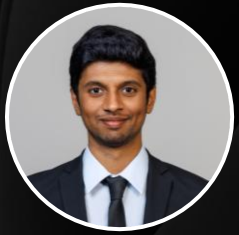
EMISSIONS OR ASSET?

Identifying Winning CO_2 Utilization Pathways



Mukunda Kaushik
Senior Analyst

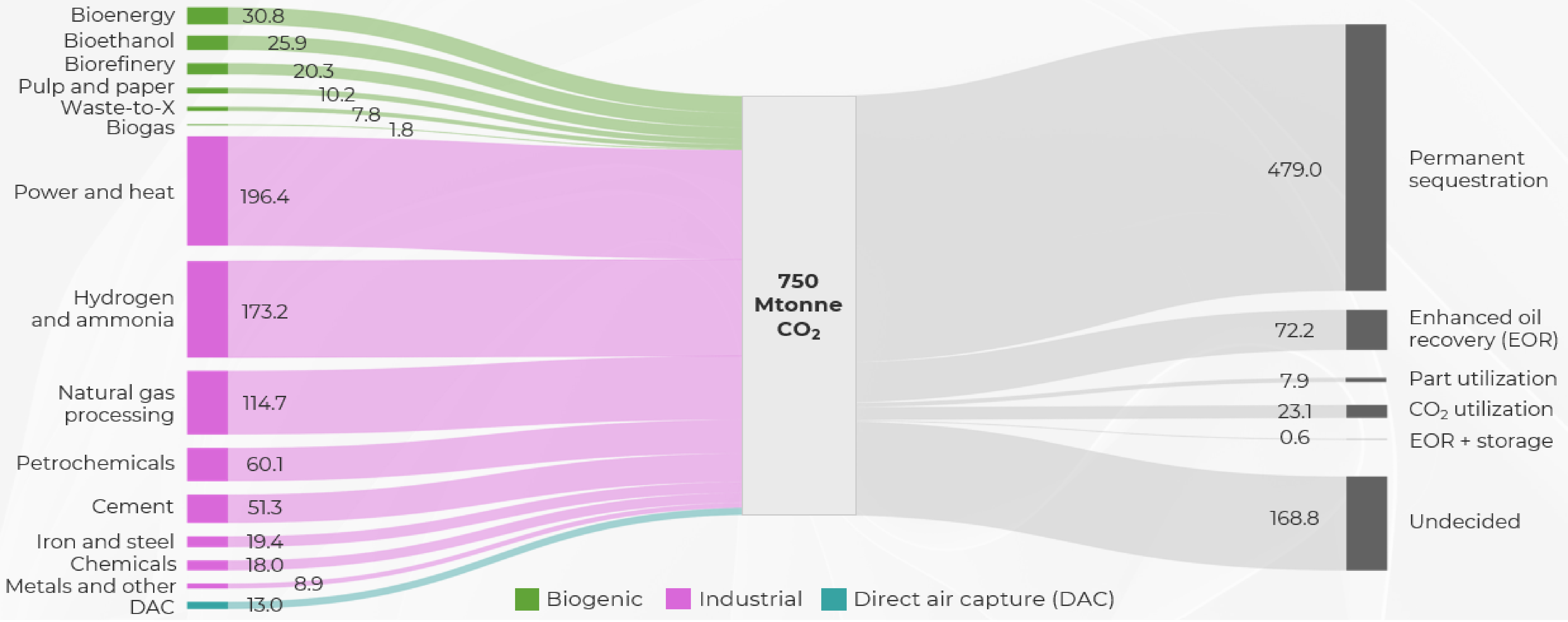
AGENDA

01 **State of the global carbon economy**

02 Building industry-specific CO_2 utilization strategies

03 Outlook and key takeaways

GLOBAL SOURCE-TO-SINK CO_2 FLOW

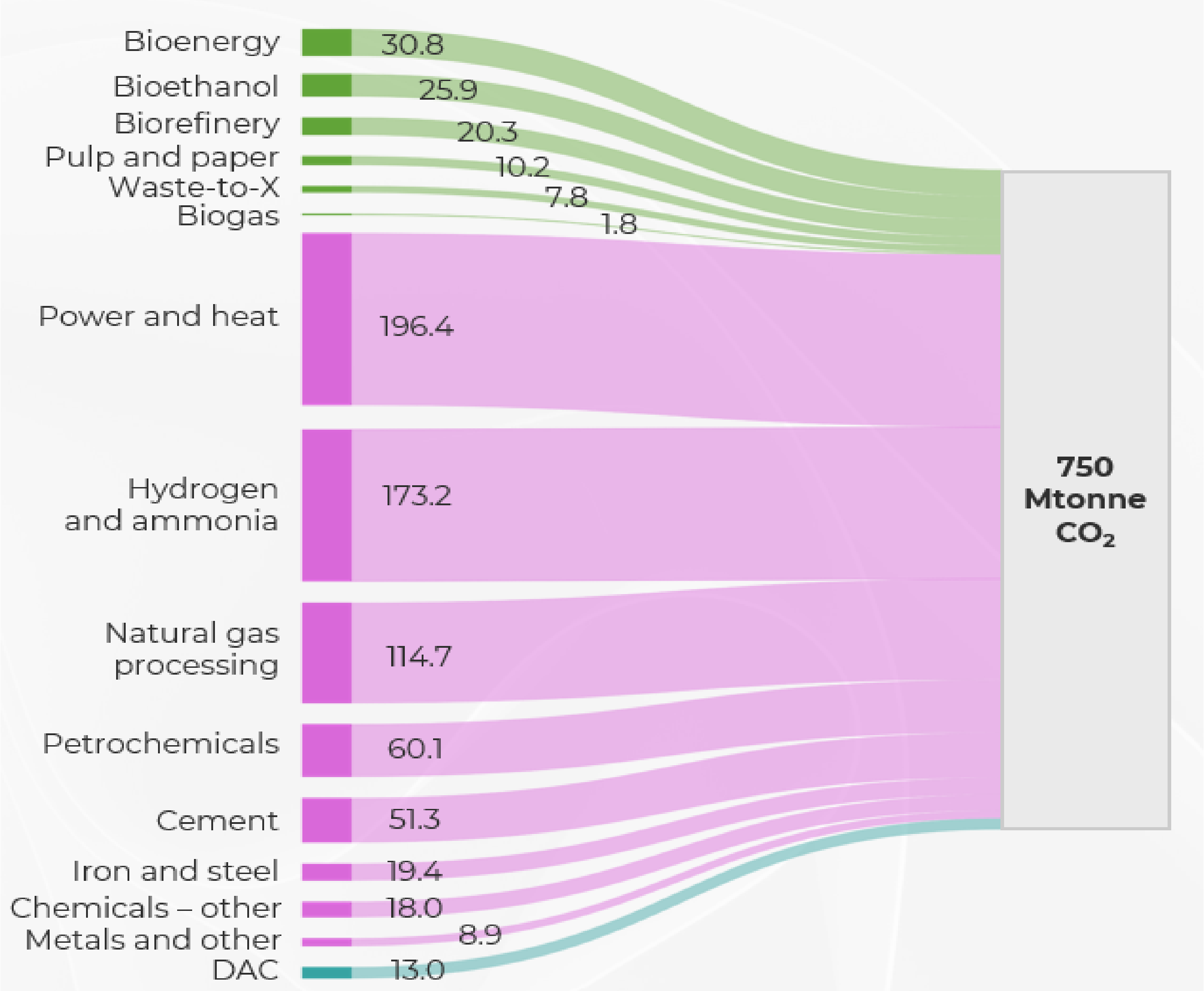


THREE MAIN CO_2 SOURCES

There is approximately **750 Mtonne/y** of announced carbon capture capacity over the next two decades.

