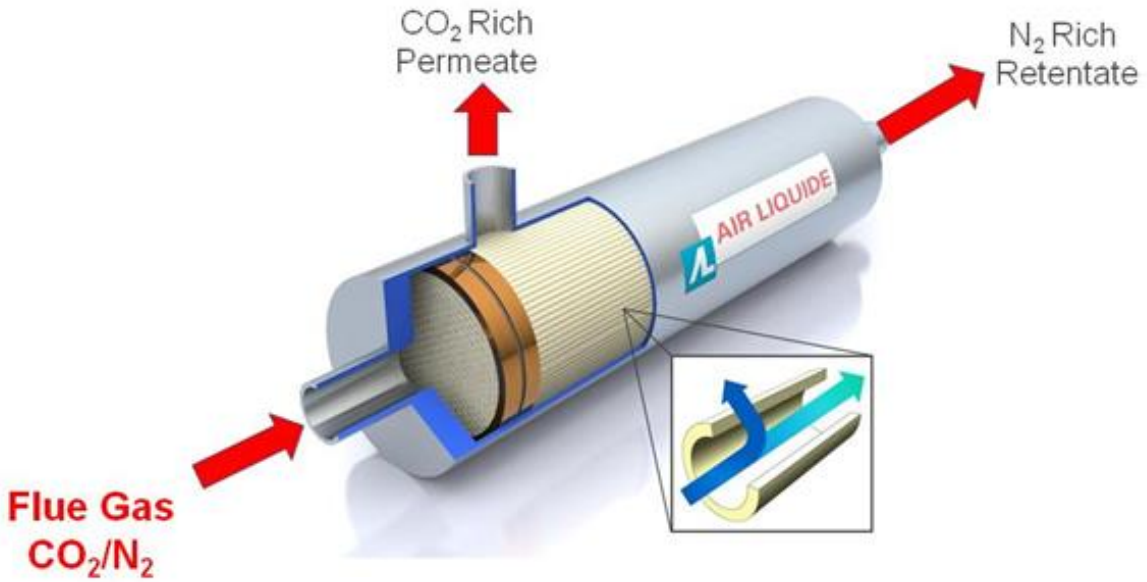
# Bench Scale Testing of Next Generation Hollow Fiber Membrane Modules (DE-FE0026422)

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**Carbon Management Technology Conference 2017**

**Houston, TX**

# Agenda

1. Air Liquide & $CO_2$

2. Project Overview

3. Current Technology Status

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# 1

# Air Liquide & $CO_2$

# Air Liquide & $CO_2$

**Market position**

- $CO_2$ as a product – 24 $CO_2$ plants in US
- Huge potential market in EOR application

Air Liquide **Cryocap™**: new range of products for this market

- Cryocap™ $H_2$: $CO_2$ capture during Hydrogen production
- Cryocap™ Oxy: $CO_2$ capture with Oxycombustion
- Cryocap™ NG: $CO_2$ capture from Natural Gas
- Cryocap™ Steel: $CO_2$ removal from Steel Production

