CARBON CAPTURE TECHNOLOGIES: ADVANTAGES AND DISADVANTAGES

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David T. Kearns, PhD
Principal Consultant CCS Technologies
david.kearns@globalccsinstitute.com

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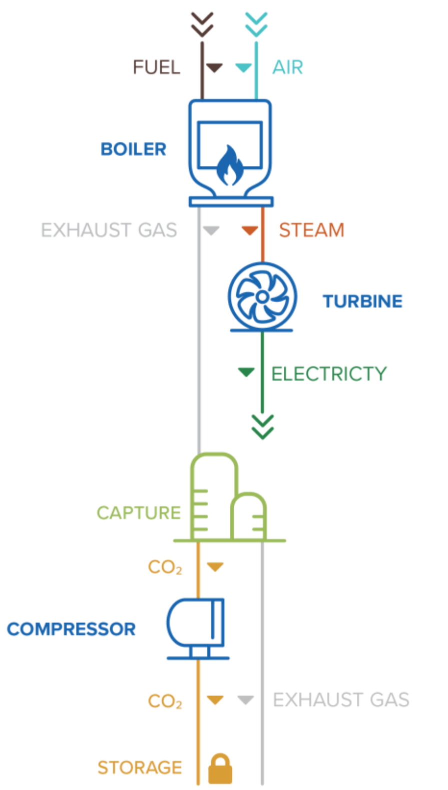
CARBON (CO_2) CAPTURE – CONFIGURATIONS (COMBUSTION)

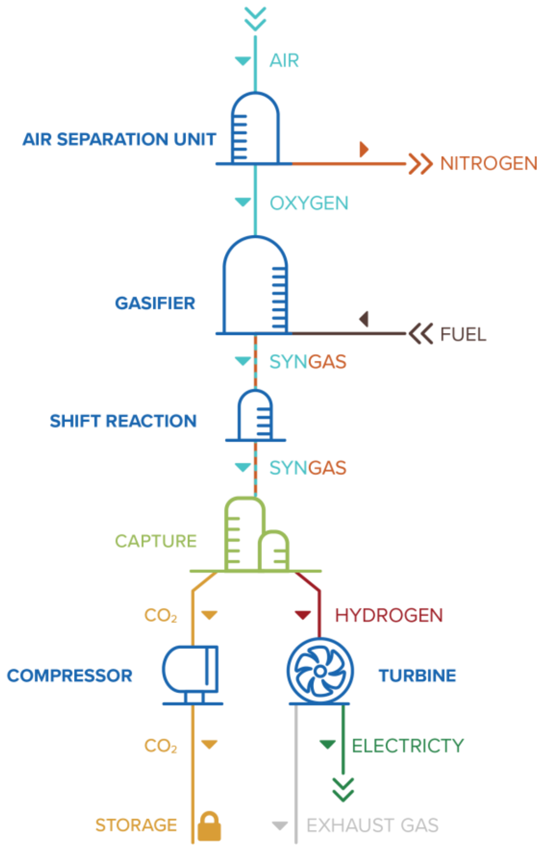
Conventional combustion produces CO_2 diluted mostly with nitrogen. 3 approaches to separating CO_2 out.

POST-COMBUSTION CO_2 CAPTURE



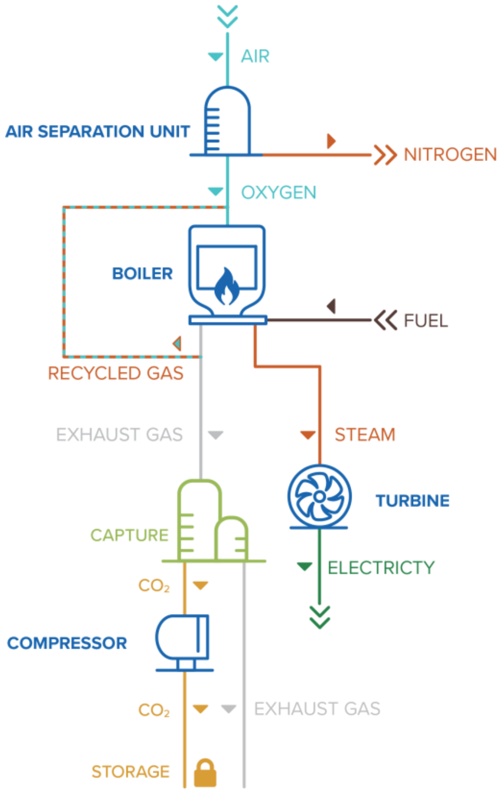
Separates CO_2 from Nitrogen

PRE-COMBUSTION CO_2 CAPTURE



Removes carbon from the fuel (as CO_2)