The CO_2 comes from:

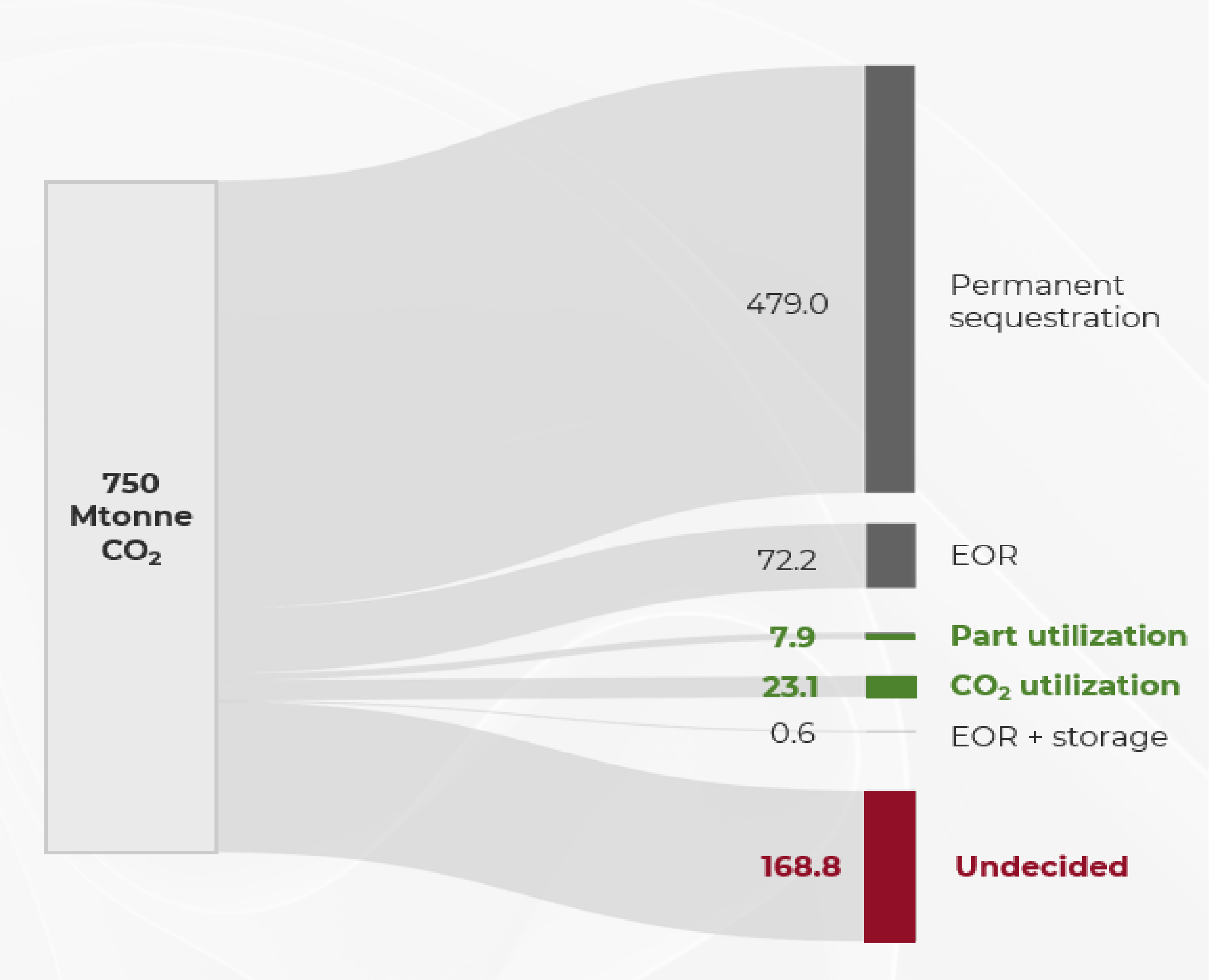
- Biogenic CO_2 (96 Mtonne)
- Industrial CO_2 (640 Mtonne)
- DAC (13 Mtonne)



Source: Lux Research, adapted from IEA (2025)

A BREWING END-USE ISSUE

- Most captured CO_2 goes toward sequestration.
- A smaller portion, 30 Mtonne, is diverted as a feedstock. This is on par with the current maturity of CO_2 utilization markets.
- Clients need to pay closer attention to the 170 Mtonne/y of CO_2 with undisclosed end-use.



