



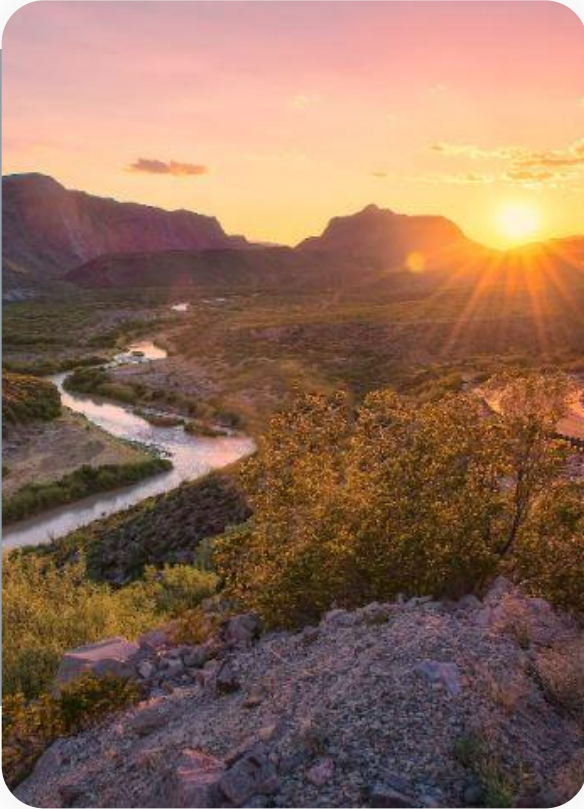
# Cryocap™, an innovative way to capture CO<sub>2</sub> for a wide range of applications

**Industrial Processes Emissions Reduction (IPER) - Technology Workshop**

*Elia Cordier, Solution Development Manager - CO<sub>2</sub> capture, Air Liquide E&C US  
January 30<sup>th</sup> 2024*

# Agenda

- 1 Air Liquide Group**
- 2 Cryocap™ products overview**
- 3 Technology demonstration**
- 4 Market momentum**