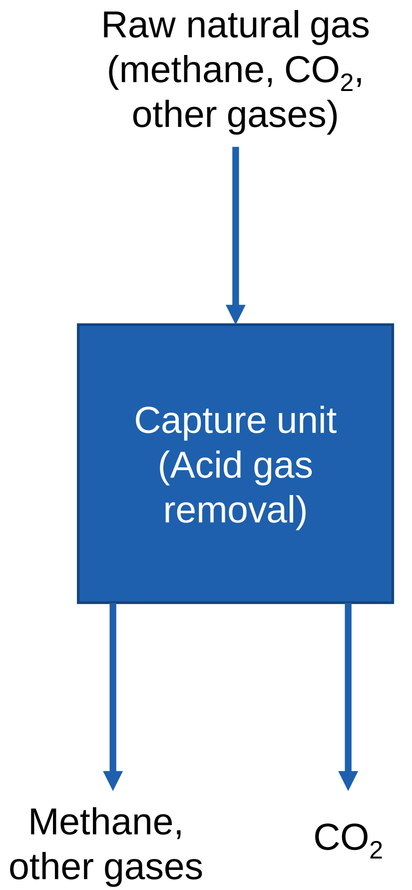
OXYFUEL CO_2 CAPTURE



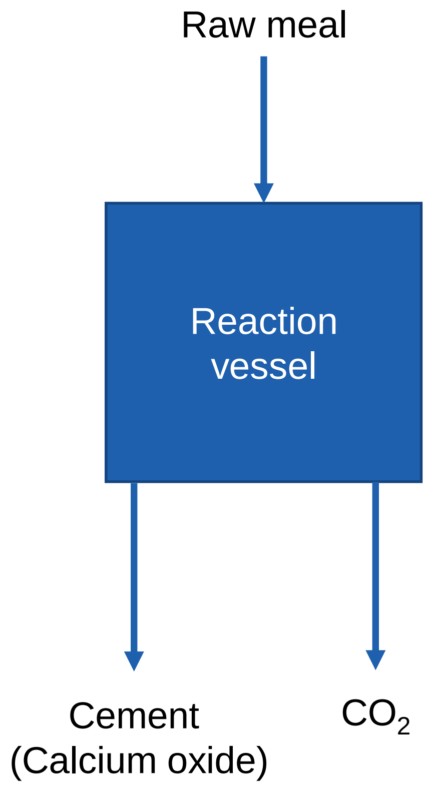
Separates nitrogen from combustion air

CARBON (CO_2) CAPTURE – CONFIGURATIONS (INDUSTRIAL)

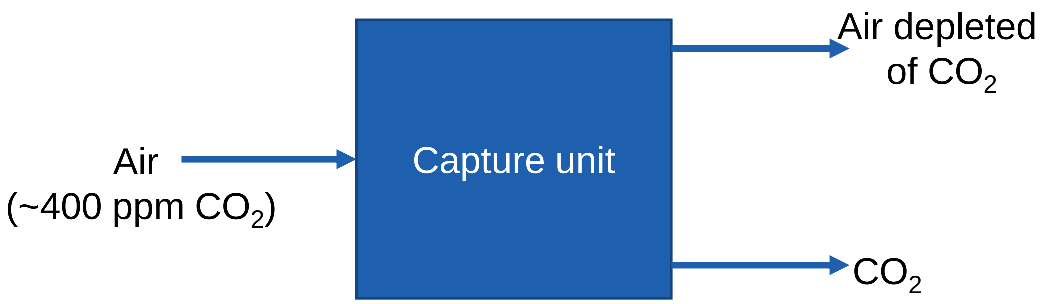
<u>Natural gas processing</u>



<u>Cement production (inherent capture)</u>



DIRECT AIR CAPTURE OF CO_2



Climeworks' Orca Direct Air Capture Plant –
4000 tonnes/year CO_2 capture capacity

Carbon Engineering Direct Air Capture Plant (artist's image) –
1 Million tonnes/year CO_2 capture capacity

ABSORPTION (SOLVENT) BASED CO_2 CAPTURE

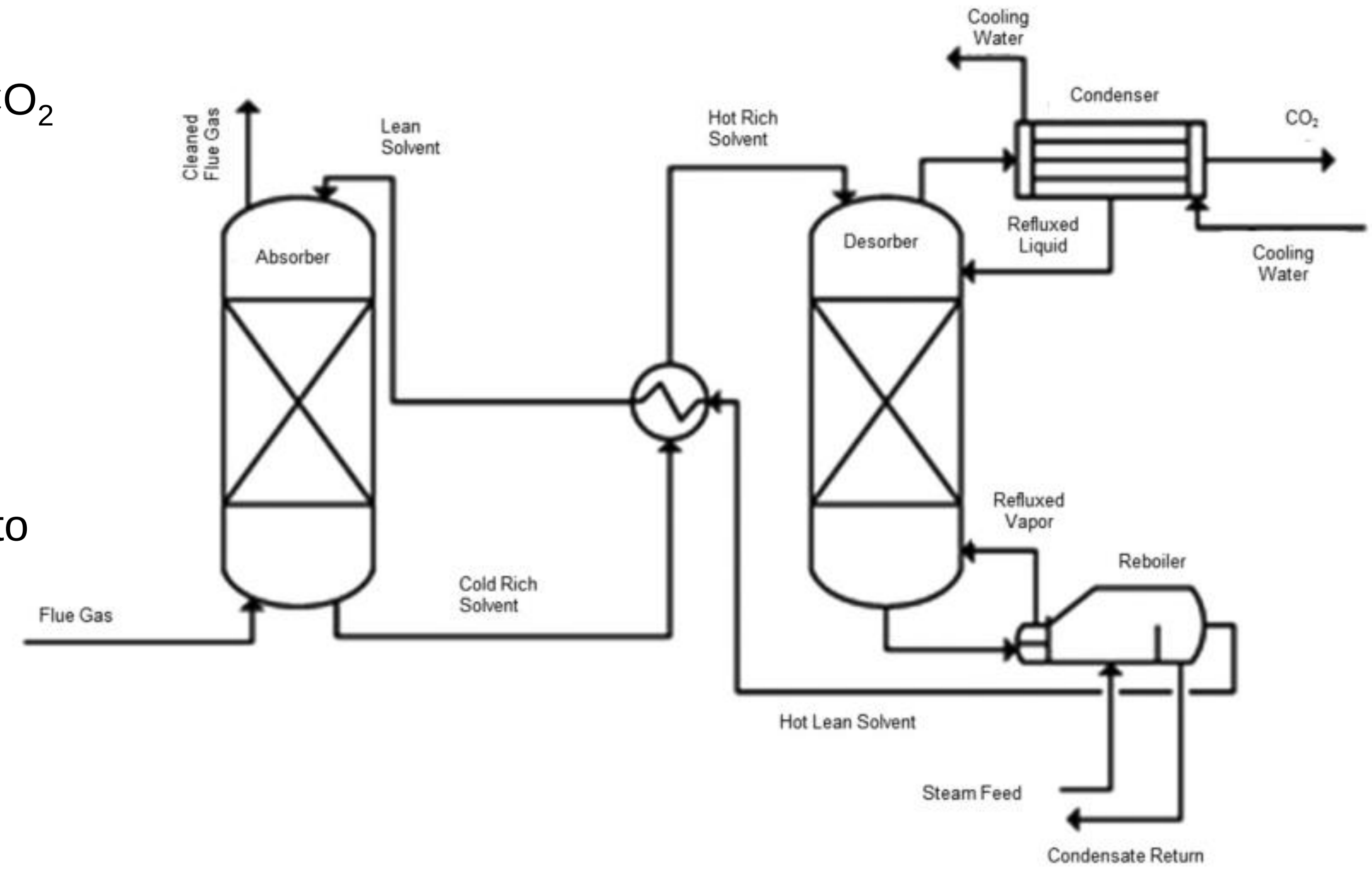
Uses a solvent that preferentially absorbs CO_2 from gas into a liquid.