Source: Lux Research, adapted from IEA (2025)

Lux Research

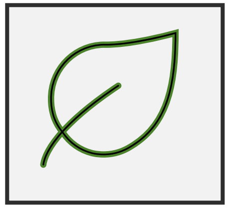
The industrial sector faces a USD 25 billion carbon management problem that needs CO_2 utilization

Assuming a carbon price of USD 150/tonne

CO_2 UTILIZATION SOLVES TWO PROBLEMS

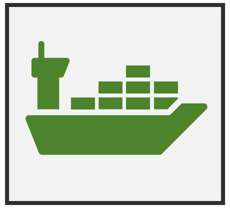
Turns cost sinks into revenue platforms

Shifts CO_2 flow away from sequestration



=

OR



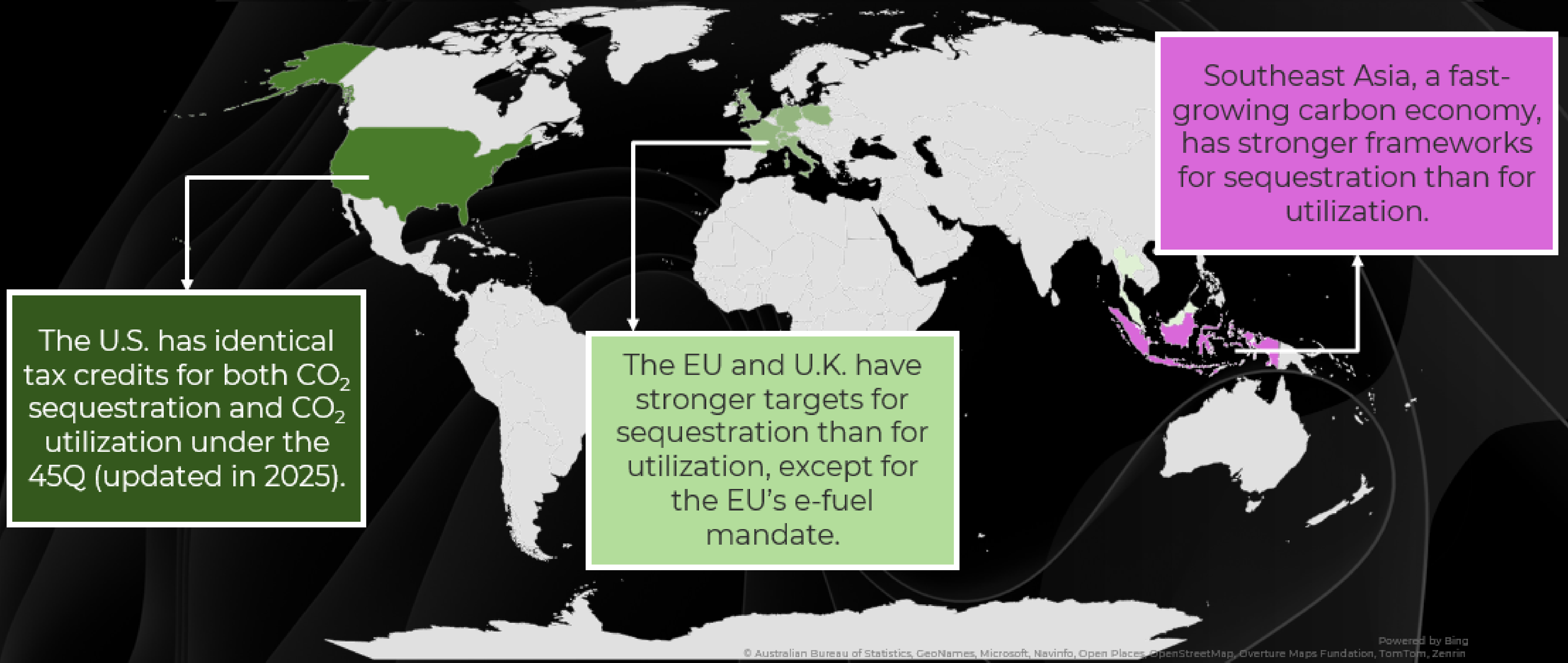
80 Mtonne of sequestered biogenic CO_2

19 Mtonne of SAF (200 facilities)

52 Mtonne of e-methanol (500 facilities)

The real opportunity cost

POLICY IS LACKING, BUT CATCHING UP



CO_2 utilization

Concrete
- CO_2 curing
- Aggregates
- Supplementary cementitious materials (SCMs)
- High-purity carbonates (HPCs)
- Bio-cement

Synthetic fuels
- Gasoline, kerosene, diesel
- Methanol
- Methane
- Propane

Chemicals
- Carbon monoxide
- Syngas
- Formic acid
- Methanol
- Ethanol
- Ethylene
- Acetates
- C3+ molecules

Polymers
- Polycarbonates (PCs)
- Polyols and polyurethanes (PURs)
- Polysaccharides
- Polyhydroxyalkanoates (PHAs)
- Monoethylene glycol (MEG)
- Other – indirect routes