**provider**

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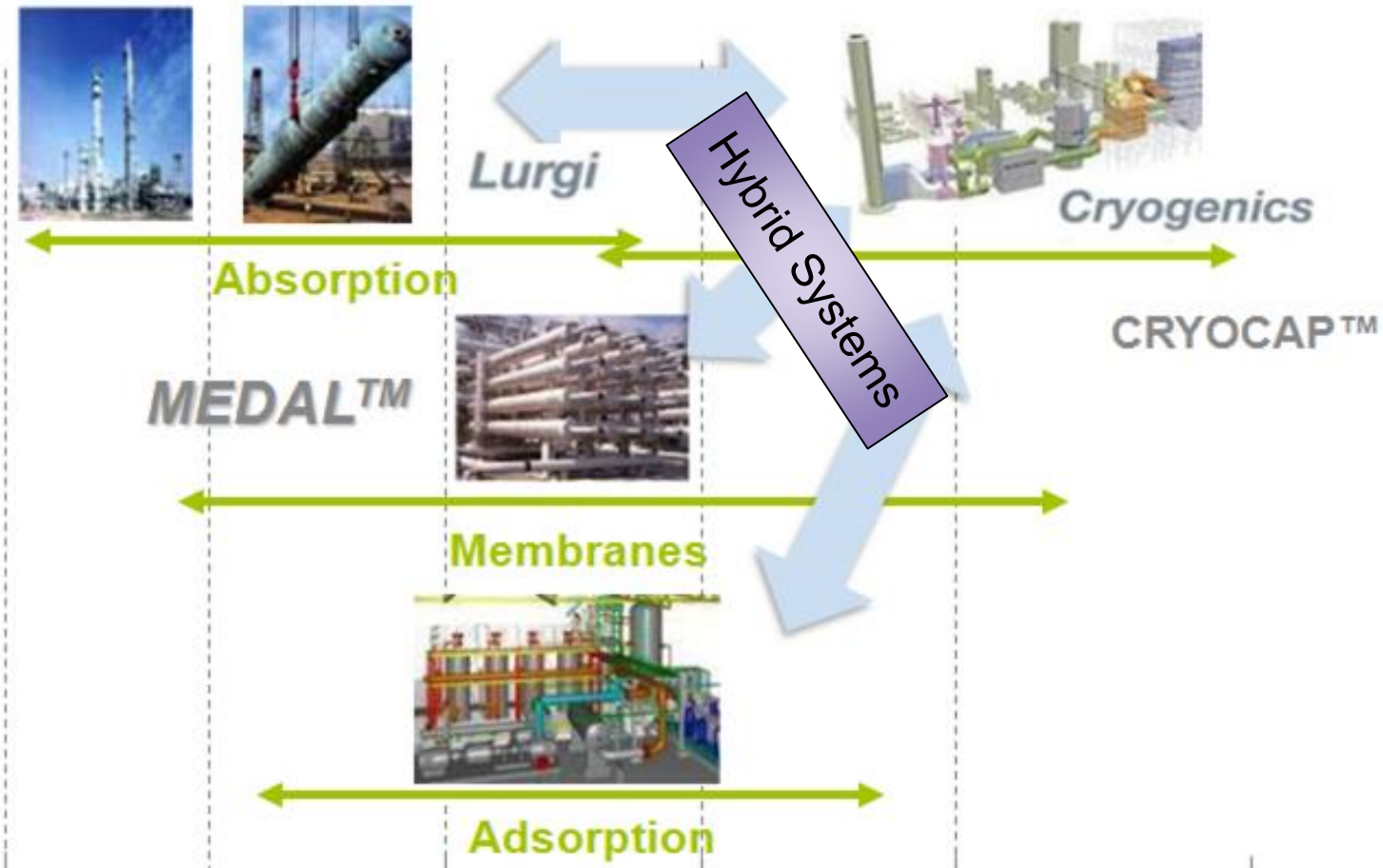
# Air Liquide -- $CO_2$ separation solution provider




Utilizing all existing techniques for the whole range of $CO_2$ feed and product purities from any $CO_2$ source