“Chemical” solvents react CO_2 and work at lower pressures. “Physical” solvents do not react absorbed CO_2 and work at higher pressuers

Uses heat to force CO_2 back out of liquid into gas in a desorber.

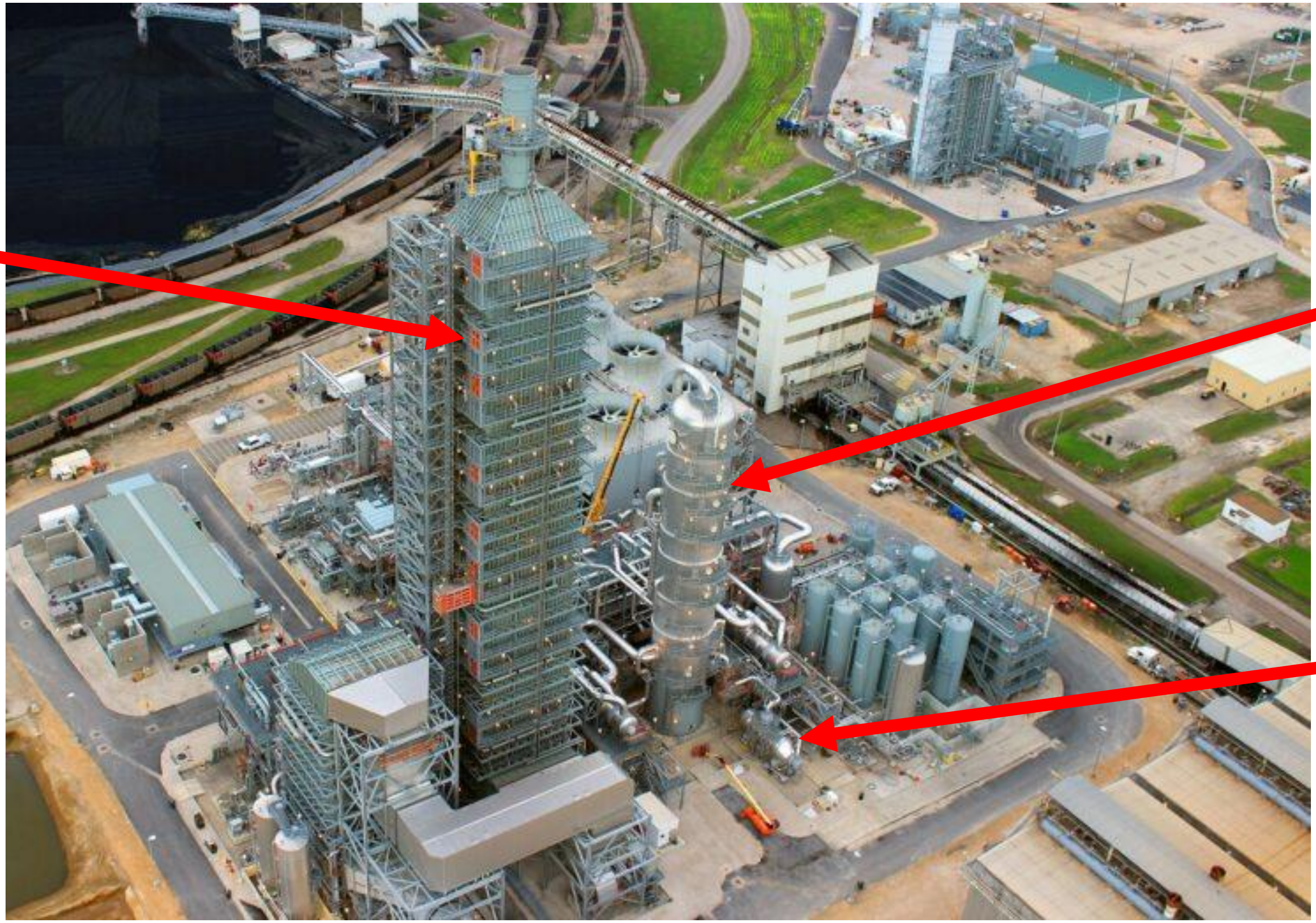
Solvent types include aqueous solutions of:

- Amines (MEA, MDEA, Piperazine, many others)
- Potassium Carbonate
- Liquid glycols (physical solvent)
- Novel new solvent types