Carbon additives
- Carbon nanomaterial (nanotubes, nanofibers)
- Carbon black

Ingredients
- Single-cell proteins (SCPs)
- Lipids

AGENDA

01 | State of the global carbon economy

02 | **Building industry-specific CO_2 utilization strategies**

03 | Outlook and key takeaways

OIL AND GAS

Target emissions source:
Natural gas processing, power generation

PETROCHEMICALS AND CHEMICALS

Target emissions source:
Petrochemical refineries, chemical manufacturing

Image sources: Chevron, BASF,

THE ENERGY SECTOR CAN IMPACT 72 MTONNE OF UNDISCLOSED CO_2 END-USE

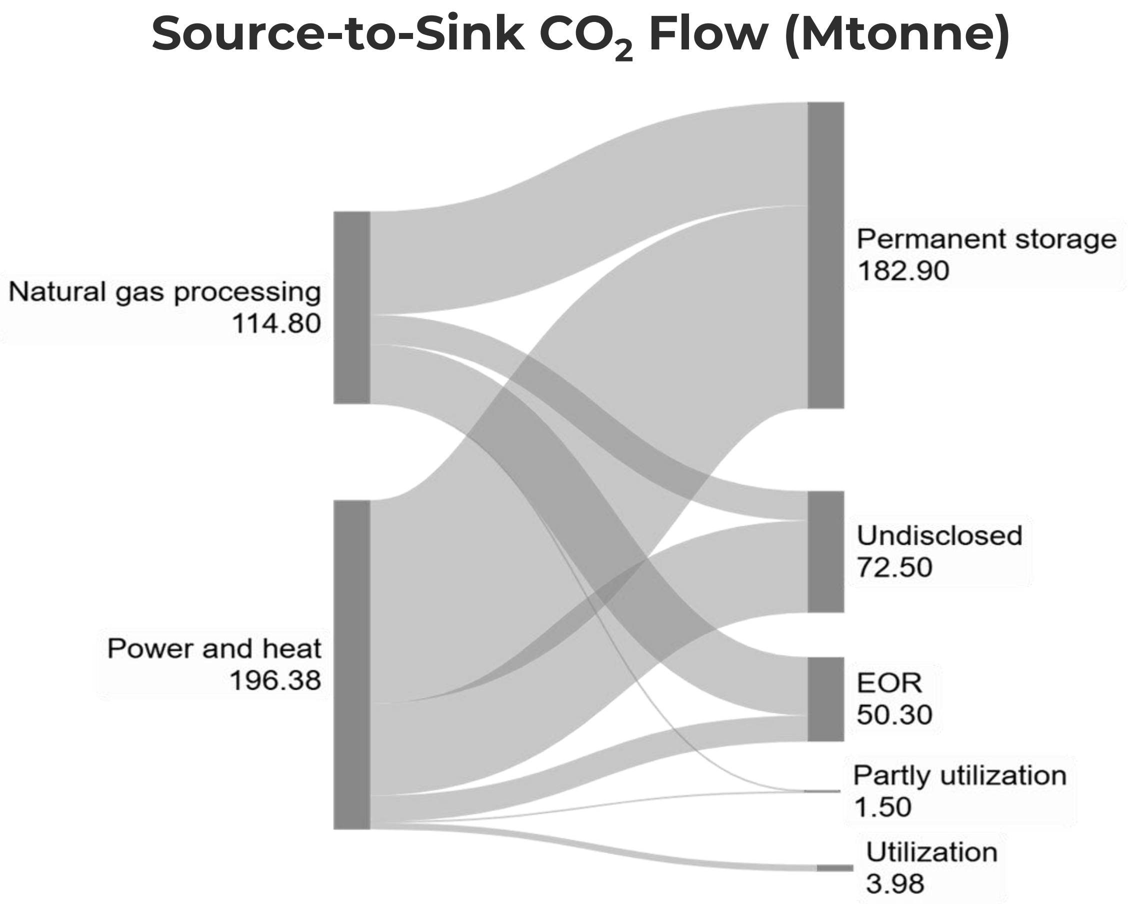


Image source: Chevron

CO_2 utilization

Concrete
- CO_2 curing
- Aggregates
- Supplementary cementitious material (SCMs)
- High-purity carbonates (HPCs)
- Bio-cement

Synthetic fuels
- Gasoline, kerosene, diesel
- Methanol
- Methane
- Propane

Chemicals
- Carbon monoxide
- Syngas
- Formic acid
- Methanol
- Ethanol
- Ethylene
- Acetates
- C3+ molecules

Polymers
- Polycarbonates (PCs)
- Polyols and polyurethanes (PURs)
- Polysaccharides
- Polyhydroxyalkanoates (PHAs)
- Monoethylene glycol (MEG)
- Other – indirect routes

Carbon additives
- Carbon nanomaterial (nanotubes, nanofibers)
- Carbon black

Ingredients
- Single-cell proteins (SCPs)
- Lipids

OIL AND GAS ACTIVITY IN SYNTHETIC FUELS

Develop technology platforms and form project partnerships

Oil and gas majors are involved in e-methanol, e-methane, and jet fuel, increasingly so in methanol to jet.

Companies also have an indirect stake in the synthetic fuels value chain by investing in carbon capture and water electrolysis companies that provide feedstock to e-fuel projects (e.g., Carbon Clean).

COP28: TotalEnergies and Masdar demonstrate Methanol-to-SAF pathway with successful test flight

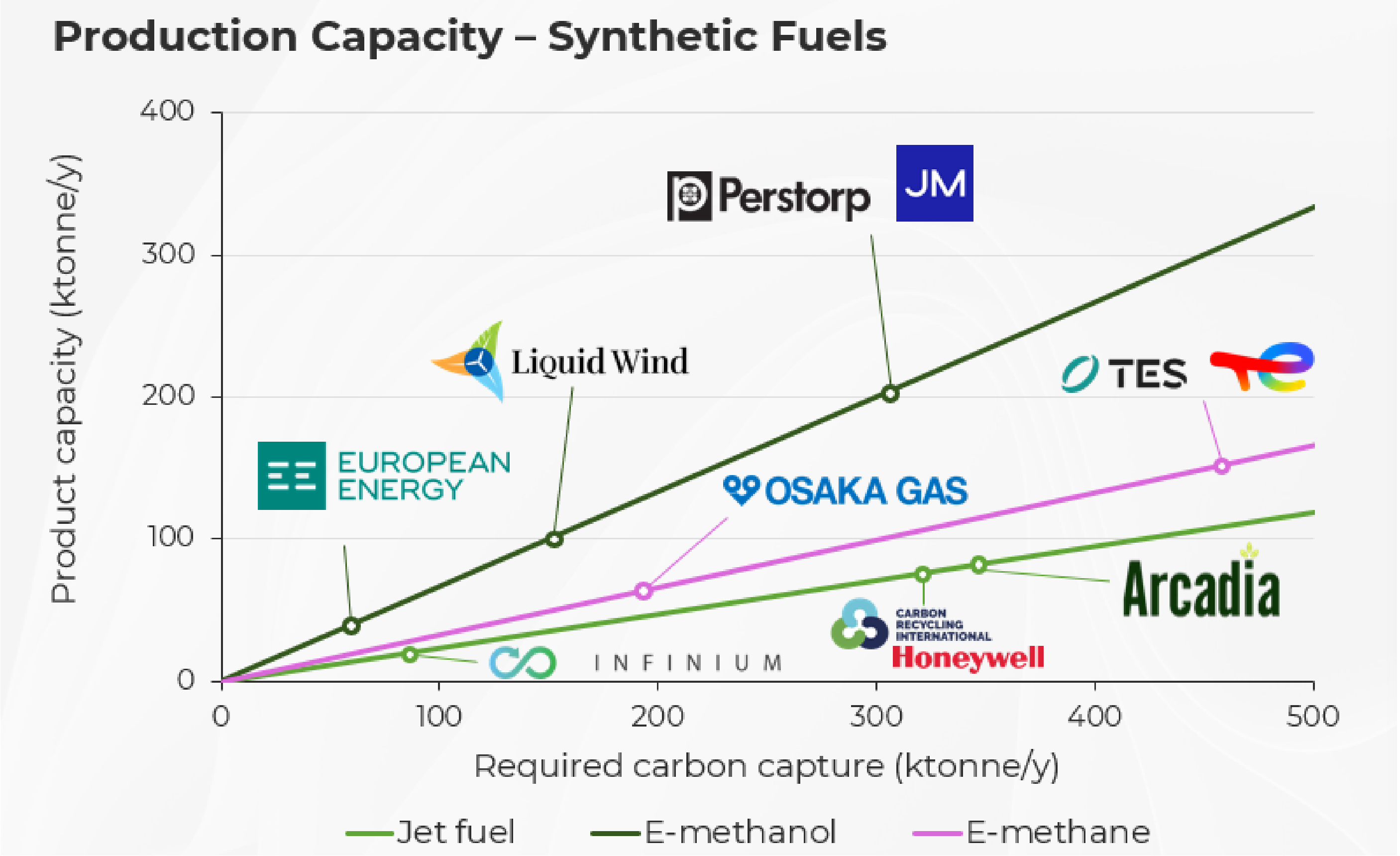
United States: TotalEnergies and TES Join Forces to Develop a Large-Scale e-NG Production Unit