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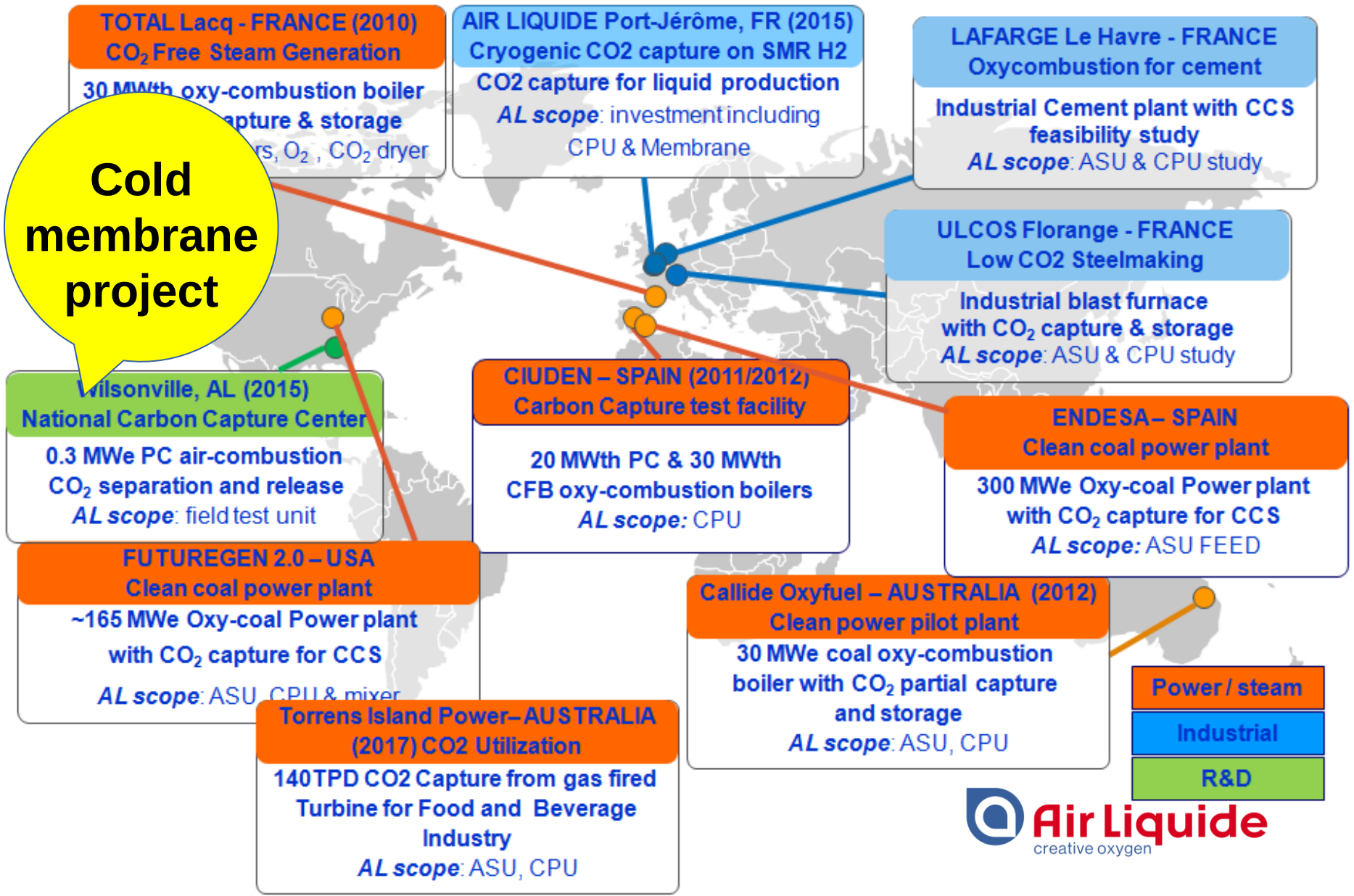
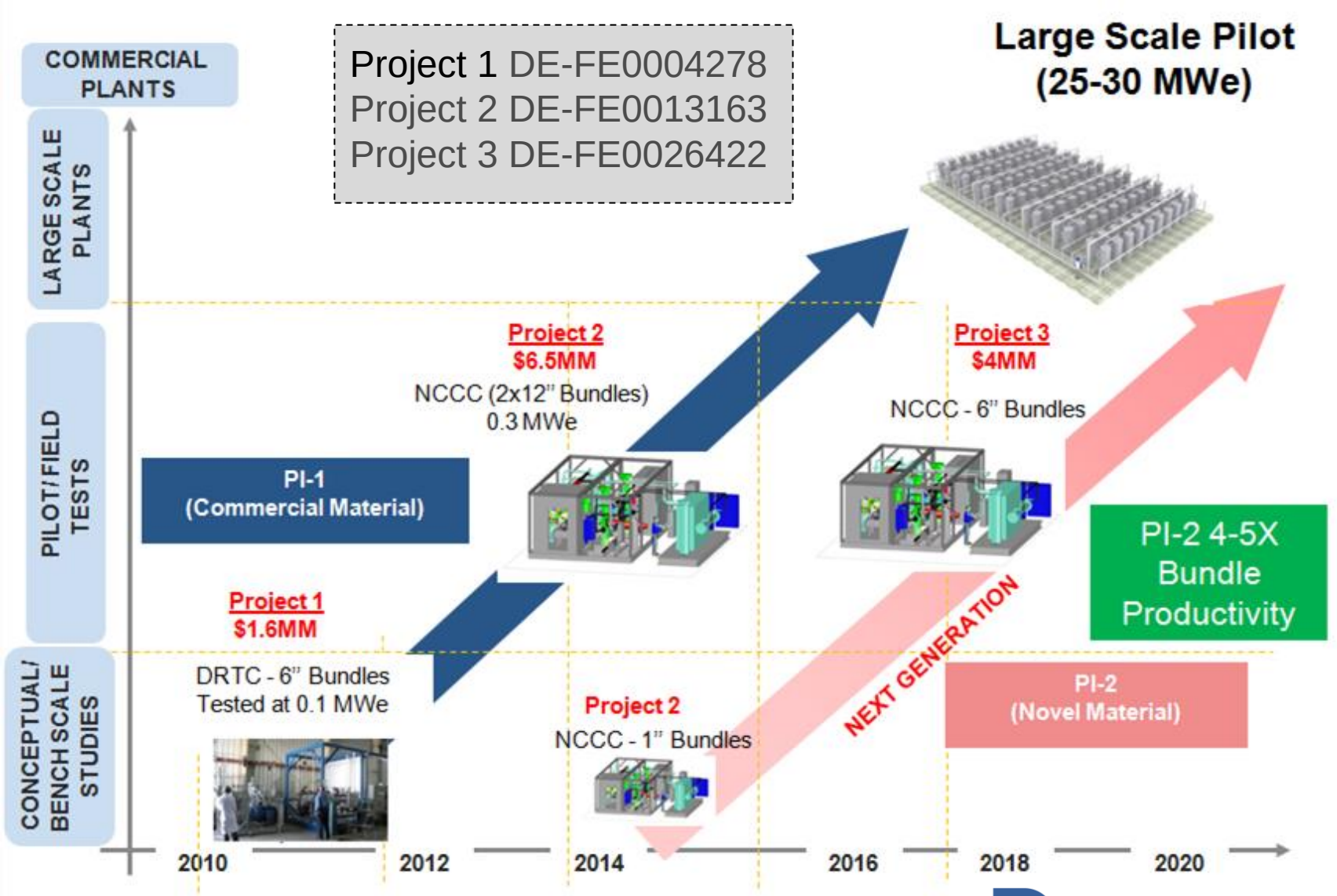
# Large Air Liquide $CO_2$ Projects



