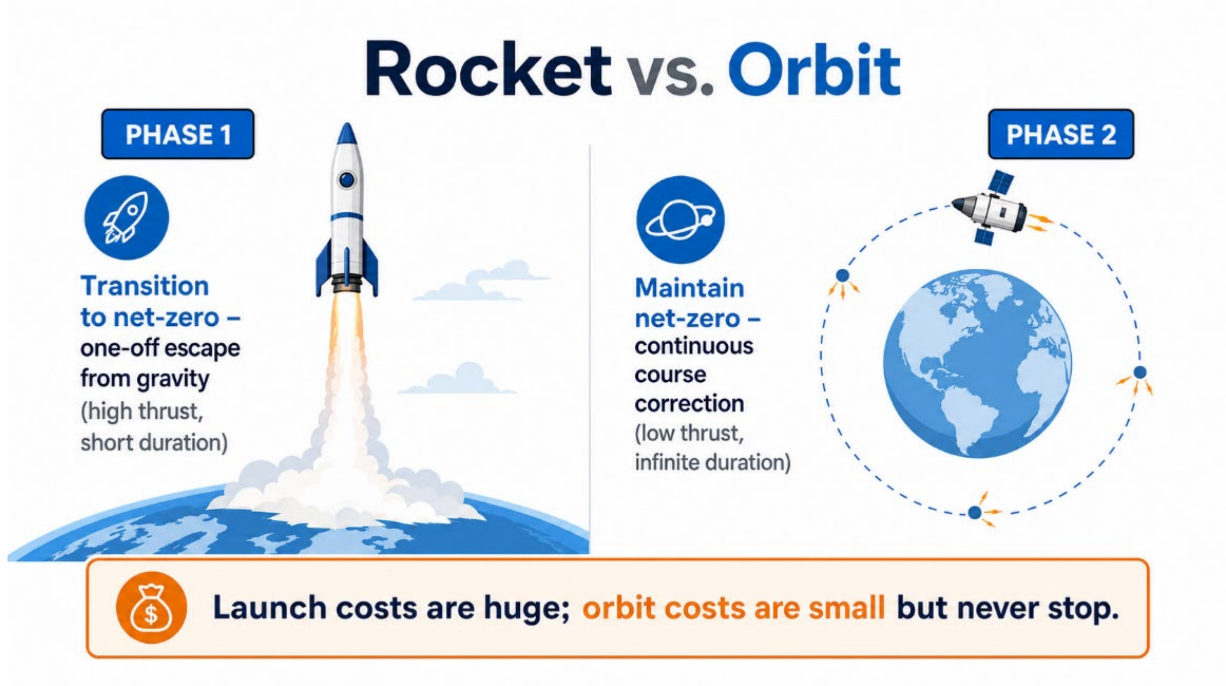
Hydrogen levelised cost from different sources (Source: IEA Global Hydrogen Review 2025)

SECTION 2 — ECONOMIC CASE FOR CCS

Impact of building CCS capacity on the cost of net zero

The Global CCS Institute operates the GENZO* macroeconomic model (Global Economic Net Zero Optimisation) to determine cost pathways under various decarbonisation scenarios.

Developed costs along two aspects: initial **transition to net zero**, and the later **maintenance of net zero**.



Scenario	Description
Global Minimum Feasible	CCS development severely constrained. Point source CCS practically absent
Historical growth – base	CCS capacity growth at same annual percentages as historical average natural gas infrastructure growth
Historical growth – high	Similar, but growing at upper-end annual percentage rates of historical natural gas infrastructure.
Global technical maximum	Upper bound of what is physically achievable given a globally coordinated effort to deploy drilling capacity dedicated to storage development

Models projected out to 2065. Point source and Carbon Dioxide Removal (CDR) – BECCS and DACCS - both included.

All decarbonisation options are included, and 24 global regions are modelled. Inter-region CO_2 transport by pipeline and ship is included.