# 01

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## Air Liquide Group

# 2022 Key Figures



**~67,100**  
EMPLOYEES



PRESENT IN  
**73** COUNTRIES



MORE THAN  
**3.9** MILLION  
CUSTOMERS &  
PATIENTS



REVENUE  
**€29.9bn**



NET PROFIT  
(GROUP SHARE)  
**€2.7bn**



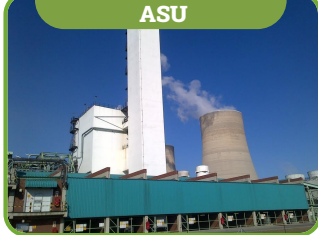
INVESTMENT  
DECISIONS  
**~€4bn**

# Air Liquide E&C - a World Leader in Technologies

Pioneering  
CO2 capture



World's largest  
ASU



Industry standard  
Lurgi MegaMethanol



World's largest  
Liquid H2 plant



One of the World's  
largest PEM plant



NH3 Synthesis



**15** ENGINEERING  
CENTERS



**3** MANUFACTURING  
CENTERS



**354** PATENT  
APPLICATIONS  
FILED IN 2021



**+60**  
PROPRIETARY  
TECHNOLOGIES



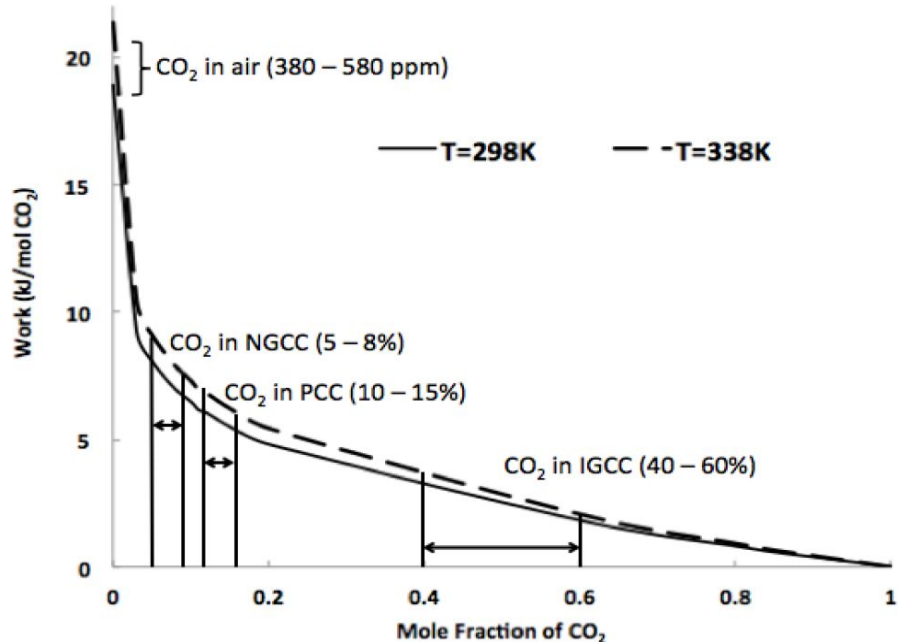
# 02

## Cryocap™ product overview

*An alternate path to steam-driven technologies to decrease cost and carbon footprint*

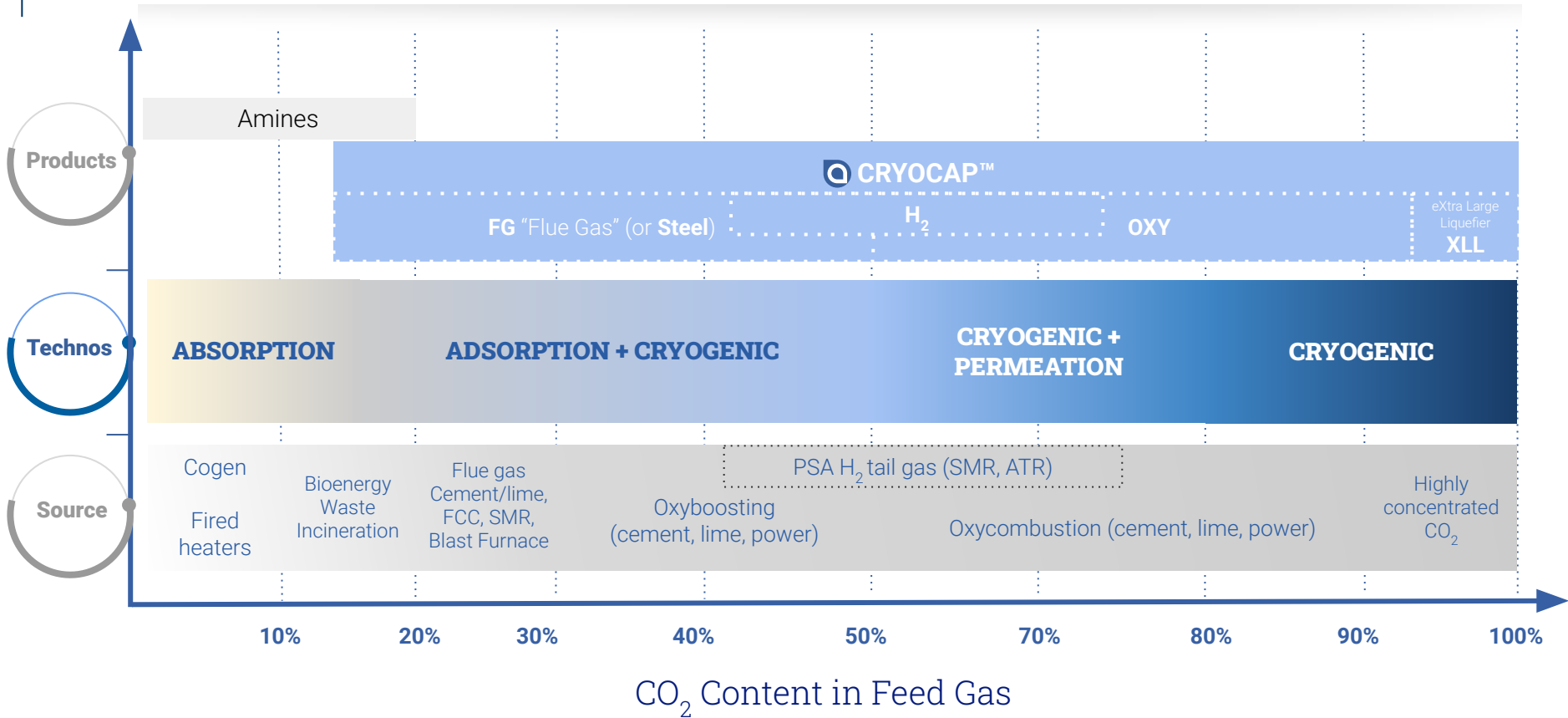
# What is the best source for carbon capture ?