# Cold Membrane Technology Roadmap



# 2

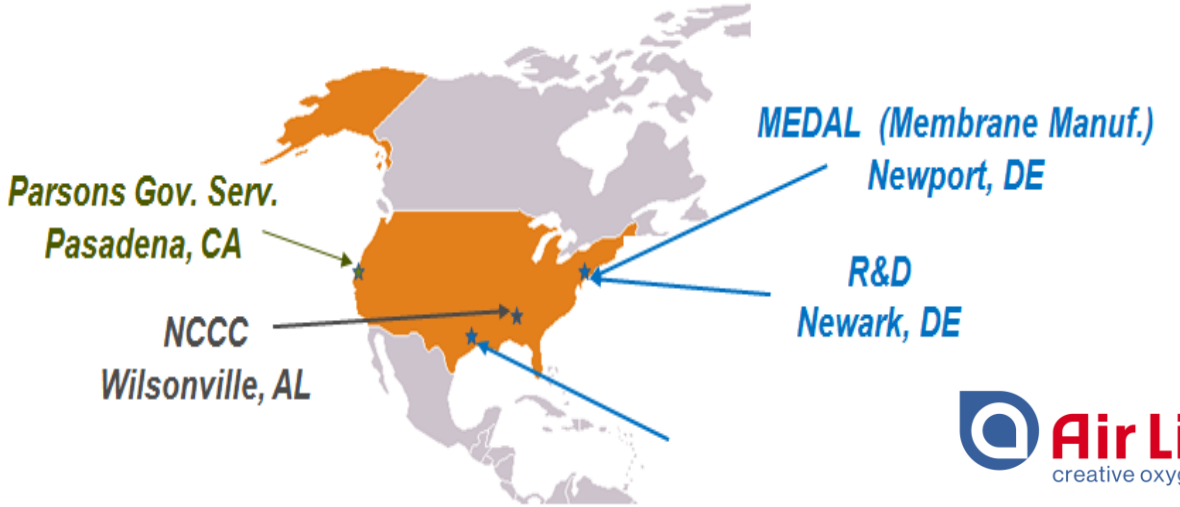
# Project Overview

# Project Overview: $CO_2$ capture by cold membrane

***Project target:*** $CO_2$ capture from coal fired power plant flue gas with AL cold membrane technology at $40/tonne:
***Total Budget:*** $4.0MM, DOE Funding - $3.0MM, AL Cost Shares - $1.0MM
***Period of Performance:*** 10/01/2015 through 12/31/2018 over 2 budget periods

| | Expenditures |
|---|---|
| Budget Period 1 (Oct 2015- June 2017) | $1,600,000 |
| Budget Period 2 (Jul 2017- Dec 2018) | $2,370,000 |