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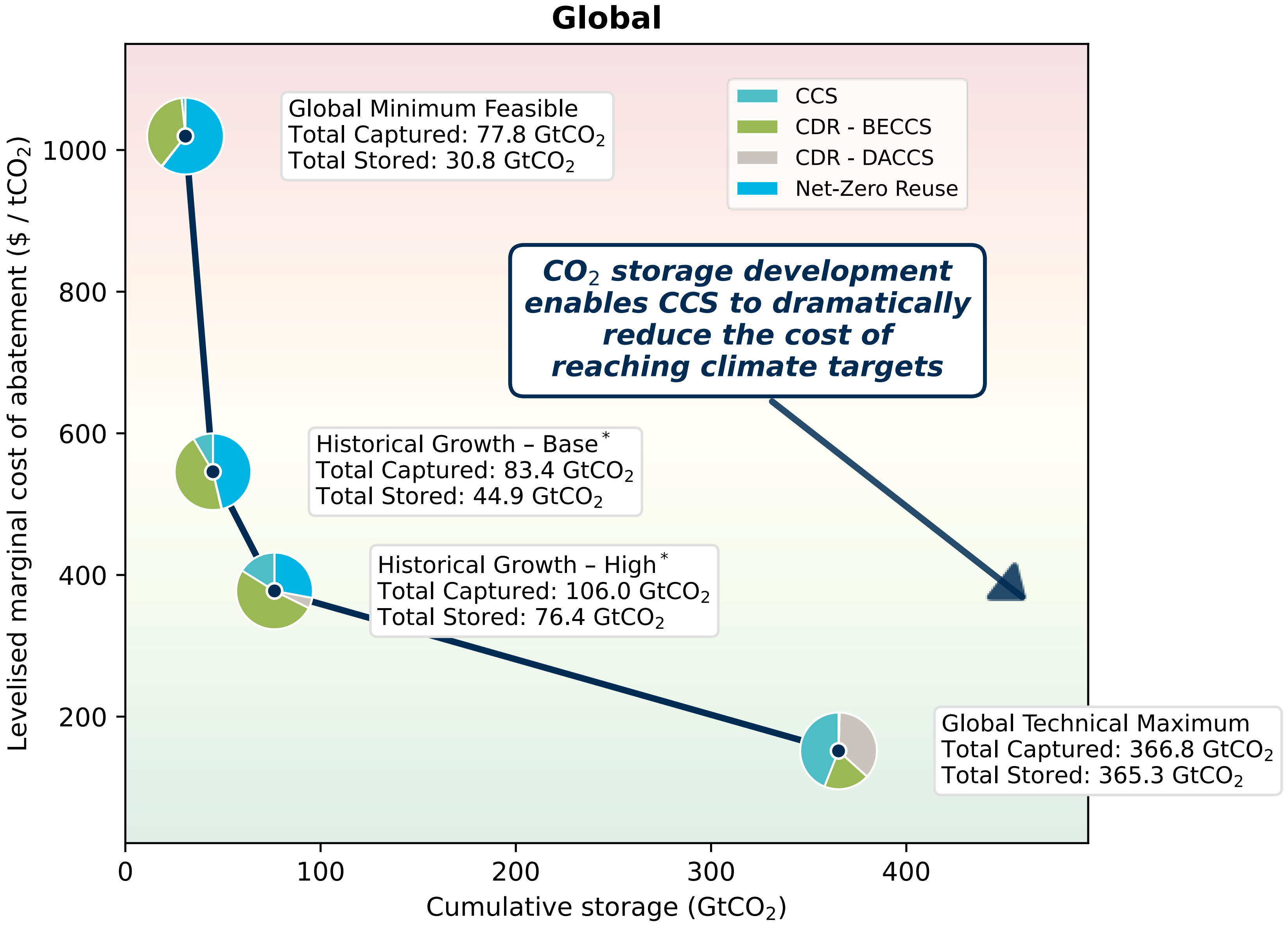
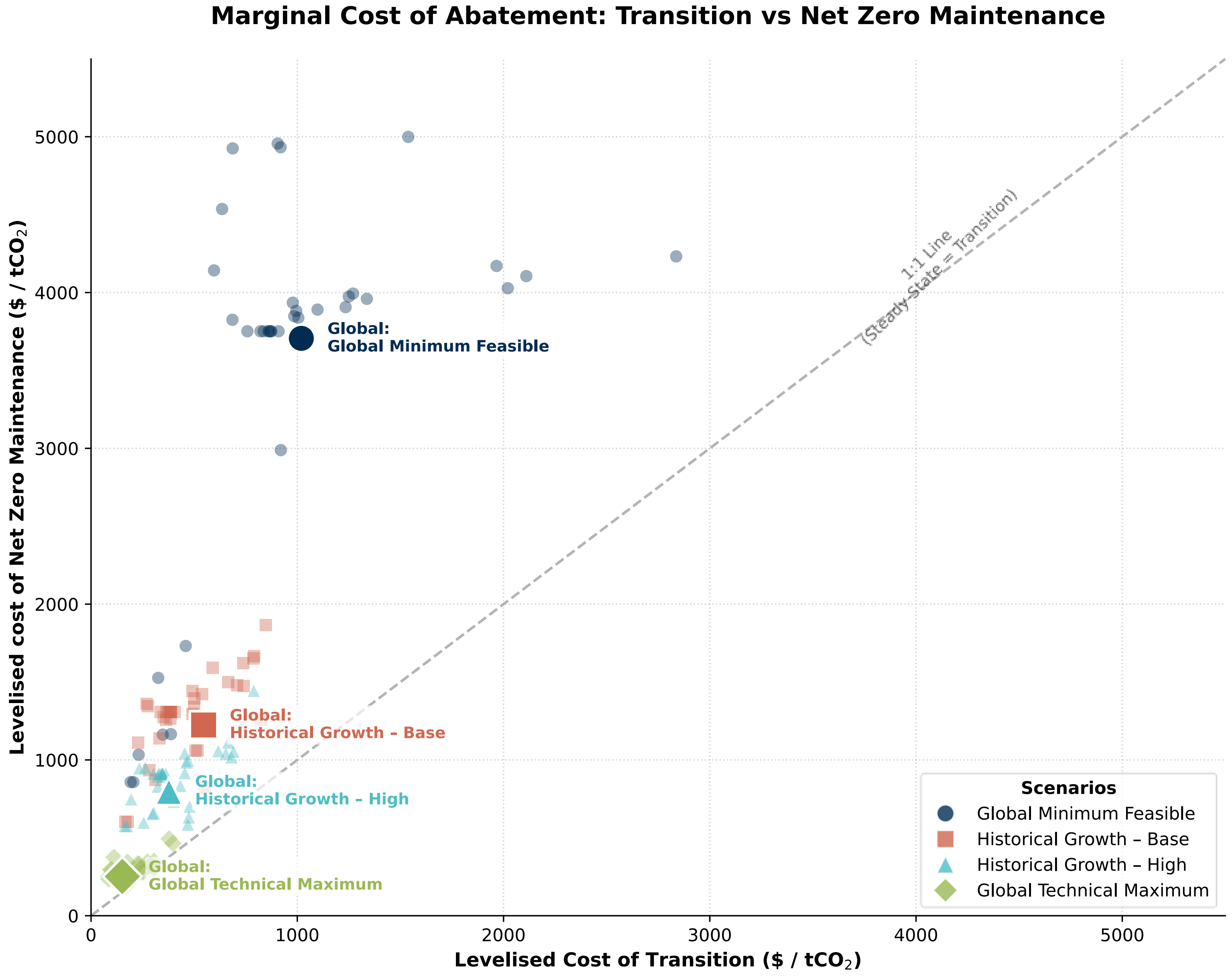
* https://status23.globalccsinstitute.com/pdf/genzo1123.pdf

DECARBONISATION COST PROJECTIONS WITH VARYING AMOUNTS OF CCS

Net zero pathways are much more expensive and slower without CCS. We don't have the luxury of capital or time to exclude CCS





* CO_2 storage development growth rates are based on historical natural gas infrastructure development in each country within GENZO model regions. The 'base' case follows the best overall match to past data, while the 'high' case allows for somewhat faster growth that is still consistent with historical patterns.

PROTECTING VITAL TRADE-EXPOSED INDUSTRIES ACROSS THE REGION

The Asia-Pacific region is central to the world's manufacturing, materials and energy.

Decarbonisation in every country depends on decarbonisation in the Asia-Pacific, especially of energy and industrial emissions.

Simply closing cement, steel, chemicals etc is not feasible as the world relies on these sectors. We need to retain the industry without the emissions intensity.

It will also be a key part of the Just Transition, retaining employment and economic opportunities in many developing nations across the region as we move to a lower emissions future.

Without CCS in these sectors, either emissions will continue or facilities will close.

Sector	Emissions in APAC (megatonnes per annum CO_2-e)
Liquefied Natural Gas	3,360 (fuel production and processing, does not include gas combustion at point of use)
Chemicals	~500
Cement	~1500
Iron & Steel	~850

Process emissions only, estimates derived from EDGAR sources

CCS AS ECONOMIC INFRASTRUCTURE

CCS facilities represent large-scale investments in every stage of the CCS value chain.