## Minimum Work for Separation



- The higher the CO<sub>2</sub> concentration in the feed gas, the lower the energy to capture CO<sub>2</sub>
- 10% ↔ inflection point
  - Carbon capture on <10% CO<sub>2</sub> sources is energy intensive
  - Linear variation of energy with CO<sub>2</sub> concentration
- Multiple technologies necessary to follow the theoretical trend

# Air Liquide techno mapping for CO<sub>2</sub> capture





# Cryocap™ : Very differentiating features

Intrinsically more efficient for >15% CO<sub>2</sub> sources

Electricity Powered

Liquid or High Pressure CO<sub>2</sub>

HSE friendly (no chemicals)

Skidded

References in the industry

Steam/heat driven

Low pressure wet gaseous CO<sub>2</sub>

Lower potential of modularization

## Cryocap™



Cryocap™  
FG



Cryocap™  
Oxy



Cryocap™  
H<sub>2</sub>



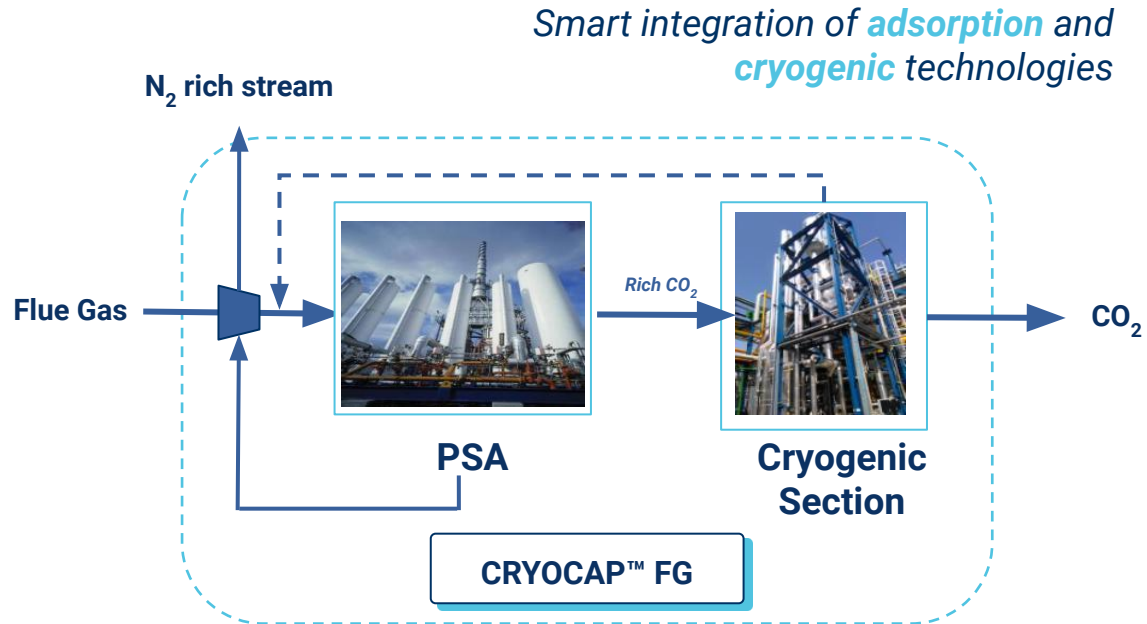
Cryocap™  
XLL



## Amines

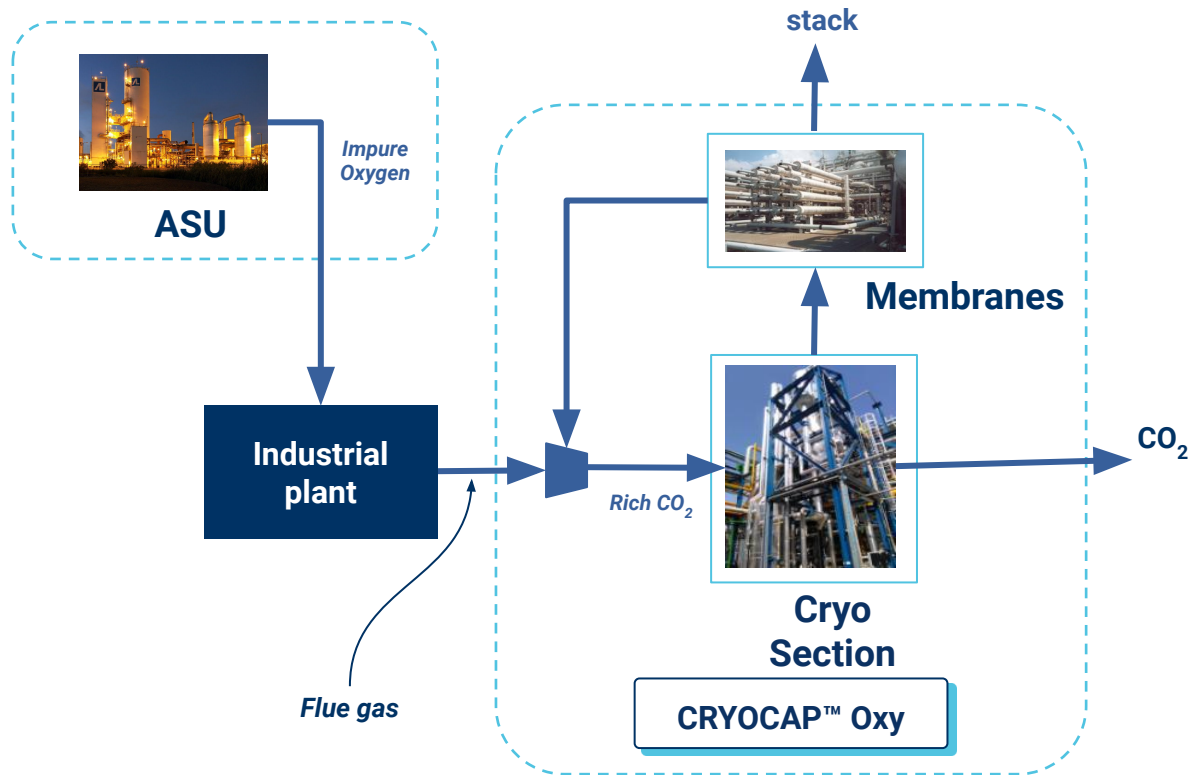
# Cryocap™ FG: CO<sub>2</sub> Capture from Flue Gas (~15% to 50% dry mol CO<sub>2</sub>)

- Suitable for Cement, Lime, SMR (flue gas), FCC,...
- PSA as a preconcentration brick
- HSE friendly (CO<sub>2</sub> cycle)
- Electricity powered (no steam needed)
- Compact & Flexible footprint: Compressors, PSA and Coldbox can be located in 3 different plots
- NO<sub>x</sub> Smart Management
- Gaseous or liquid CO<sub>2</sub>
- CO<sub>2</sub> capture rate: 95%+