***NETL Project Manager:*** José Figueroa
***Project Partners:*** ALAS (membrane scale-up and manufacturing), NCCC (field testing), E&C (engineering cost analysis), Parsons (TEA review)

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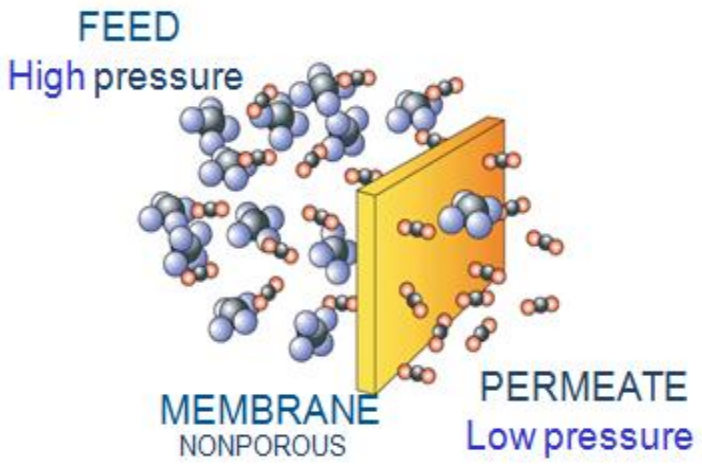
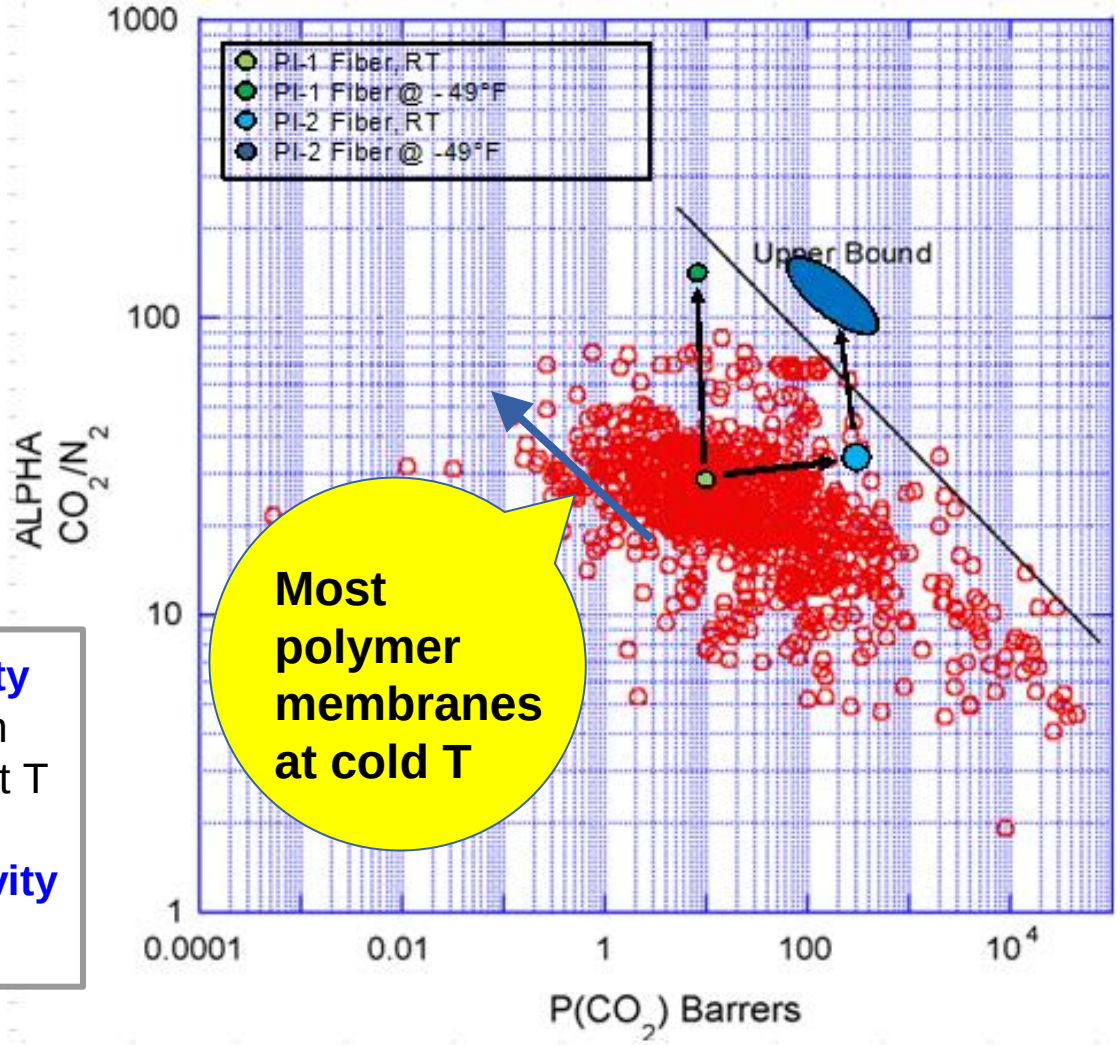
# Motivation: Membrane? Why cold? Why PI-2