These are not just a cost, they also represent significant investments in technology development, engineering, equipment fabrication, construction, port infrastructure and operations.

This is positive for national tax revenues, employment opportunities, spending on R&D.

The future will require decoupling economic growth from emissions growth. CCS enables this.

Northern Lights CO_2 receiving terminal in Øygarden, Norway
Phase 1 capacity: 1.5 Mtpa. Currently under expansion to 5.0 Mtpa (not shown)

Global-scale CO_2 shipping infrastructure will require facilities with 1000x this capacity or more

Projected Global CCS Investments

To 2030	USD 80 billion
2031-2035	USD 200 billion
To 2050	USD 622 billion (WoodMac)

SECTION 3 — PROJECTS AND TECHNOLOGY PROGRESS

Evolution of CCS – demonstration to commercial deployment

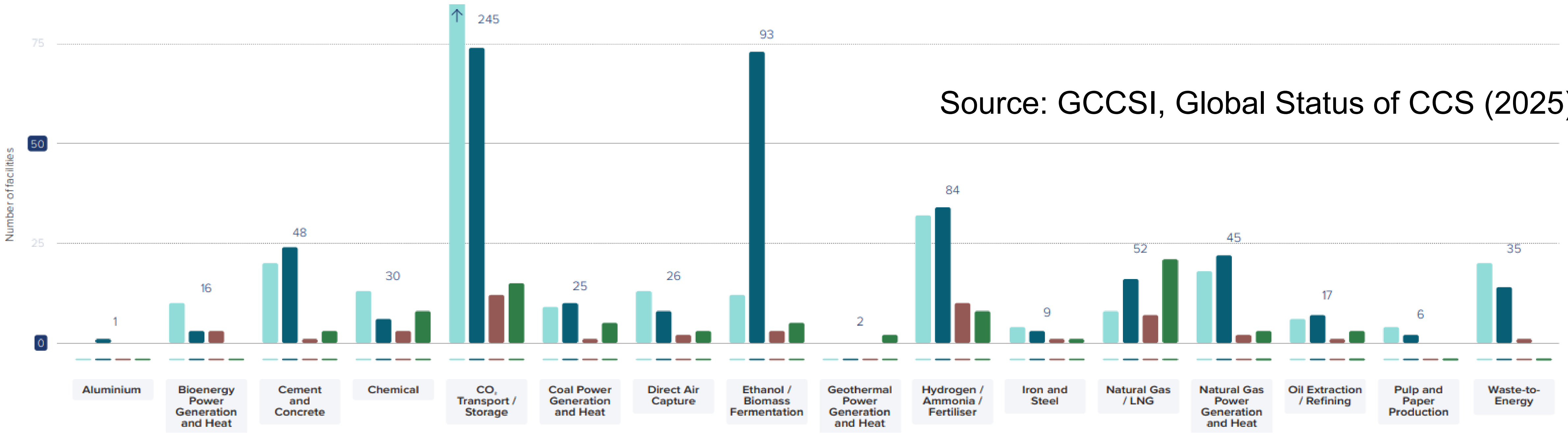
Earliest CO_2 capture was acid gas removal from natural gas – started in 1930s (amine-based capture)

CO_2-based enhanced oil recovery since 1970s. Built thousands of km of CO_2 pipelines mostly in North America and Middle East.

First climate-focussed CO_2 storage was Sleipner in North Sea – commissioned 1996. Enabled by Norway's carbon tax on offshore emissions, underscoring role of supportive policy.

Industry broadening significantly beyond capture from raw natural gas

Number of projects by industry and stage of development



Source: GCCSI, Global Status of CCS (2025)

CCS is real and happening today

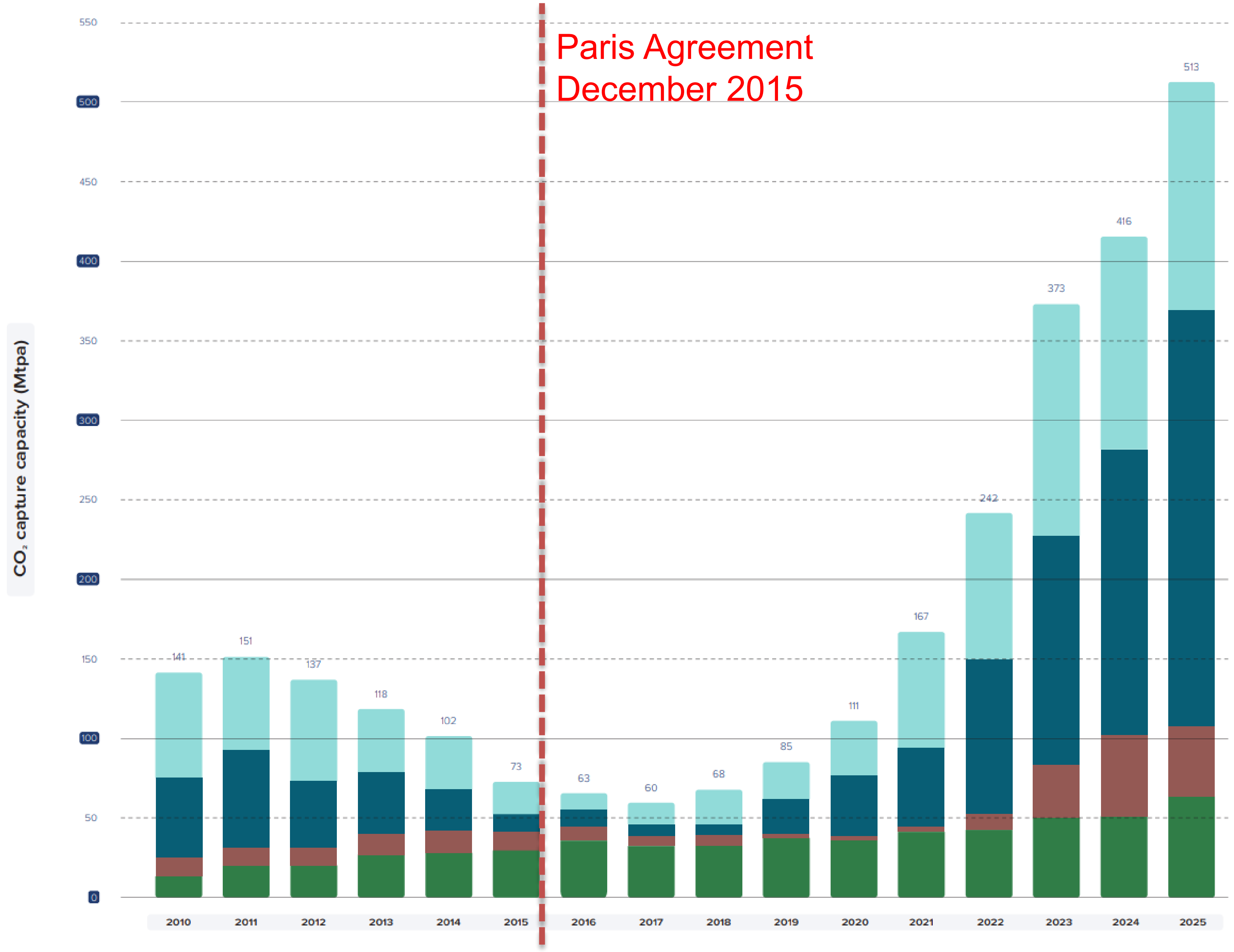
It is not "unproven" as some critics claim – 77 operating commercial facilities worldwide with dozens more being built now.