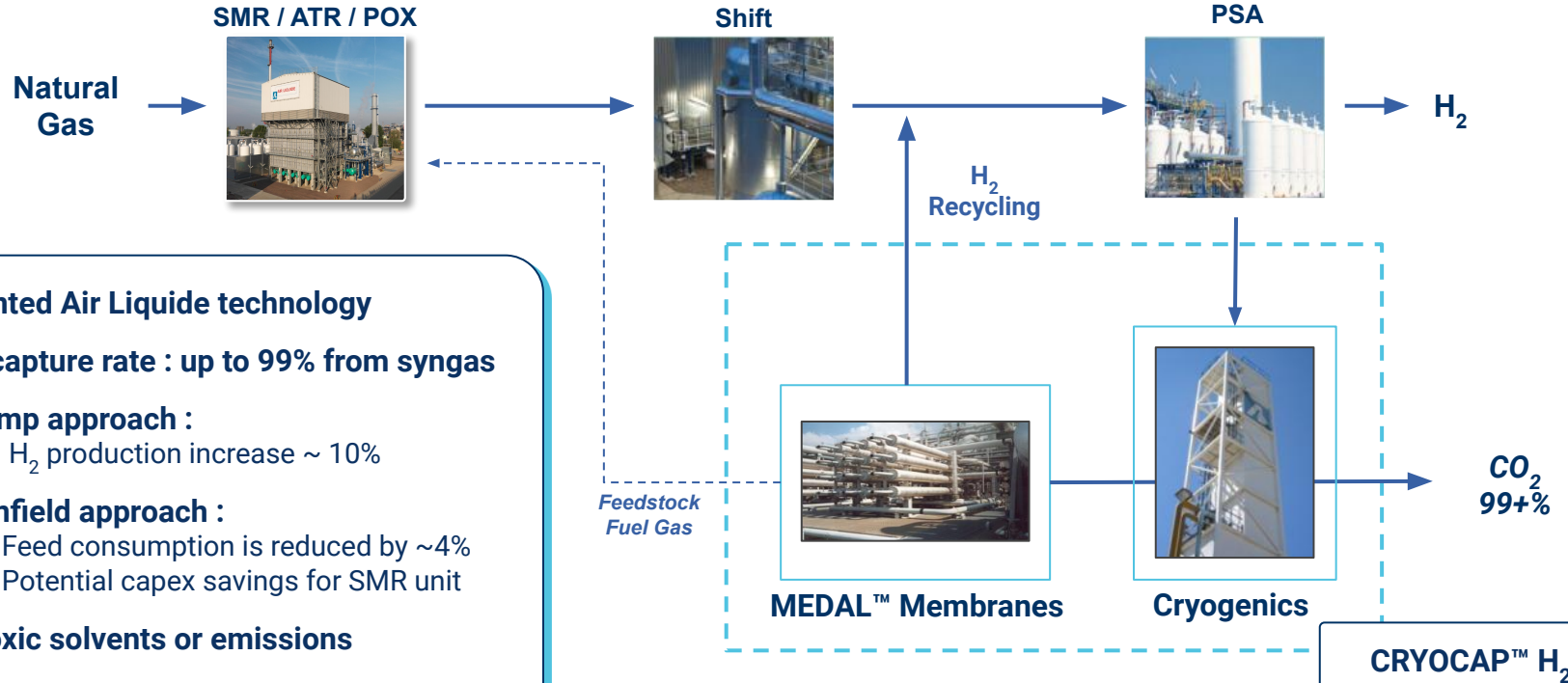
# Cryocap™ Oxy (50%-95% CO<sub>2</sub>) : O<sub>2</sub> enrichment coupled with CO<sub>2</sub> capture

- Uses oxycombustion to enrich flue gas in CO<sub>2</sub> (>50%)
- No need of preconcentration before cryogenics
- HSE friendly (no chemicals and no flammables)
- Electricity powered (no steam needed)
- NO<sub>x</sub> Smart Management
- Gaseous or liquid CO<sub>2</sub>
- CO<sub>2</sub> capture rate: 95%+



# Cryocap™ H<sub>2</sub>: CO<sub>2</sub> Capture from PSA Tail Gas

Combinaison of *cryogenic* and *membrane* technologies



- Patented Air Liquide technology
- CO<sub>2</sub> capture rate : up to 99% from syngas
- Revamp approach :
  - H<sub>2</sub> production increase ~ 10%
- Greenfield approach :
  - Feed consumption is reduced by ~4%
  - Potential capex savings for SMR unit
- No toxic solvents or emissions
- Electricity powered
- Gaseous or liquid CO<sub>2</sub>