ABSORPTION (SOLVENT) BASED CO_2 CAPTURE

Absorption column



Desorption (stripper) column

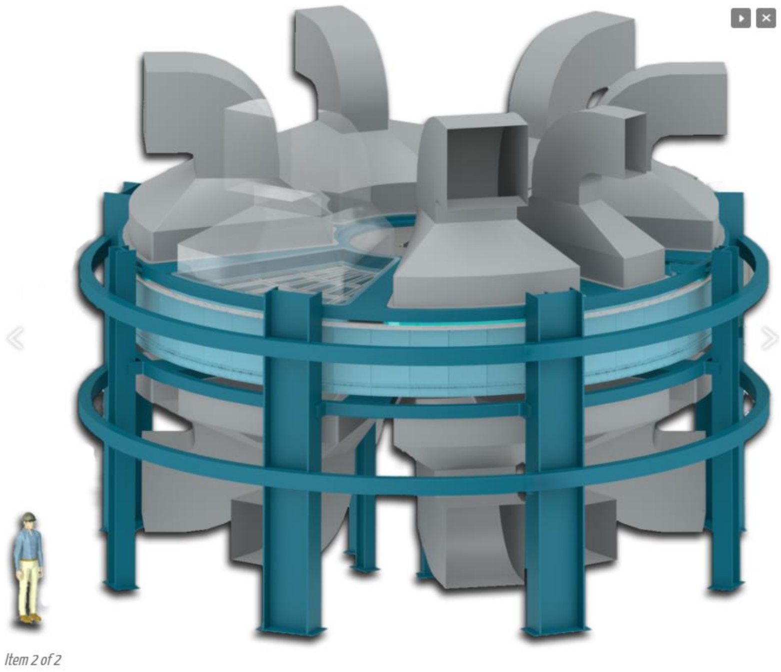
Reboiler (heat energy source)

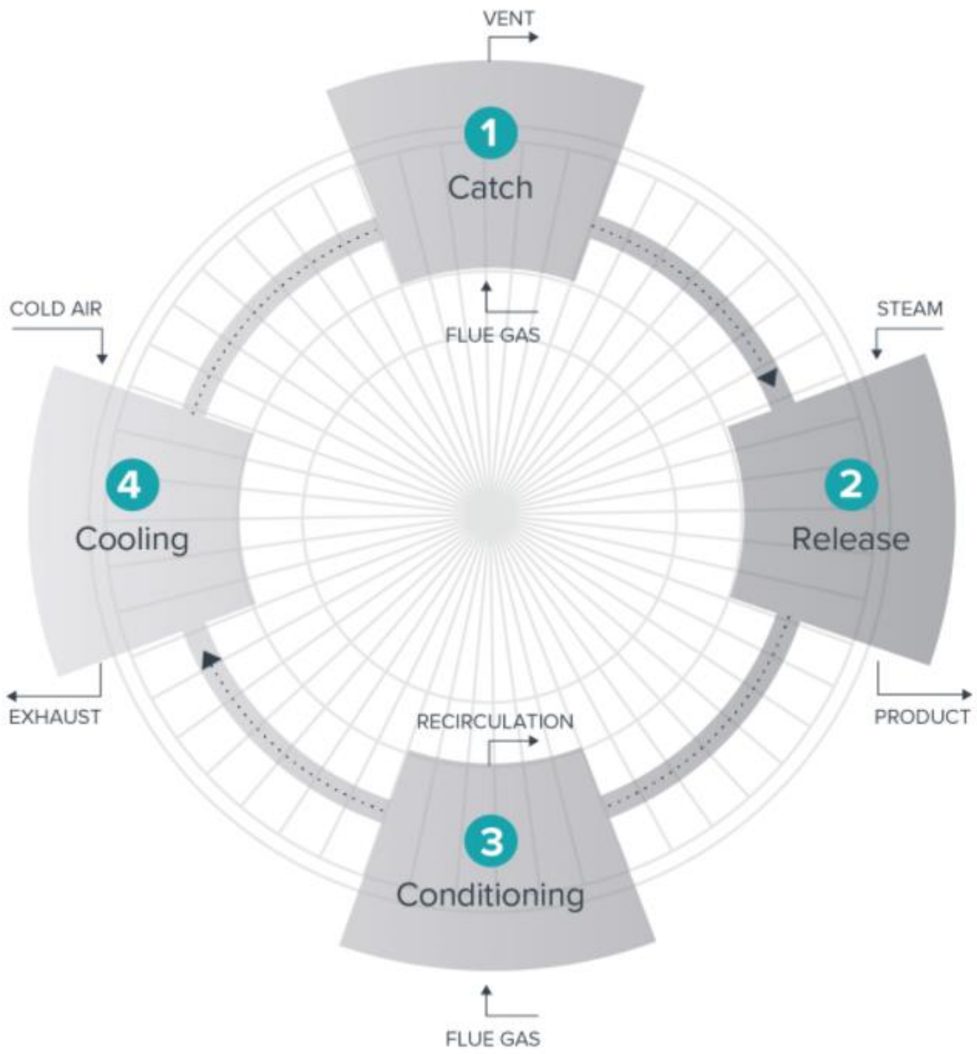
ADSORPTION (SOLIDS) BASED CO_2 CAPTURE

Uses a porous solid that preferentially adsorbs CO_2 from gas onto solid surface.

Uses heat or a drop of pressure to force CO_2 off solid back into the gas phase.

Configured as temperature swing adsorption (TSA) or pressure swing adsorption (PSA)





Svante’s Veloxotherm TSA cycle

MEMBRANE BASED CO_2 CAPTURE

Similar technology to that used in reverse-osmosis desalination of seawater.