It is an essential part of our toolkit for decarbonising the global economy

Facility Status	
Early Development	313
Advanced Development	297
In Construction	47
In Operation	77
Overall Total	734

EVOLUTION OF CCS – DEMONSTRATION TO COMMERCIAL DEPLOYMENT

CO_2 capture capacity of commercial CCS facility pipeline since 2010



Source: GCCSI, Global Status of CCS (2025)

CCS Projects tracked by capacity (Mtpa) rather than by facility count

Rapid acceleration in project pipeline since the Paris Agreement

Highlights the key role that regulation and incentives play in making CCS deployment possible.

Historically CO_2 could be emitted for free or at very low cost.

CCS can only happen if a business case can be made, which requires incentives for investment, penalties for emissions, or combinations

The limit to deployment is not technology, it's enabling policy and incentives

CO_2 CAPTURE TECHNOLOGIES TODAY – POINT SOURCE AND DIRECT AIR CAPTURE

Type	Capture medium	Mechanism	Typical fit	Key considerations
Chemical absorption	Liquid solvents, usually amines or alkaline solvents	CO_2 chemically reacts with the solvent, then heat regenerates the solvent and releases concentrated CO_2	Post-combustion flue gas, gas processing, hydrogen, cement, waste-to-energy	Most mature and widely deployed; energy use for solvent regeneration, solvent degradation, corrosion and emissions management are key issues. IEA identifies chemical absorption as one of the most advanced and widely adopted capture routes. (IEA)
Physical absorption	Liquid solvents such as methanol, Selexol-type solvents or other physical solvents	CO_2 dissolves under high pressure and is released by pressure reduction or heating	High-pressure, high-CO_2 streams such as natural gas processing, syngas, pre-combustion capture	Works best where CO_2 partial pressure is high; generally less suited to dilute flue gas without compression. Physical separation is also among the more mature capture approaches.
Adsorption	Solid sorbents: zeolites, activated carbon, metal-organic frameworks, amine-functionalised solids, etc.	CO_2 binds to a solid surface and is released by changing temperature, pressure, vacuum, humidity or electricity	Post-combustion, direct air capture, modular systems, niche gas separations	Potentially lower regeneration energy, corrosion and emissions than solvent systems, but scale-up, durability, heat management and moisture sensitivity can be challenging.
Membranes	Polymeric, ceramic, metallic or hybrid membranes	CO_2 preferentially passes through a selective barrier, separating it from N_2, H_2, CH_4 or other gases	Natural gas sweetening, hydrogen/syngas separation, post-combustion polishing, compact applications	Compact and modular, with no chemical regeneration step; performance depends on selectivity, permeability, pressure ratio and tolerance to impurities. Membranes are a major R&D focus alongside solvents and sorbents.
Cryogenic separation	Low-temperature phase change / liquefaction or solidification	Gas is cooled and/or compressed so CO_2 condenses, liquefies or freezes, then is separated	High-concentration CO_2 streams, oxyfuel systems, some industrial gases, LNG-related applications	Can produce high-purity CO_2 but is energy-intensive for dilute streams; often more attractive where refrigeration or high pressure is already available.
Calcium looping	Solid calcium oxide/calcium carbonate cycle	CaO reacts with CO_2 to form $CaCO_3$; calcination releases concentrated CO_2 and regenerates CaO	Cement, lime, power and high-temperature industrial processes	Attractive for high-temperature integration and cement synergy; challenges include sorbent degradation, heat demand and solids handling. IEA lists calcium looping among important emerging capture routes.
Chemical looping	Metal oxide oxygen carriers	A solid oxygen carrier transfers oxygen to fuel without direct air-fuel mixing, creating a CO_2-rich exhaust after water removal	Power, hydrogen, industrial heat, fuel conversion	Avoids conventional post-combustion separation by redesigning combustion/conversion; still generally less mature than solvents. IEA and NETL both list chemical looping among advanced/novel capture concepts.
Oxyfuel combustion	Process mechanism: combustion in oxygen rather than air	Fuel is burned in near-pure O_2, producing flue gas mainly of CO_2 and water; water is condensed to concentrate CO_2	Power, cement, glass, steel reheating and high-temperature furnaces	Shifts the separation challenge from CO_2/N_2 separation to oxygen production and flue-gas recycle; can suit high-temperature industrial retrofits.
Direct air capture-specific media	Liquid alkaline solvents or solid amine/sorbent materials	CO_2 is captured from ambient air, then released via heat, vacuum, humidity swing or electrochemical methods	Atmospheric CO_2 removal, synthetic fuels, durable carbon removal	Much lower CO_2 concentration than point sources, so energy and cost are higher; useful where removals are needed rather than only emissions avoidance.
Electrochemical / electro-swing capture	Redox-active liquids, membranes or electrodes	Electrical potential changes the affinity of a material for CO_2, enabling capture and release	Early-stage point-source capture, DAC, modular systems	Promising for lower-temperature operation and renewable electricity integration, but generally earlier-stage than solvent, sorbent and membrane systems. Recent reviews identify electroswing among emerging capture mechanisms