High CO<sub>2</sub> recovery combined with H<sub>2</sub> production boost

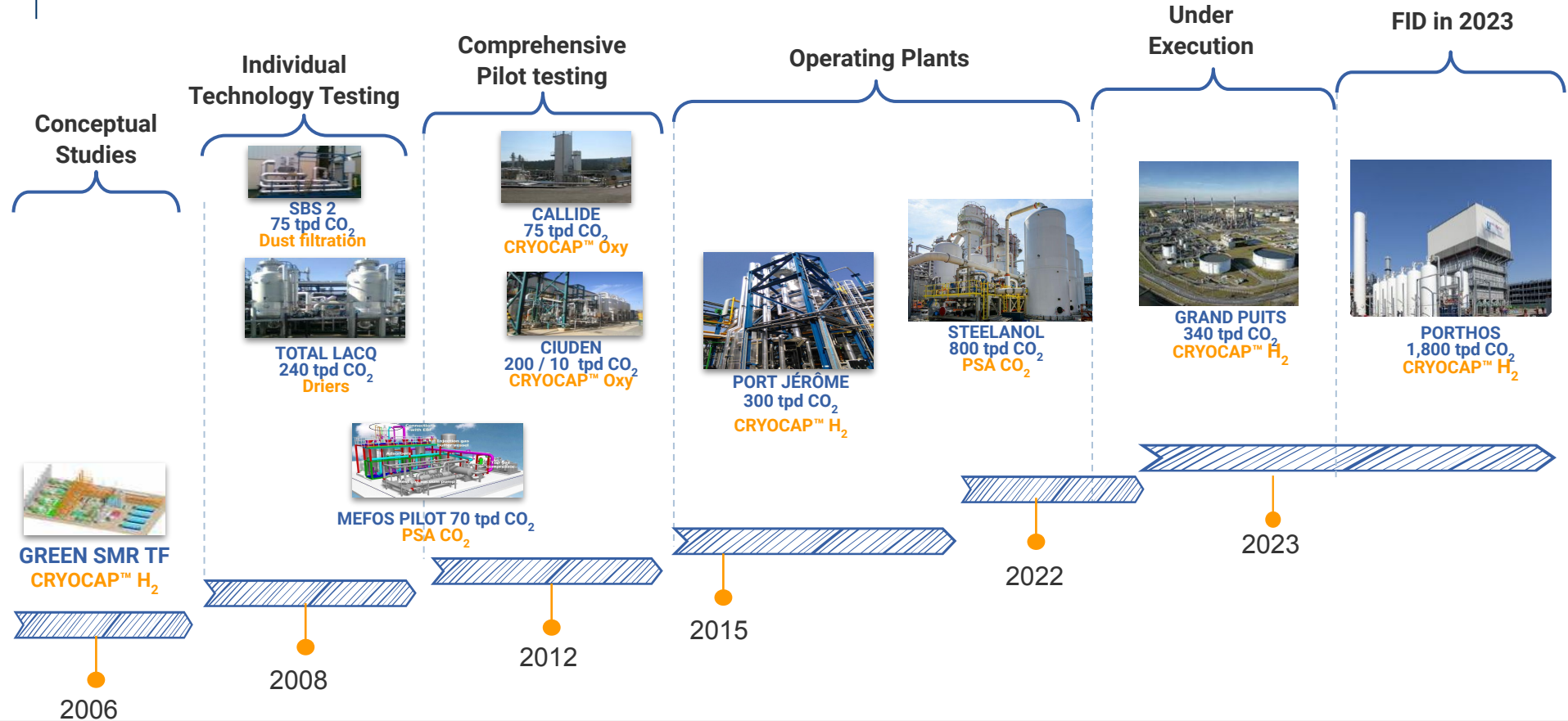


# 03

## Technology demonstration

*An overall maturation roadmap to a product ready for commercialization*

# Cryocap™: 18+ years of Legacy



# Selected reference - Cryocap™ H<sub>2</sub> Port Jerome, France



A unique  
World's  
Reference

## ➤ Start up in H1 2015 : ~9 years of reliable industrial operation

- **Reliable** operation of the compressor, cold box and membranes
- **Increase of H<sub>2</sub> production** flow
- Get **significant return of experience** while addressing technical challenges
  - Deep integration with an existing SMR **with no impact on H<sub>2</sub> reliability**
  - Centrifugal compressor on fluctuation PSA tail gas
  - Operation of a Cryo unit close to CO<sub>2</sub> triple point
  - Ageing of membranes & adsorbents