Based on differential rates of mass transfer of CO_2 and other gases across an engineered membrane wall.

Usually sensitive to moisture, so molecular sieve dryer is often required.

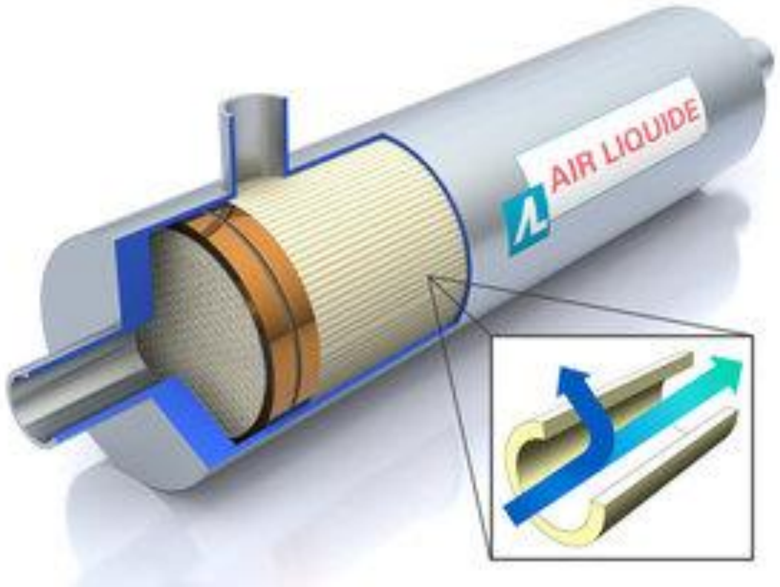
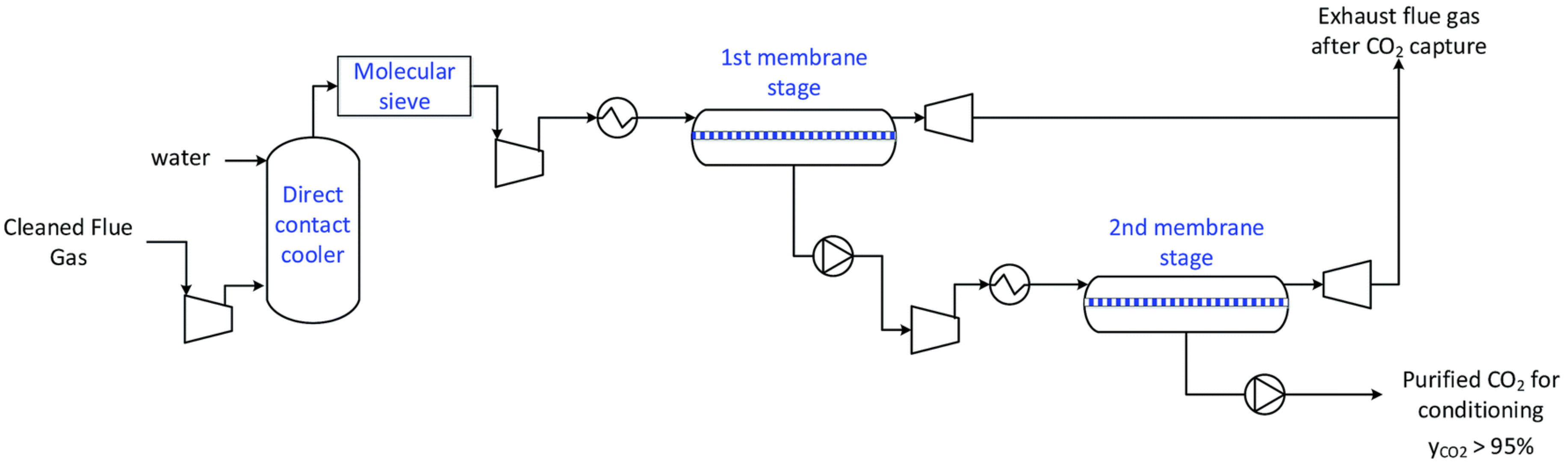