- ❖ **Why cold? -- improve selectivity**
- ★ Discovered by Air Liquide R&D in 2008: Improved $CO_2$ selectivity at T below ambient
- ❖ **Why PI-2? -- improve productivity**
- ★ 4-5 X higher $CO_2$ productivity

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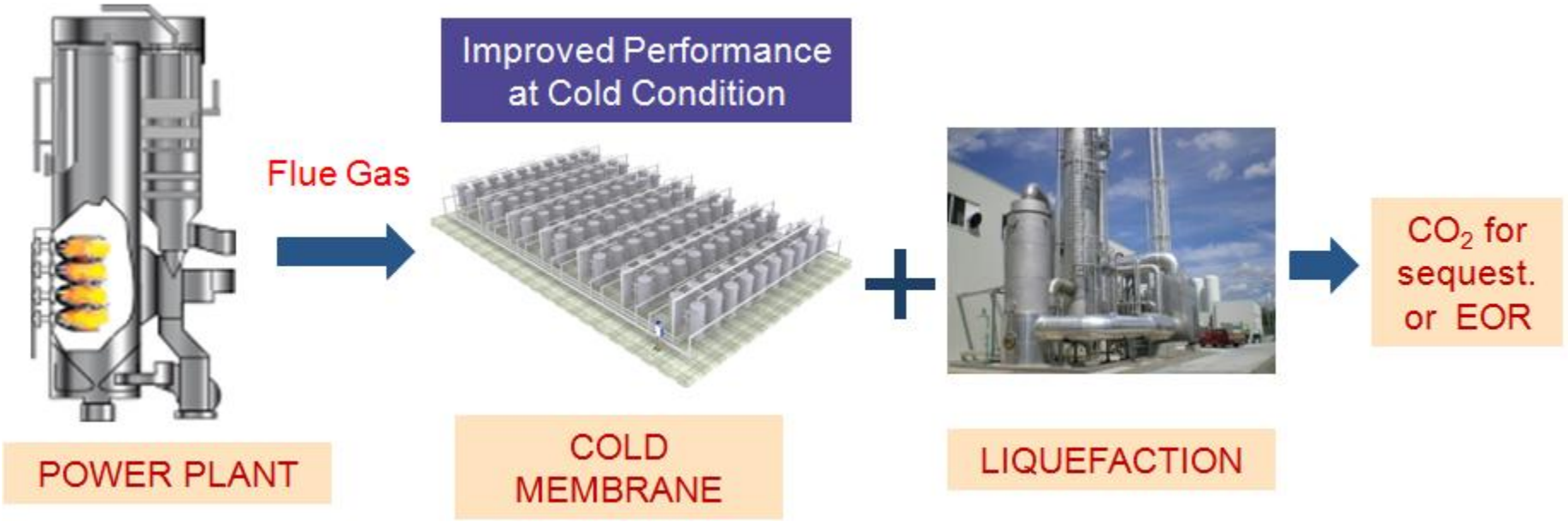
# Air Liquide Capture Technology Summary

❖ **Air liquide hybrid cold membrane - liquefaction process**

- Novel cold membrane technology
- Well established liquefaction




Synthetic flue gas at 0.1 MWe (TRL4) bench scale skid

→

Actual flue gas from coal fired power plant at 0.3 MWe (TRL5) field test unit at NCCC