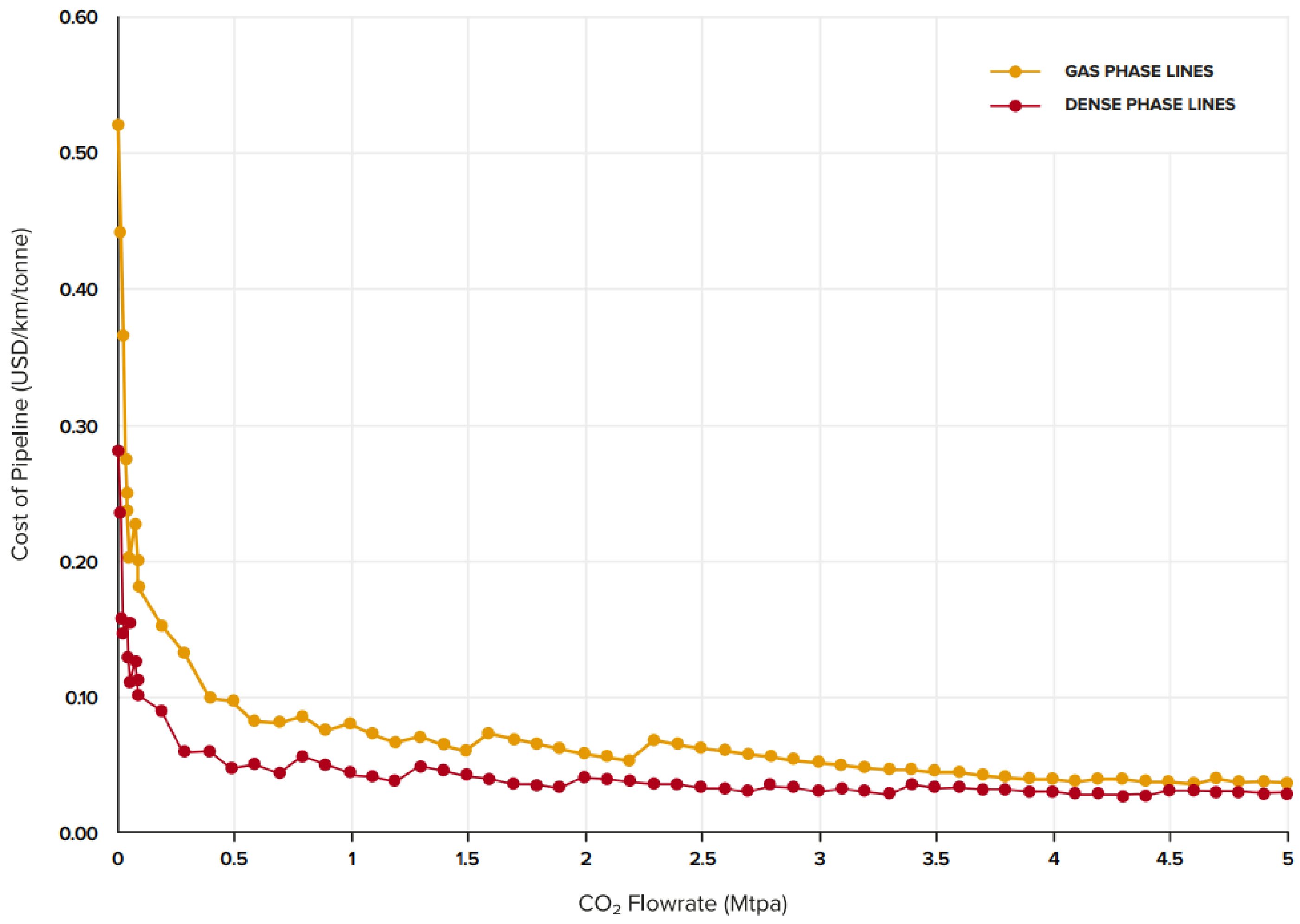
Available at globalccsinstitute.com

All capture technology types are under active development today – see our Technology Compendium for many examples.

TRANSPORT OF CO_2 – PIPELINES

Pipelines

Typically constructed of carbon steel, no external insulation needed
CO_2 can be transported as a gas or in the dense phase (>critical pressure of 73.8 bar).
Dense phase more common for bulk transmission of CO_2 (lower cost)
Gas phase more common within capture facilities or over shorter distances
Unit cost ($/km/tonne) levels off above around 1 Mtpa



Source: Kearns, Liu and Consoli (2021)

Implications

Capex dominates, capex scales linearly with distance. Gives a cost advantage where storage site is geographically close to the capture source(s)

Economies of scale dominate in pipeline systems.

Aggregating CO_2 streams can substantially reduce the costs of transport.

Incentivises the "hub" model of CCS deployment. Multiple CO2 capture systems feeding into shared pipeline and storage infrastructure.

Porthos CO_2 pipeline Network under construction in Rotterdam, Netherlands. Source: European Commission (2025)

TRANSPORT OF CO_2 – SHIPPING

Ships require CO_2 to be liquified
Liquefaction is needed to boost density to reasonable levels, as is observed in LNG shipping. Must be at pressure to enable liquid CO_2 to form (avoid sublimation)

Low pressure CO_2 – 6-10 bar, -50 to -45°C
Medium pressure – 15-18 bar, -30 to -25°C

Requires CO_2 to be liquified (electricity intensive) and capital-intensive ships.

Costs have significant base cost, with unit costs scaling with distance and volume

Carbon Destroyer 1 in the North Sea as part of Project Greensand
Source: Royal Wagenborg

Cost drivers incentive larger ships and low-pressure CO_2

In the Asia Pacific, shipping distances are vast (much more than in Europe).

As distances exceed 2000 km there is incentive to make ships as large as possible. Eventually their size will be limited by ability to navigate ports (similar to LNG ship constraints)

Double the distance means twice as many ships, all else being equal. So capital can become significant if ships are not big enough.

Unit costs of ship-based transport of liquid CO_2
Source: Barlow, Shahi & Kearns (2025)

STORAGE IS THE CRITICAL ENABLER

CCS is a resources industry – the resource is suitable subsurface pore space.

Without this resource, projects cannot happen. Storage is the foundation of all CCS projects.