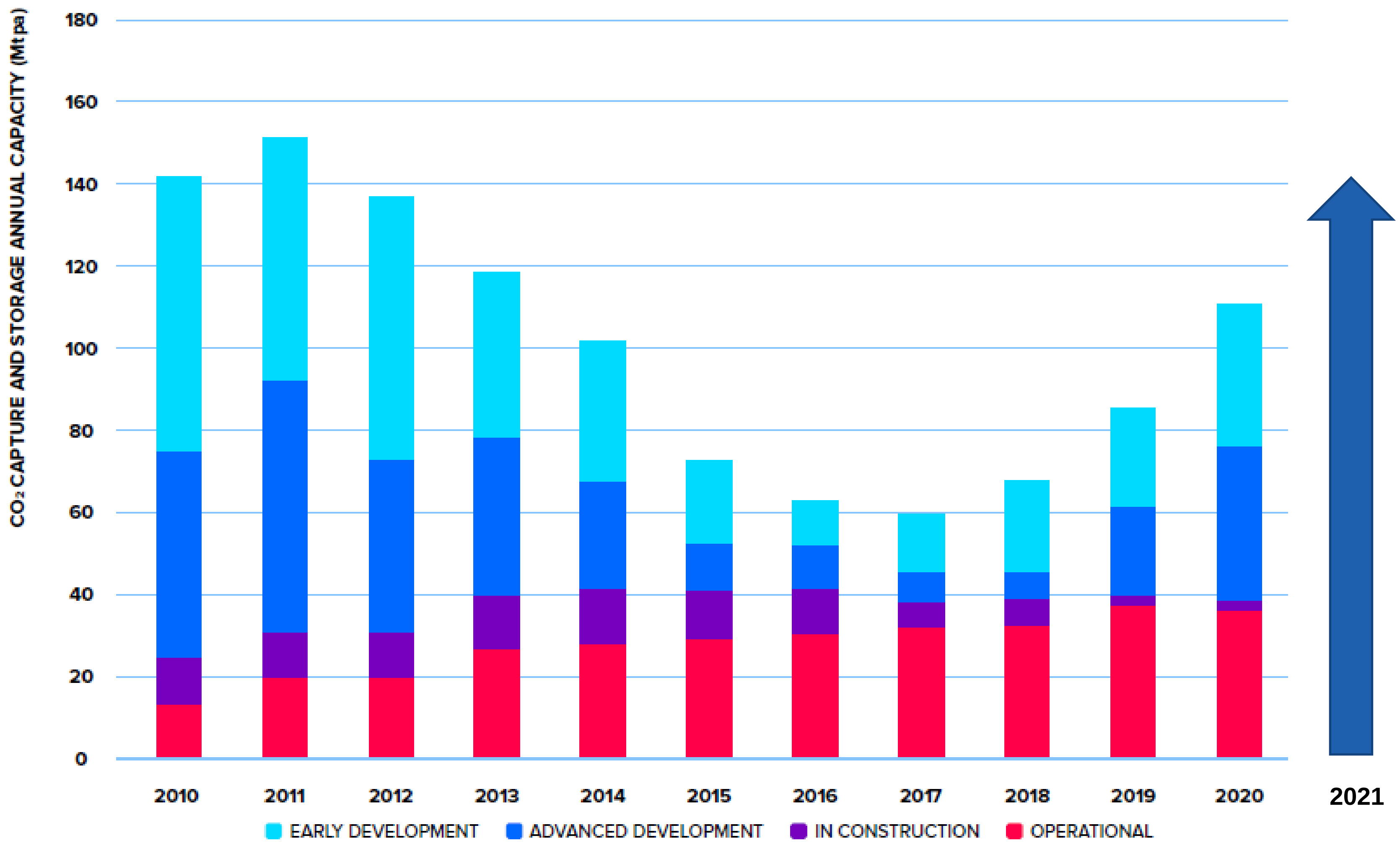
Image: Air Liquide



CO_2 CAPTURE TECHNOLOGIES

Capture technology type	Absorption (solvent)	Adsorption (solid)	Membranes
Energy type	Heat (typically 100-140 C steam)	Electricity (Pressure swing adsorption) or heat (temperature swing adsorption)	Electricity and/or from feed gas pressure (natural gas processing)
Most suitable for	High gas flows	Low-medium gas flows	Low-medium gas flows
Advantages	Many solvent types available	Modular, non-toxic materials.	Small footprint, light weight (suitable for offshore), modular
Disadvantages	Solvent degradation, large plant footprint	Capital costs per tonne become high for high flowrates.	Produces CO_2 at low pressure (more compression required after capture). High purity CO_2 a challenge. Not suitable for low partial pressure CO_2.