# Synthetic flue gas testing

## 0.1MWe (TRL 4) bench scale skid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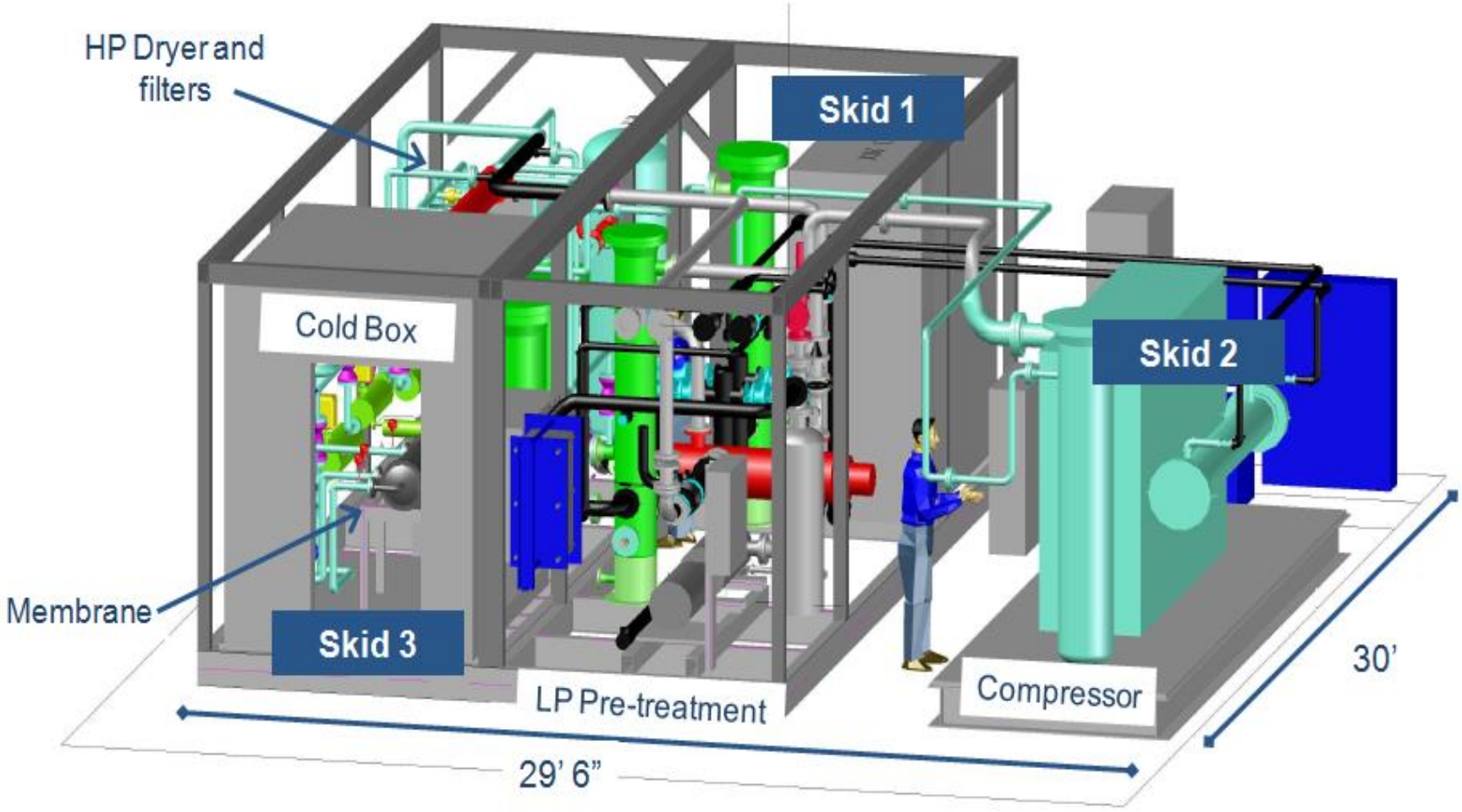
# Actual flue gas testing at NCCC

## 0.3MWe (TRL 5) field test unit

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# Actual flue gas testing at NCCC

## 0.3MWe (TRL 5) field test unit

# 3

# Current Technology Status

# Membrane bundles - lab scale to commercial scale

| | Diameter in. (mm) | Length ft. (m) | Fiber Count |
|---|---|---|---|
| Mini permeator | 0.25 - 0.5" (6.4 – 12.7) | 0.5-2.8 (0.15-.085) | <1000 |
| Permeator | 1" (25.4) | 1.6 (0.5) | 2 – 20x |
| Prototype Permeator | 2.5" (63.5) | | 10 – 100x |
| R&D prototype bundle | 4" (101.6) | 2.8 (0.85) | 100 – 400x |
| 6" bundle (commercial) | 6" (152.4) | | 200 - 1000x |
| 12" bundle (commercial) | 12" (304.8) | | 500 - 4000x |