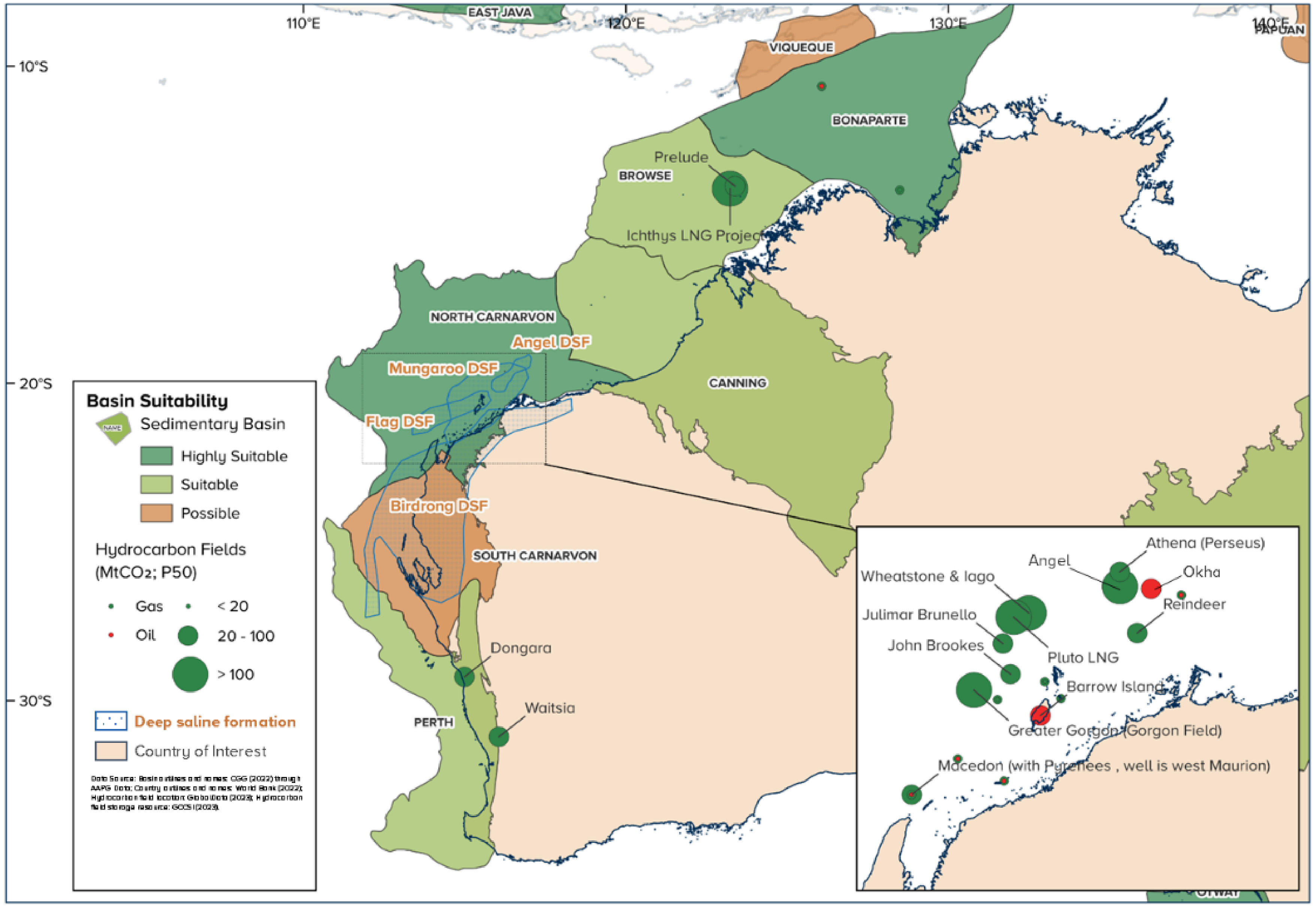
Storage happens at high enough depths to keep CO_2 in the dense phase (>73.8 bar) – i.e. below 800m deep.

Storage maps have been developed by Geological Services in various countries, allowing assessments of potential basins for CO_2 storage.

In many instances storage formations are offshore, requiring more involved arrangements for construction and operation.

In all relevant countries, the subsurface is the property of the State, and thus use must be enabled and authorised by appropriate regulations

Storage types:
Saline aquifer (most common)
Depleted oil and gas fields (lower cost due to infrastructure reuse)
Basaltic rock (niche, in use in Iceland with DAC (Climeworks/Carbfix)



Storage Resources basin suitability map for Northern and Western Australia

Only fields with prospective capacity over 20 $MtCO_2$ are shown
Source: Global CCS Institute (2025)

STORAGE RESOURCES IN THE ASIA-PACIFIC

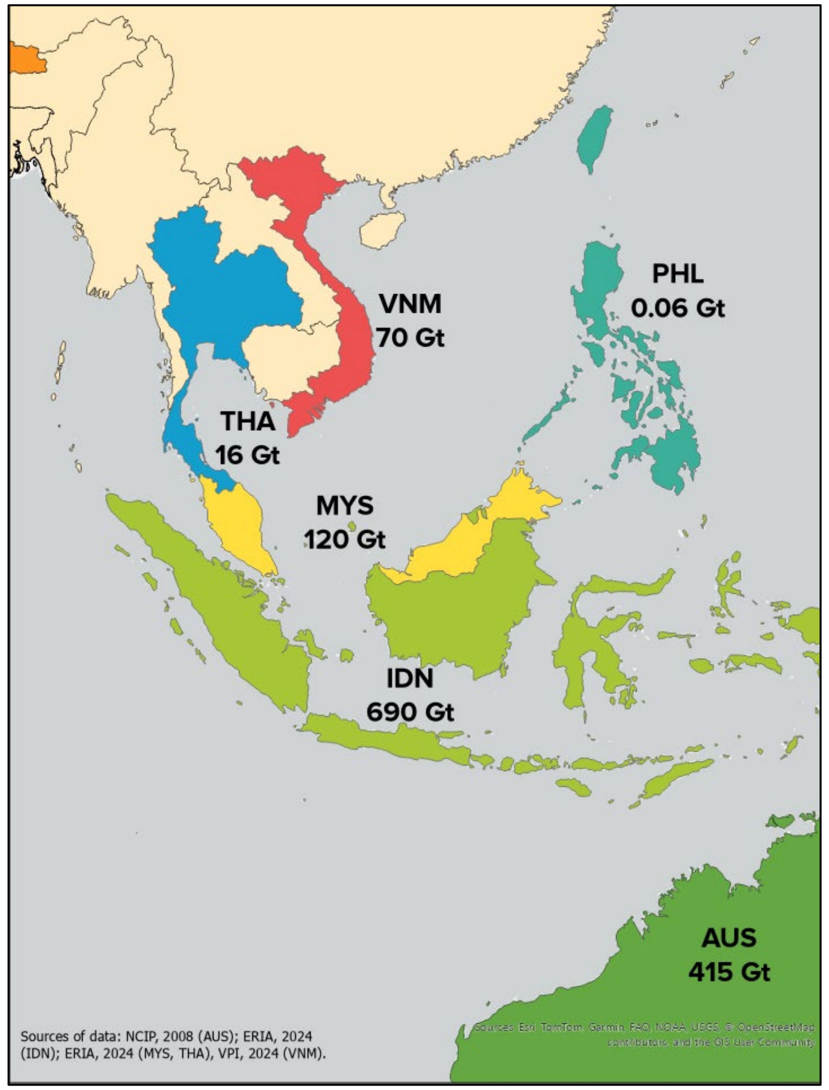
Large storages in China and India (domestic CO_2 focus).