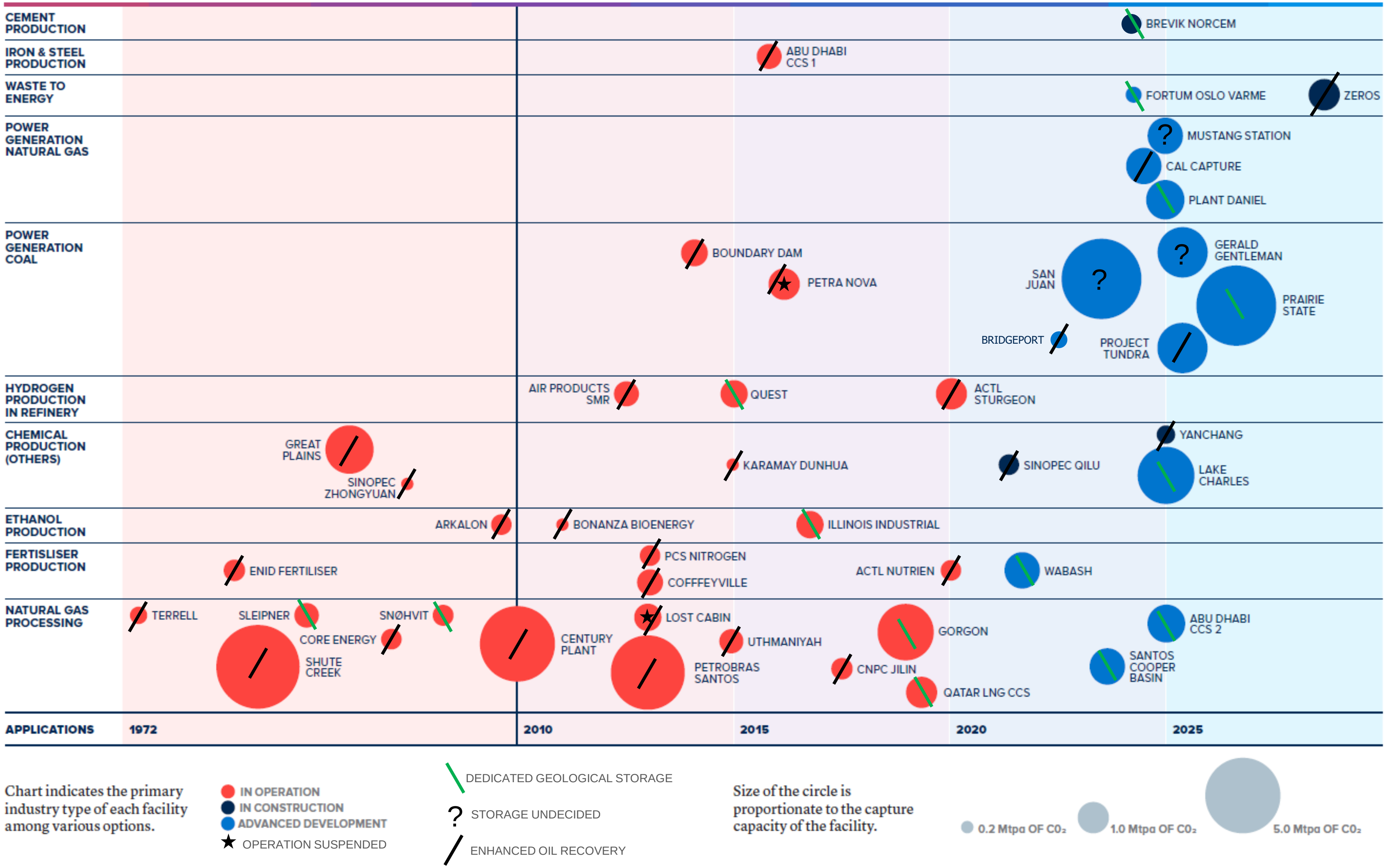
CCS PROJECTS ARE GROWING STRONGLY



Facilities that have not announced their capacity are not included in this chart

- Average 30%yoy growth since 2017
- Accelerated in 2021

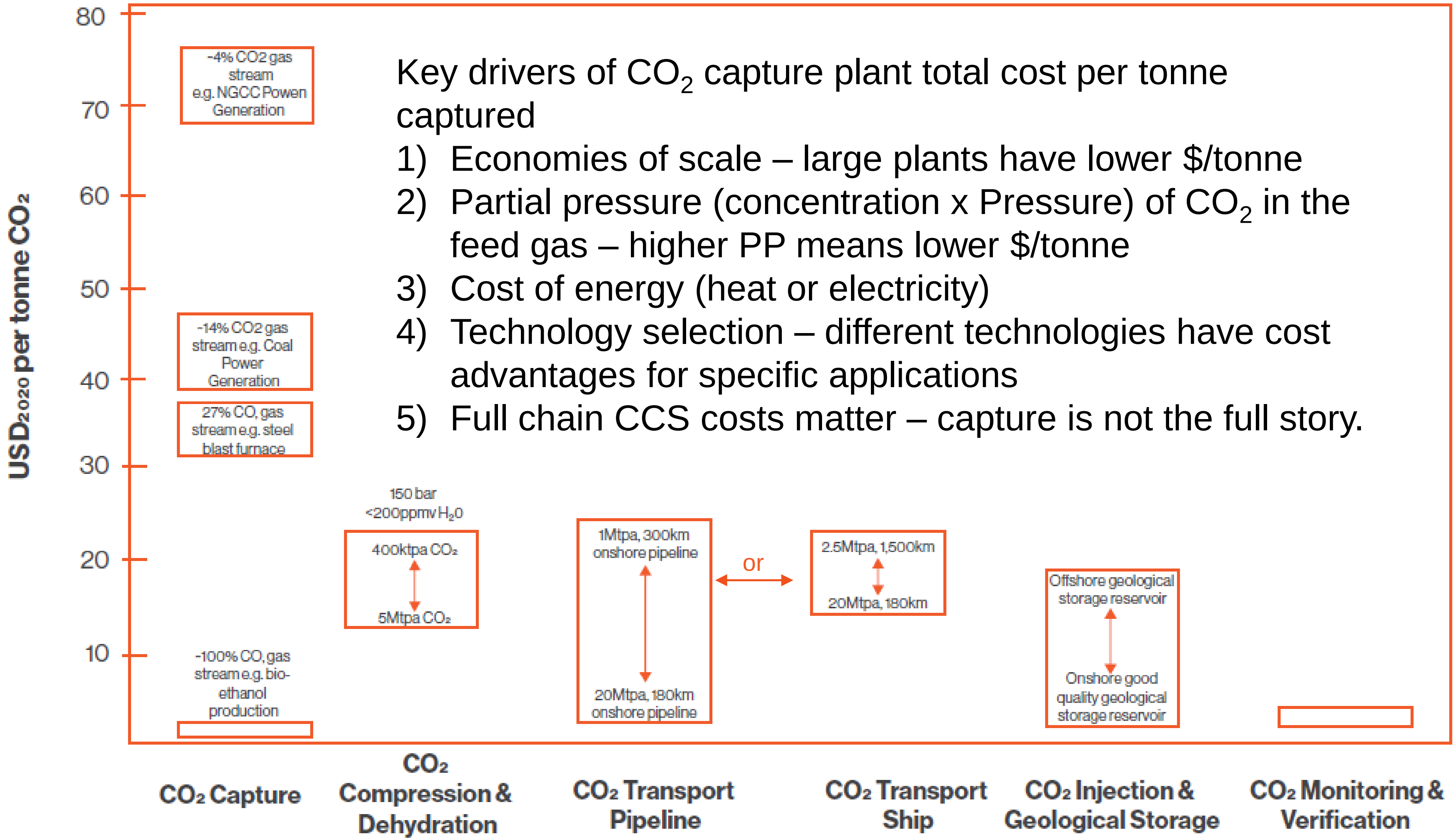
COMMERCIAL CCS FACILITIES – OPERATING, IN CONSTRUCTION AND ADVANCED DEVELOPMENT



Advanced projects are now operating or under development in a wide range of sectors around the world.