ExxonMobil methanol to jet technology to provide new route for sustainable aviation fuel production

Johnson Matthey and bp technology chosen for the world's largest Fischer Tropsch SAF production plant

ExxonMobil TotalEnergies bp

E-FUELS PROJECTS CARRY HIGH-RISK

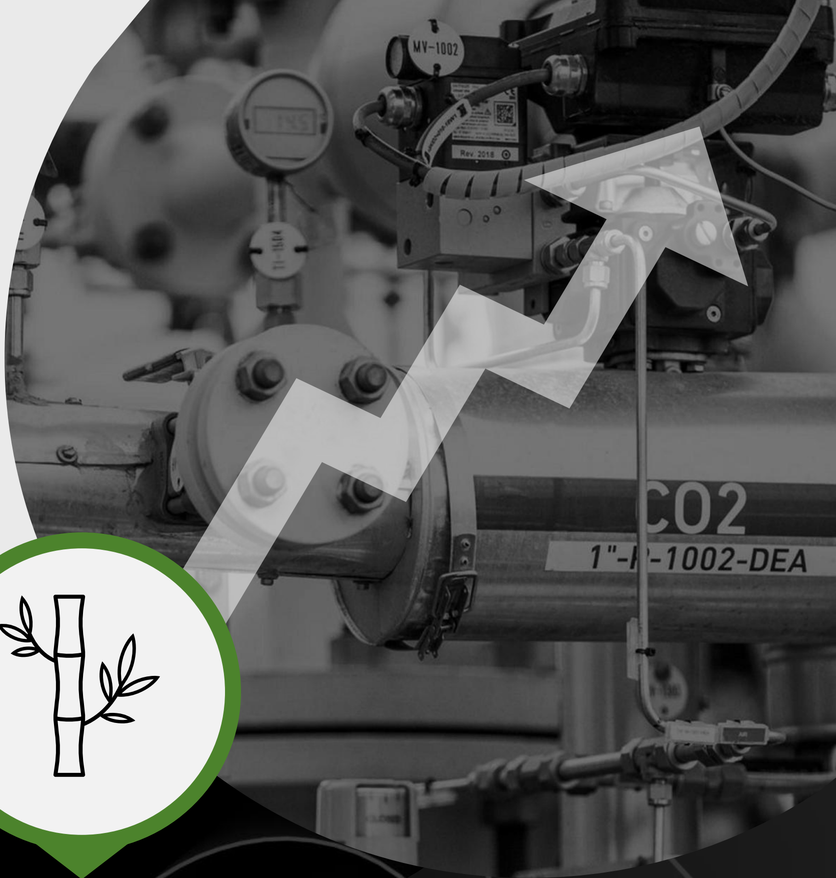


LUX TAKE

- 2025–2028 is a pivotal FID window, but challenges will persist even after.
- Methanol's cross-sector fit in aviation and shipping spreads out risk.
- Biogenic CO_2 is critical for synthetic fuels.

Key trends and signals in synthetic fuels

High costs keep e-fuels as a long-term play, with projects limited to regions with low-cost renewables. However, stronger project development and unlocking new feedstock supply will help derisk the segment.



Corporate consolidation reduces integration costs

Methanol vs. FT is center stage for cost reduction, but keep an eye on opportunities beyond

Increased upstream engagement unlocks feedstock value

Image source: Honeywell UOP

OIL AND GAS ACTIVITY IN POLYMERS

Acquisitions for portfolio diversification and expansion into new markets

"This strategic partnership aligns with ADNOC's future-proofing strategy and our vision to become a top 5 global chemicals company. It reinforces our commitment to diversifying ADNOC's portfolio."