Indonesia, Malaysia and Australia are three key nations with significant storage resources in excess of domestic needs.

Limited and lower quality storage in South Korea and Japan. They are developing domestic capacity but will need much more – planning to export by ship.

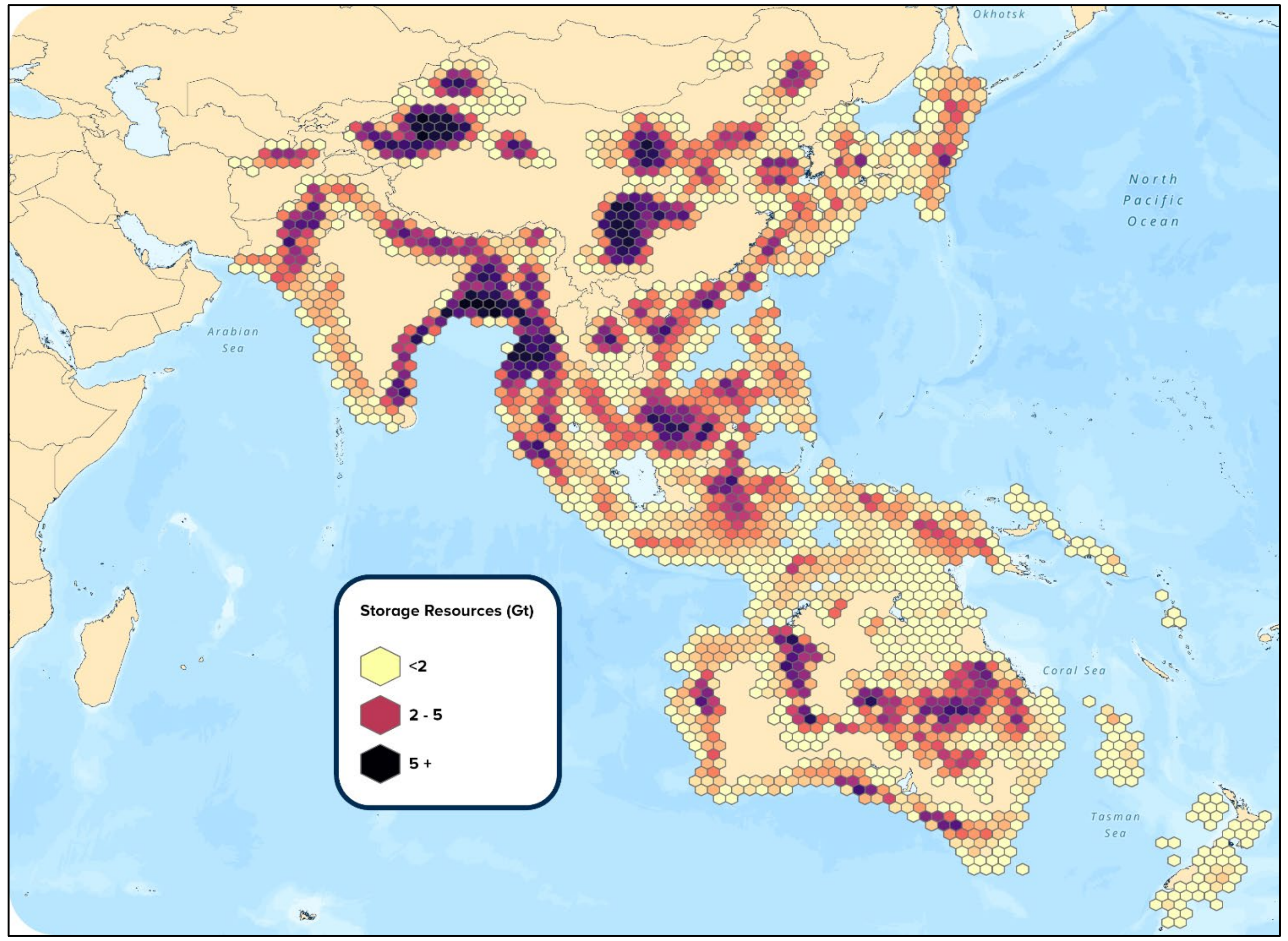
Opportunity for a new import/export industry:
CO_2 exporters: Japan, Korea, Singapore
CO_2 importers: Australia, Indonesia, Malaysia

Competition expected between storage countries to contract CO_2 shipments.
Each country to determine balance between storage use for domestic and imported CO_2



Storage resources across APAC region
Source: GCCSI analysis

Hexagon size 150 km across (19,486 km^2 area)
For reference, around 400 Mt (0.4 Gt) stored since 1996



WHAT DOES EFFECTIVE CCS POLICY LOOK LIKE

In order for CCS Projects to be built, developers need to have a sufficiently attractive business case, and for CCS to be lower cost than alternate options available.

These require two things:

Enablers: the legal right to access subsurface storage resources that belong to the State, plus usual permitting needed for pipelines and industrial facilities, and;

Incentives: A combination of carrots and sticks to encourage decarbonisation in general and/or CCS in particular.

Enablers

- Regulation of subsurface – permits (exploration and operating)
- MMV (Measurement, Monitoring, Verification)
- Long-term liability (who is responsible for CO_2 over 20+ year time scales post-closure)

Incentives

- Investment tax credits
- Production tax credits (e.g. 45Q in the US)
- Loan guarantees
- Capital grants (Innovation Fund in the EU - €40 billion to 2030)
- Carbon credits (e.g. Australian ACCUs)
- Operating support
- Carbon Contracts for Difference (CCfDs) – primarily in UK and European Union. Provides stability of abatement price under a fluctuating Emissions Trading Scheme (ETS) and supplements carbon price incentive.