Source: Global CCS Institute

COST DEPENDS ON APPLICATION & LOCATION



Key drivers of CO_2 capture plant total cost per tonne captured

1) Economies of scale – large plants have lower $/tonne
2) Partial pressure (concentration x Pressure) of CO_2 in the feed gas – higher PP means lower $/tonne
3) Cost of energy (heat or electricity)
4) Technology selection – different technologies have cost advantages for specific applications
5) Full chain CCS costs matter – capture is not the full story.

Source: Global CCS Institute

THANK YOU

david.kearns@globalccsinstitute.com
+61 403 322 161
globalccsinstitute.com

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DRIVERS OF CCS DEPLOYMENT

- Lower cost capture applications first (higher CO_2 partial pressure)
  - Natural gas processing/oil refining → chemical production including H_2→ biofuel production → steel making → coal power

- Policies that mitigate market failures and create a business case for investment
  - Value on CO_2, clear regulation of CO_2 storage, support for storage resource appraisal, appropriate management of long-term liability for geologically stored CO_2

- Lower cost CO_2 geological storage
  - Existing data from hydrocarbon exploration/production

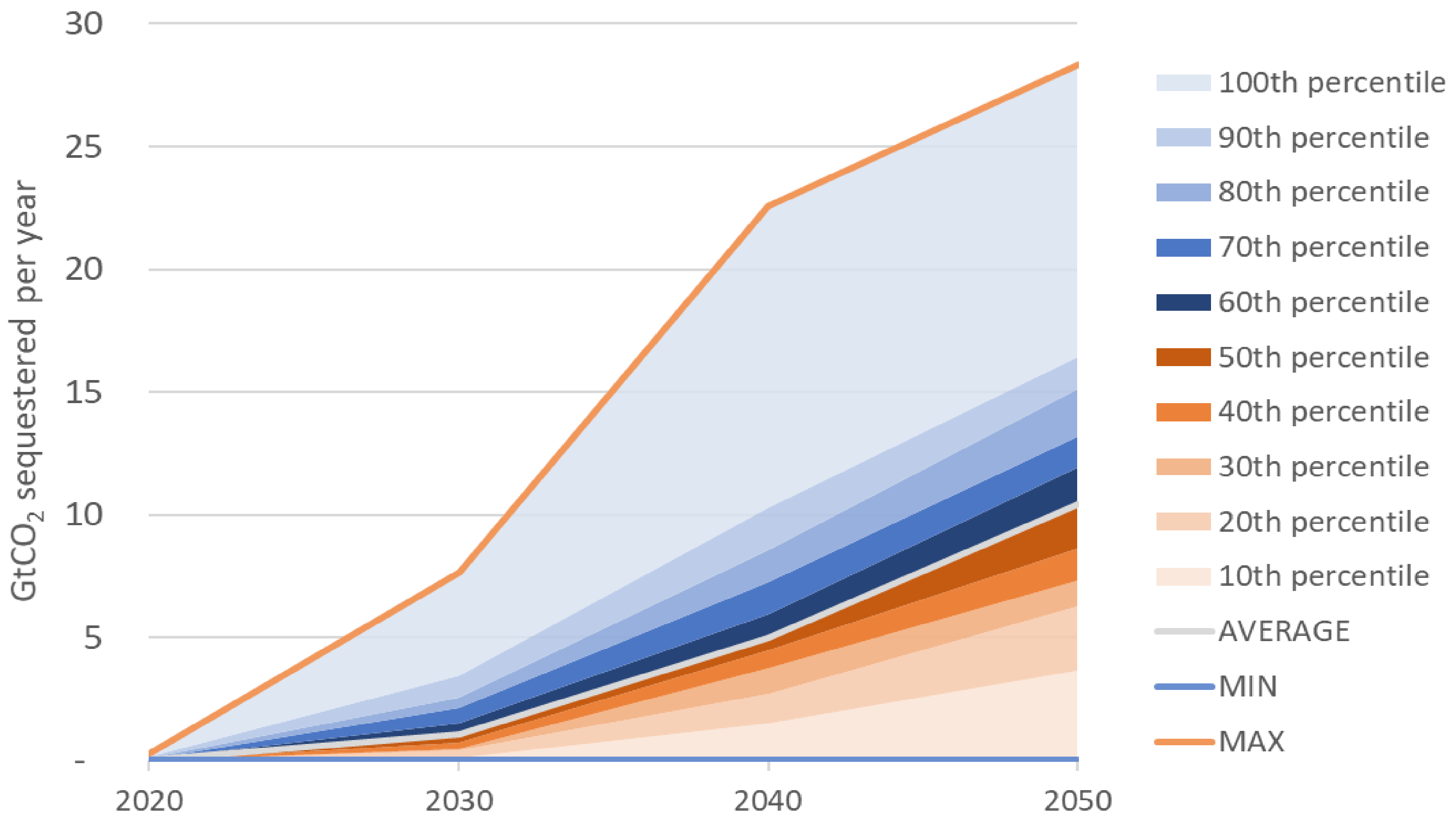
- Opportunities for CCS hubs to deliver economies of scale and mitigate risk
  - CO_2 sources located proximate to each other, and geological storage resources

- Net Zero Commitments – avoidance of stranded assets

CCS IS ESSENTIAL TO MEET CLIMATE TARGETS

The average mass of CO_2 required to be stored in the year 2050, across all 90 scenarios studied by the IPCC in its Special Report on Global Warming of **1.5° Celsius** was 10Gt.

Annual CO_2 Stored in the 90 1.5°C Consistent Scenarios Reviewed in the IPCC Special Report on Global Warming of 1.5°C



Source: GCCSI analysis of IIASA 1.5C Scenario Explorer