## ➤ Design to scalability approach:

- Pure scale up to go to full CCS scale

## ➤ Retrofit of an Air Liquide SMR in Port Jerome

- SMR supplying 50,000 Nm<sup>3</sup>/h H<sub>2</sub> to **ExxonMobil** refinery
- **Synergies with AL merchant business: 300 tons/day** food-grade liquid CO<sub>2</sub>



**World's largest and unique reference of cryogenic solution at industrial scale (syngas capture)**



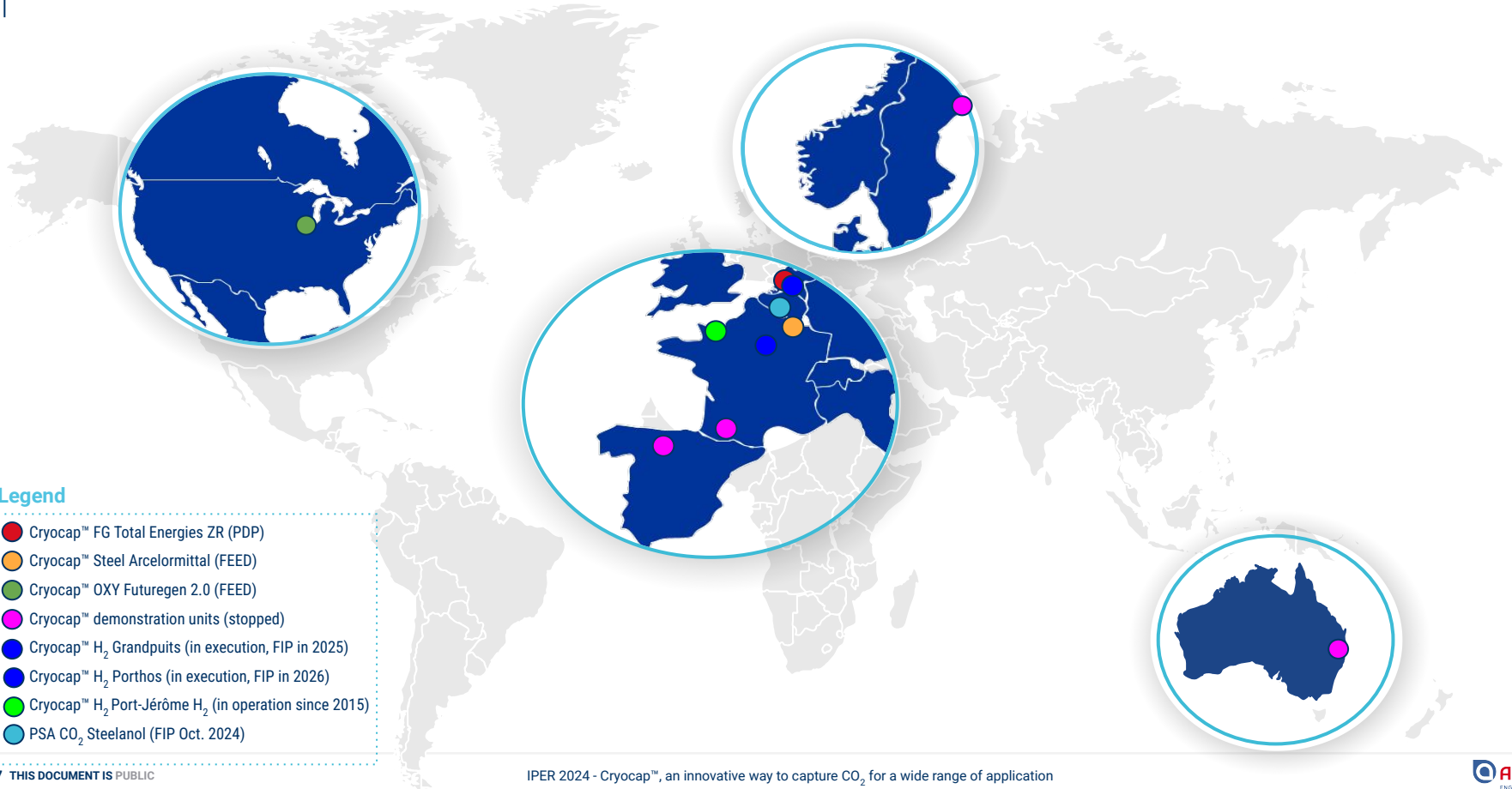
# 04

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## Market Momentum



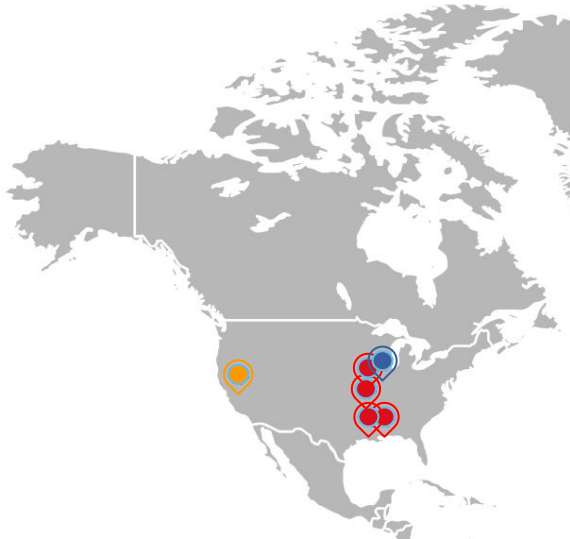
# Air Liquide Cryocap™ - Post FID projects - World map of public references



# Air Liquide Cryocap™: Increasing Number of “at-scale” CCUS Projects

*Publicly announced*

DOE awarded FEED's



IF and CEF awarded projects



JOGMEC awarded studies



 Cryocap™ FG

 Cryocap™ OXY

 Cryocap™ H2

 Cryocap™ XLL

# Our key references - Cryocap™ FG

Blue H<sub>2</sub>

## Zeeland Refinery

World's only referenced cryogenic solution at industrial scale on flue gas capture (PDP+License)



*PDP executed*

Cement



## Holcim St. Genevieve

FOIK for cryogenic capture on Cement flue gas (FEED)  
DOE Awarded

*FEED under execution*

Lime

## Lhoist Réty

FOIK for cryogenic capture on Lime flue gas  
2022 Innovation Fund Awarded



*Subsidies granted  
FEED start-up Q1 2023*