Regional Spotlight

Australia, SE Asia and India

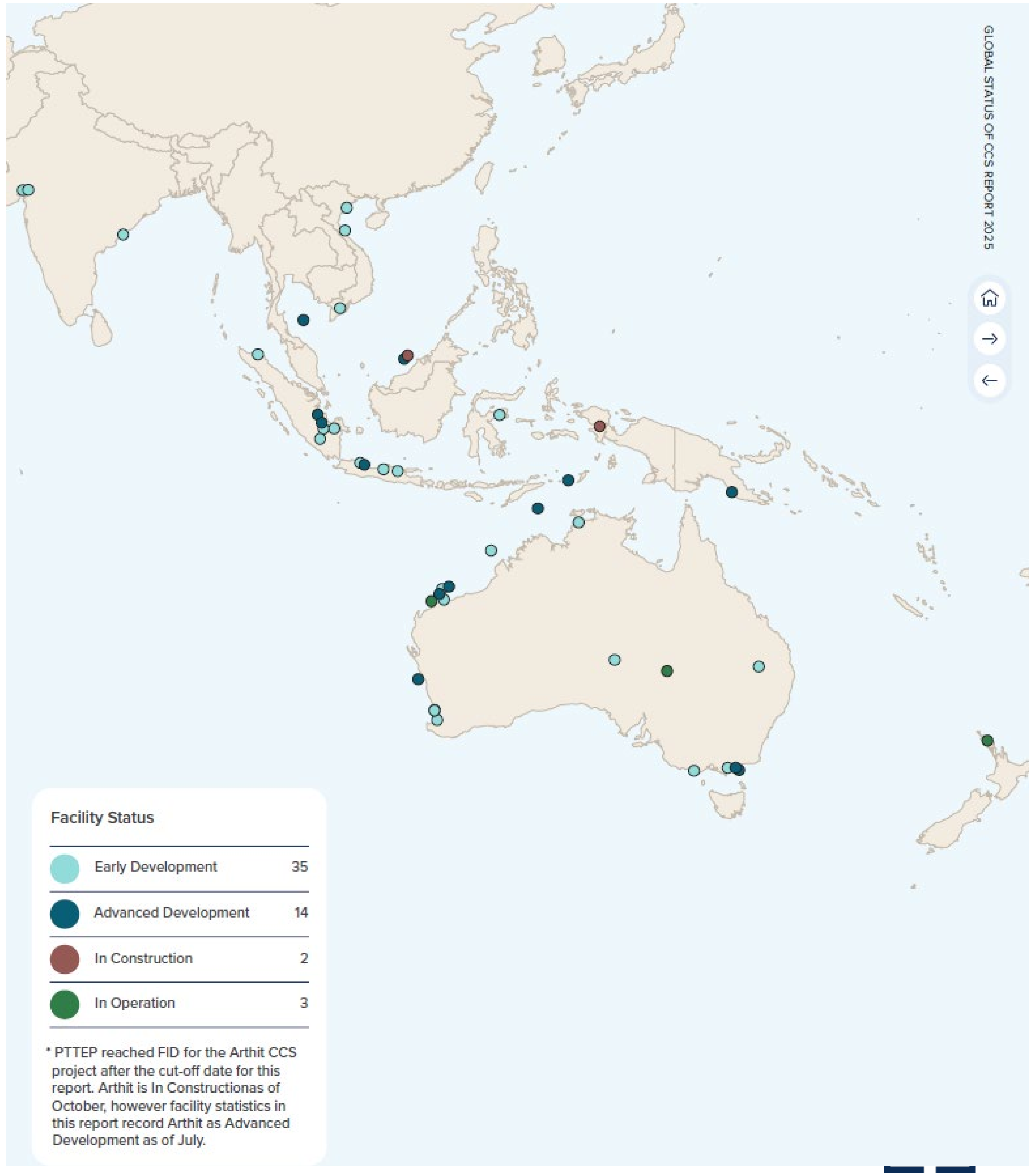
Critical role of CCS creating both opportunities and challenges

Progress: Key regulatory gains in Australia, Indonesia & Malaysia.

Collaboration: Cross-border CO_2 trade advancing as governments strike deals & companies form JVs/MoUs.

Challenges: Low-cost CCS applications moving ahead, but higher-cost projects lack policy support.

Momentum: New projects and studies announced as CCS opportunities gain traction.



Regional Spotlight

Australia, SE Asia and India

Regulation, projects, collaboration

- Regulatory progress: Governments are establishing CCS regulations and carbon frameworks, but incentives and clarity are not yet sufficient to fully unlock large-scale investment and deployment.

- Operational & developing projects: Gorgon and Moomba online; Kasawari, Tangguh, Arthit under construction; 54 facilities in earlier development across APAC.

- Collaboration & transport: Cross-border MoUs, CO_2 shipping hubs, and innovative dual-cargo vessels improving regional CCS deployment.

Regional Spotlight

China

World’s largest coal-power CCS project marks China’s next phase

Milestone: Huaneng’s 1.5 Mtpa coal power CCS project positions China as global leader in fossil decarbonisation.

Foundation: Policy support strengthening since 2024, with CCS embedded in sectoral transition plans, especially coal power.

Progress: Tech manufacturing and demos advancing; Chinese firms improving efficiency, cutting costs, scaling CCS solutions.

Momentum: 15th Five-Year Plan could embed CCS, providing long-term policy clarity and national alignment.

Image courtesy of Huaneng Clean Energy Research Institute

Regional Spotlight

Japan

Clear policy shifting CCS closer to commercial reality

Momentum: Govt reaffirms CCS as core to 2050 net zero; nine projects & 240 Mtpa roadmap.

Drivers: 2024 CCS Act enables licensing & pipelines.

Progress: Govt & industry advancing CO_2 ship transport R&D, standards & cost reduction for LCO_2 carriers.

Challenge: Limited onshore storage drives reliance on partners; FIDs by 2026 need govt drilling support.

Market Incentives: Govt designing CAPEX-OPEX support schemes and launching GX-ETS cap-and-trade system from 2026.

CCS: A PRACTICAL PATHWAY FOR INDUSTRIAL DECARBONISATION IN THE ASIA-PACIFIC

CCS enables hard to abate sectors to be decarbonised while providing jobs, services and materials the modern world needs

CCS supports energy security, especially in places like China where all power generation options are required to meet demand

CCS reduces the costs of the energy transition – getting there and staying there

CCS creates a new economic opportunity for countries across the Asia-Pacific, including developing areas in South East Asia

Tomakomai CCS Project, Hokkaido Island, Japan
Image: IEA

THE WINDOW FOR ACTION IS NOW

Many nations have committed to net zero by 2050.

Climate science is showing considerable overshoot on current trajectory.

We do not have the luxury of time or excess capital to leave any options off the table, or to wait for new technologies to emerge. We must use what we have today.

The Petra Nova Carbon Capture Project
(Image: Mitsubishi Heavy Industries)

NET ZERO IN ASIA-PACIFIC WILL BE PRACTICALLY IMPOSSIBLE WITHOUT CCS

Suboptimal deployment will will delay net zero and make it more expensive

Momentum is building but it is way below what is needed

Increased incentives and clearing regulatory barriers will enable these critical investments to be made at faster pace

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Q & A

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