~ ADNOC Managing Director and Group CEO

19 December 2024

ADNOC takeover offer for Covestro successful

أدنوك
ADNOC

covestro

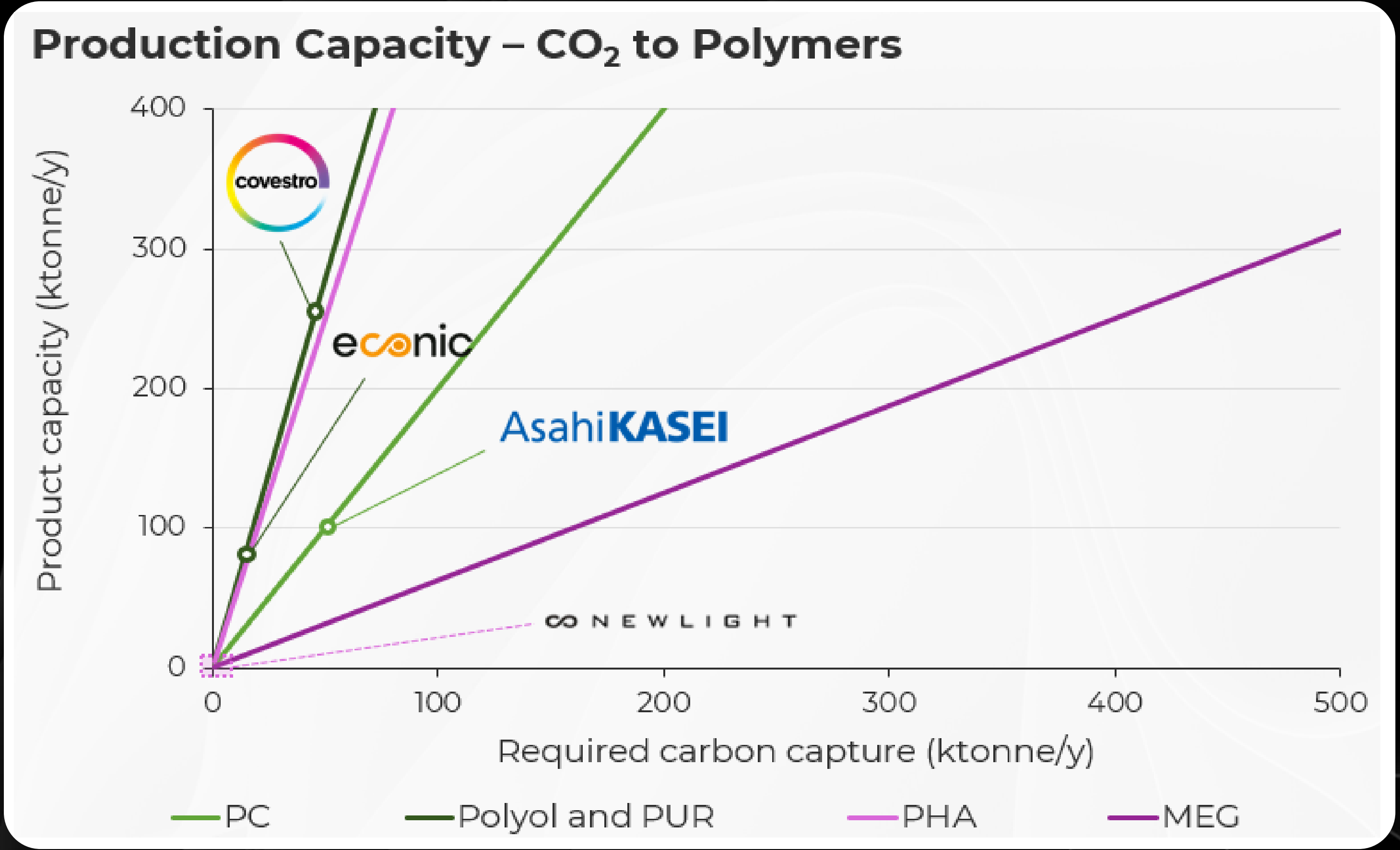
8 APRIL 2025

Econic Signs Strategic Licensing Agreement with Saudi Aramco Technologies Company (SATC) for CO_2 Polyols

aramco

econic

ADNOC CAN HIT THE GROUND RUNNING



LUX TAKE

- PURs and PCs are ready to deploy and available for licensing.
- Performance over sustainability is essential for consumer acceptance.
- Developments in MEG and indirect routes are ripe for monitoring.

PETROCHEMICALS CAN IMPACT 18 MTONNE OF UNDISCLOSED CO_2 END-USE

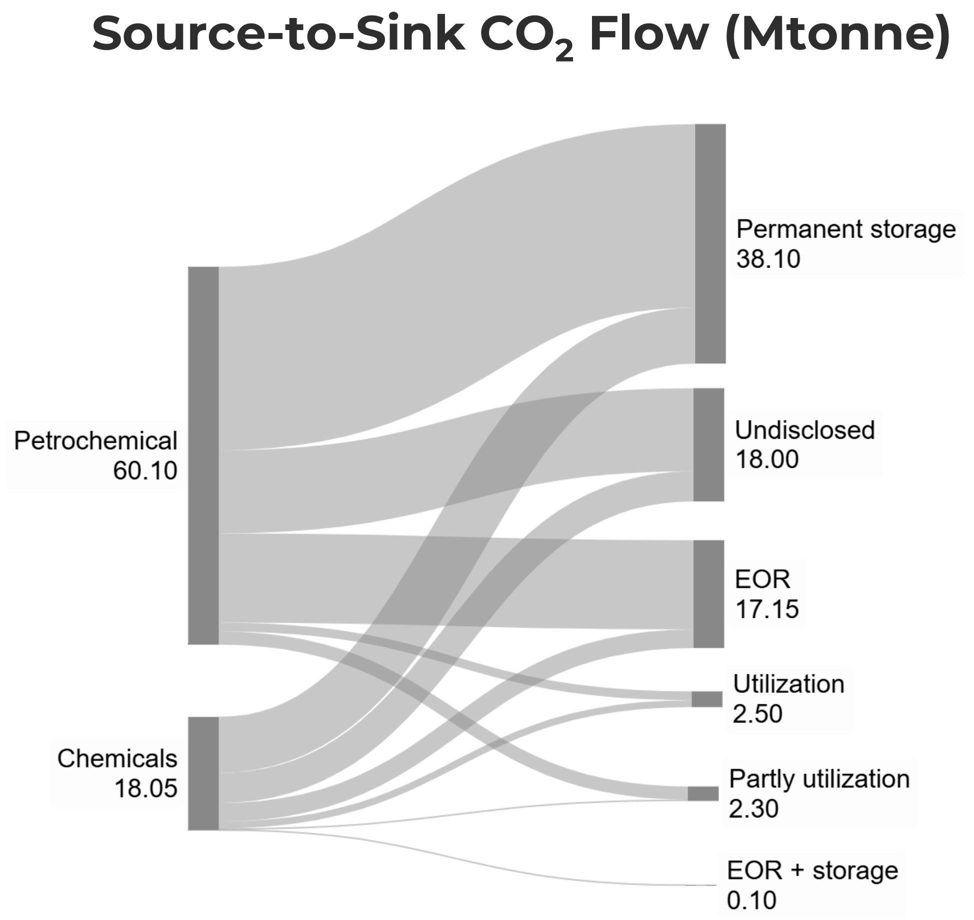


Image source: BASF

CO_2 utilization

- **Concrete**
  - CO_2 curing
  - Aggregates
  - Supplementary cementitious material (SCM)
  - High-purity carbonates (HPC)
  - Bio-cement
- **Synthetic fuels**
  - Gasoline, kerosene, diesel
  - Methanol
  - Methane
  - Propane
- **Chemicals**
  - Carbon monoxide
  - Syngas
  - Formic acid
  - Methanol
  - Ethanol
  - Ethylene
  - Acetates
  - C3+ molecules
- **Polymers**
  - Polycarbonates (PC)
  - Polyols and polyurethanes (PUR)
  - Polysaccharides
  - Polyhydroxyalkanoates (PHA)
  - Monoethylene glycol (MEG)
  - Other – indirect routes
- **Carbon additives**
  - Carbon nanomaterial (nanotubes, nanofibers)
  - Carbon black
- **Ingredients**
  - Single-cell proteins (SCP)
  - Lipids

INDUSTRY ACTIVITY IN CO_2 TO CHEMICALS

Consortium partnerships, early investments, and R&D partnerships

Activity from chemicals majors and refineries is limited mainly because of the high price differential between CO_2-based chemicals and their fossil counterparts.

Companies are more engaged when there is a continuous downstream partner offtaking the base chemical (e.g., Flue2Chem) or when innovative startups show product differentiation (e.g., New Iridium).

Copenhagen-based Again secures €39M to decarbonise the petrochemical industry: Here's how

BASF joins Flue2Chem to produce ethanol for surfactants and consumer products

Dow announces intent to invest in new world-scale carbonate solvents facility in the U.S.