Cement



## Lafarge Holcim Kujawy

CO<sub>2</sub> capture from the single line kiln  
2022 Innovation Fund Awarded

*Subsidies granted  
FEED start-up Q1 2023*

# Our key references - Cryocap™ Oxy

*Cement*

## Lafarge 1500 tpd (2009 - 2012)

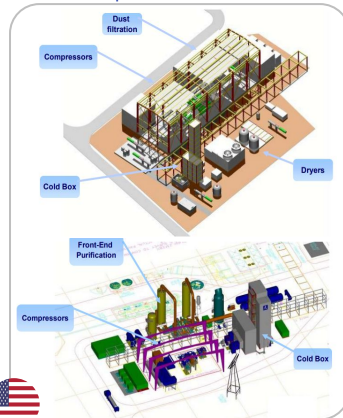
Oxycombustion in pre-calcliner  
Liquid CO<sub>2</sub> production  
Retrofit a 3500 tpd clinker



*pre-FEED executed*

## FutureGen 2.0

210 MW coal fired power plant  
Oxycombustion  
FEED performed in 2012



*FEED executed*

*Cement*

## EQIOM

Developing one of the first  
carbon-neutral cement plants  
in Europe  
2021 Innovation Fund Awarded



*Subsidies granted  
Ongoing FEED*

*Cement*

*IF Subsidies awarded*



## Holcim GO4ZERO

1.1 mty CO<sub>2</sub> to be captured on a  
new cement plant  
2023 Innovation Fund Awarded  
FEED Q1 2024



# Air Liquide E&C key reference on Cryocap™ H<sub>2</sub>

## Port-Jerôme

The world's first carbon capture plant in operation in France



*In operation*

*Under execution*



## Grandpuits

Capture new AL SMR  
25 kNm<sup>3</sup>/h H<sub>2</sub> plant  
Project under execution  
**340 tpd CO<sub>2</sub>**



Capture from existing AL large SMR 140  
kNm<sup>3</sup>/h H<sub>2</sub> plant  
2021 SDE++ Awarded  
**1800 tpd CO<sub>2</sub>**



*Under execution*



**Thank  
you**