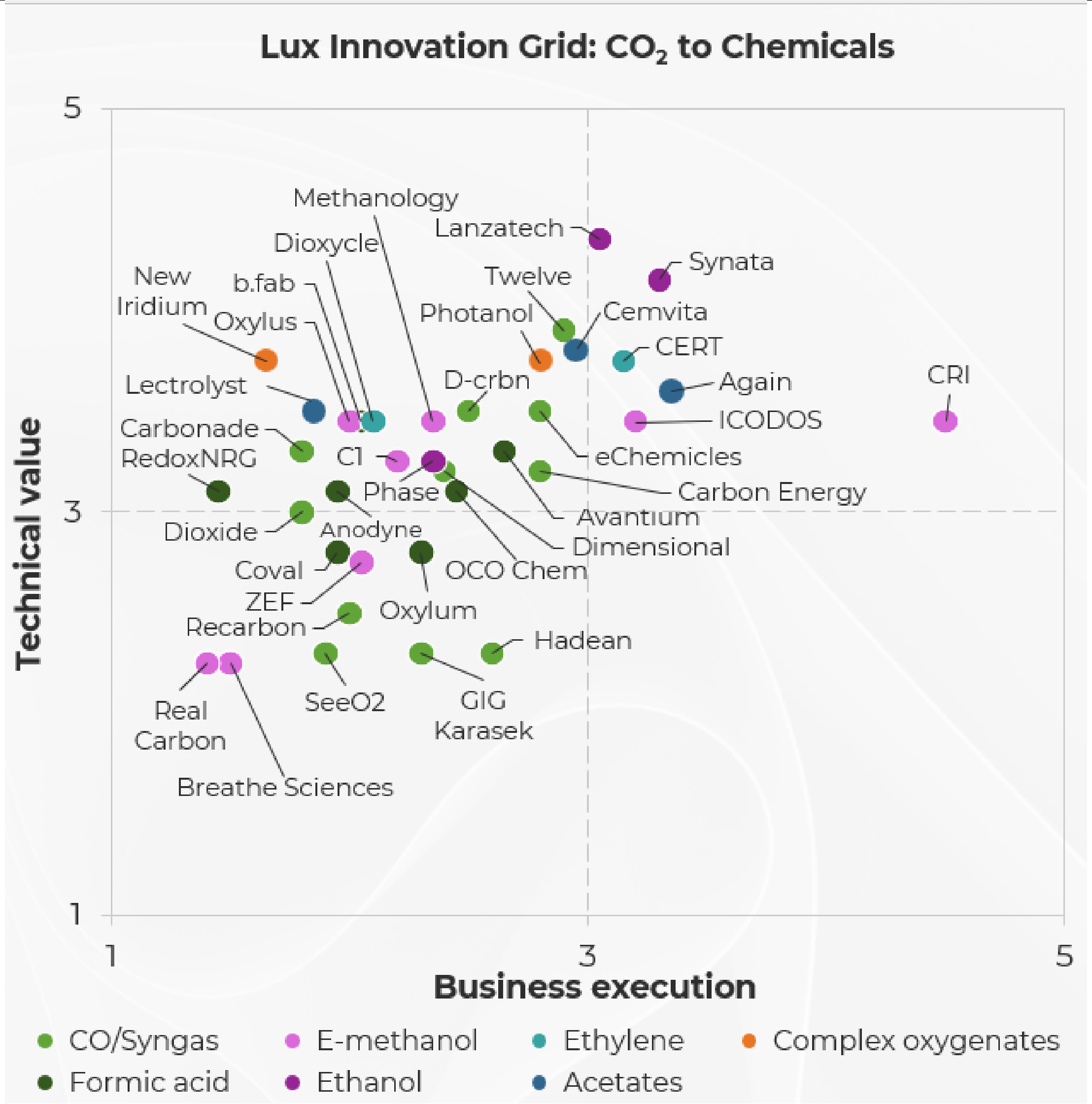
Braskem partnering with startup New Iridium on photocatalytic CO2 conversion

INNOVATIONS IN CO_2 TO CHEMICALS

Chemicals is the most diverse but one of the least mature segments.

CO_2 utilization will face challenges in breaking past the C2 barrier for chemicals — companies should monitor for pathway innovations.

Early stage activity focuses on ethylene, acetates, and formic acid.



Source: Lux Research

Key trends and signals in CO_2 to chemicals

The current and next phase of this segment is still developmental, not scaling. There are two ways to successfully differentiate — product novelty or reducing the cost of producing an already sought out end-product.

Synbio resurges for product differentiation

Photocatalysis finds a niche in bypassing intermediates

Continuous CO_2 capture and conversion bypasses energy-intensive desorption

Image source: VoltaChem

AGENDA

01 | State of the global carbon economy

02 | Building industry-specific CO_2 utilization strategies

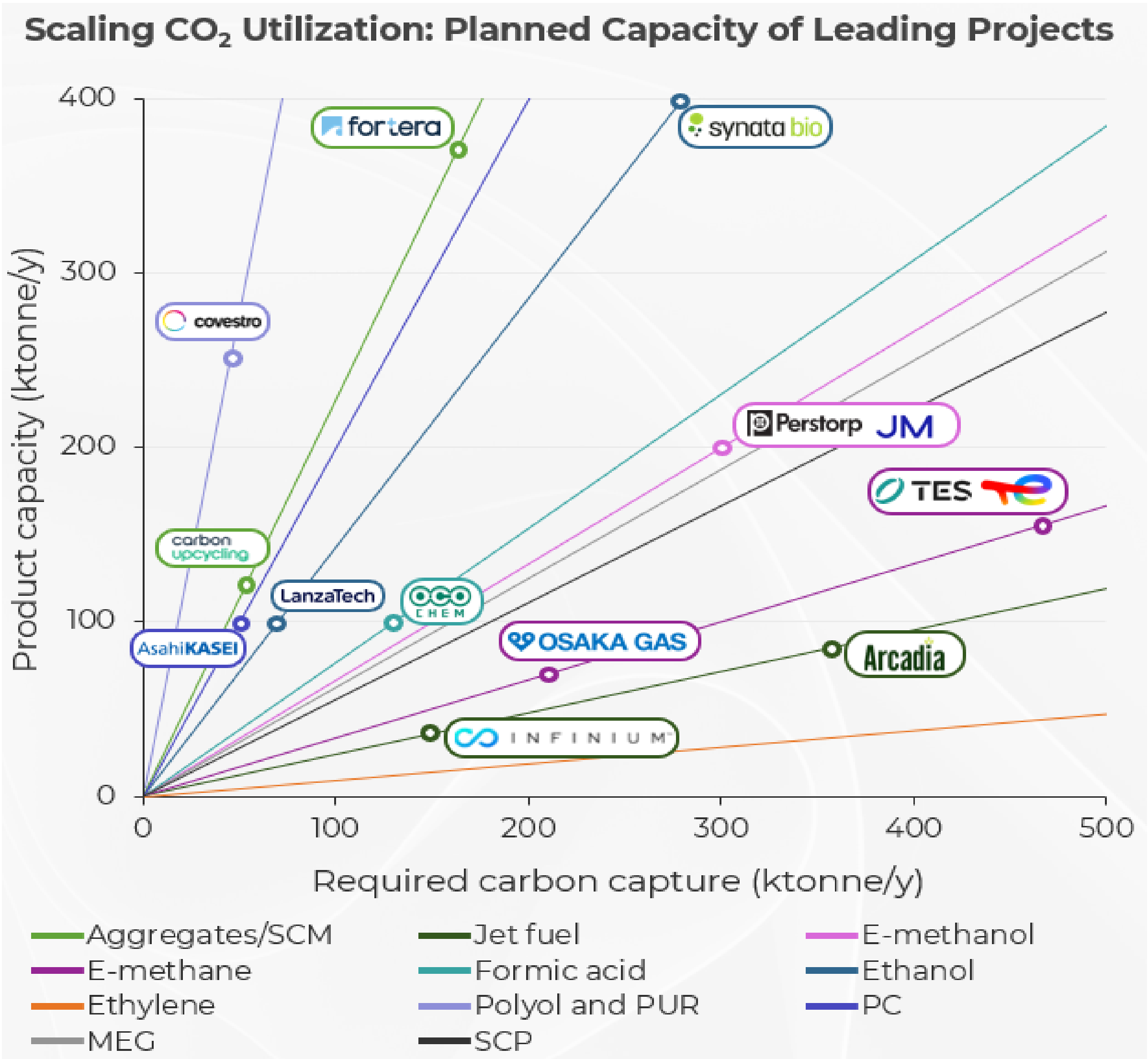
03 | **Outlook and key takeaways**

THE LARGEST PLANNED PROJECTS

The largest planned CO_2 utilization projects will require 50–500 ktonne/y of CO_2

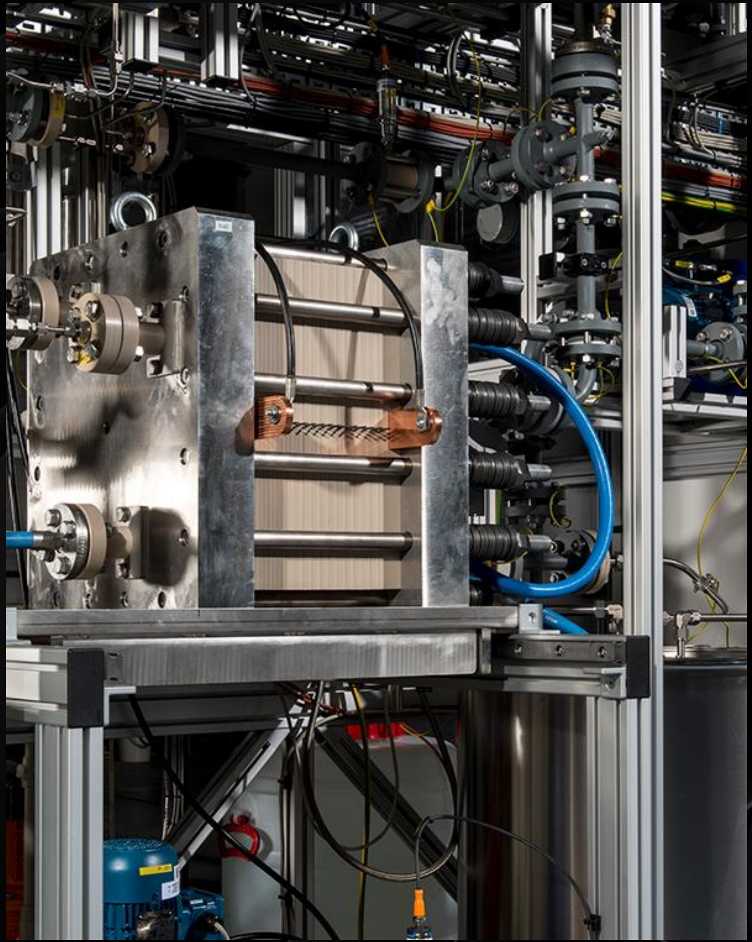
E-methanol, jet fuel, ethanol, and aggregates/SCMs have the largest planned capacities. These pathways are at TRL 8/9.

The main emerging product that shows signs of scaling is formic acid.



ENERGY PRICES WILL CREATE REGIONAL HUBS

ALIGN SCALE OF CO_2, PATHWAY, AND PRODUCT



FINDING INITIAL OFFTAKE MARKETS

Image sources: DEWA, VoltaChem, Maersk

KEY TAKEAWAYS

1

Scaling CO_2 utilization secures the long-term viability of today's carbon capture investments.

2

Align CO_2 utilization products with your business strategy to decarbonize an existing portfolio or target new markets and then benchmark against alternative pathways.

3

Move upstream, as regulatory support will increasingly be tied to feedstock sourcing and transparency.

THANK YOU

READ
http://www.luxresearchinc.com/blog/

LISTEN
Innovation Matters Podcast - Spotify

VISIT
www.luxresearchinc.com

EMAIL
questions@luxresearchinc.com

FOLLOW
@LuxResearch

CONNECT
LuxResearch

ABOUT LUX

Our mission is to advise leaders about commercially viable science and technology to enable sustainable innovation. We deliver research and advisory services to inspire, illuminate, and ignite innovative thinking that reshapes and grows businesses. Using quality data derived from primary research, fact-based analysis, and opinions that challenge traditional thinking, our experts focus on finding truly disruptive innovations that are also realistic and make good business sense.

The "Lux Take" is trusted by innovation leaders around the world, many of whom seek our advice directly before placing a bet on a startup or partner — our clients rely on Lux insights to make decisions that generate fantastic business outcomes. We pride ourselves on taking a rigorous, scientific approach to avoid the hype and generate unique perspectives and insights that innovation leaders can't live without.

READ
http://www.luxresearchinc.com/blog/

VISIT
www.luxresearchinc.com

FOLLOW
@LuxResearch

CONNECT
LuxResearch

LISTEN
Innovation Matters Podcast - Spotify

EMAIL
questions@luxresearchinc.com