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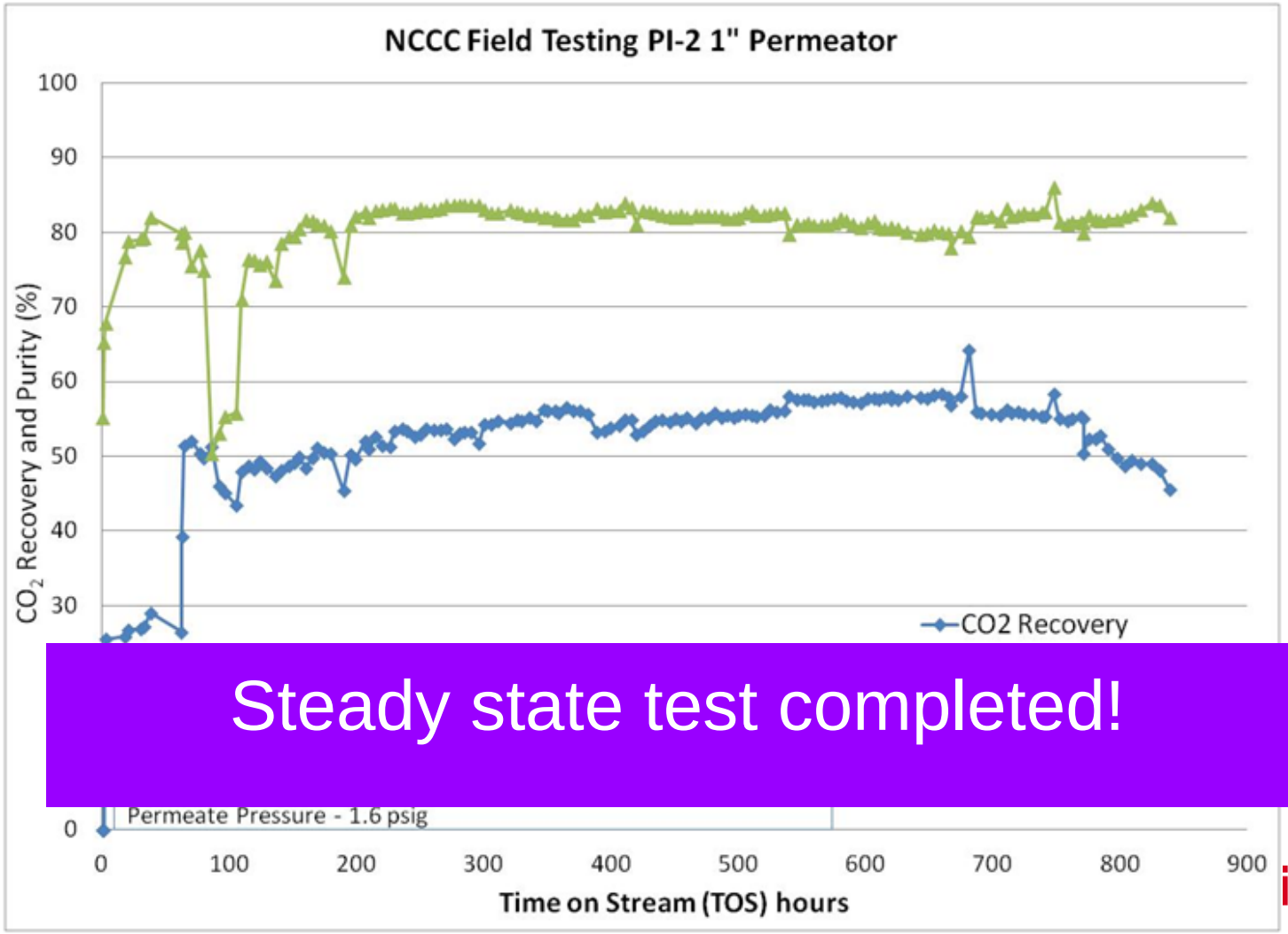
# PI-2 1” mini permeator tested at NCCC (2016)

★ Testing for viability of PI-2 membrane in treated flue gas service
★ Tested during the previous DOE-AL project (DE-FE0013163)




Steady state test completed!

# Design/Manufacture 4” PI-2 Bundles (2017)

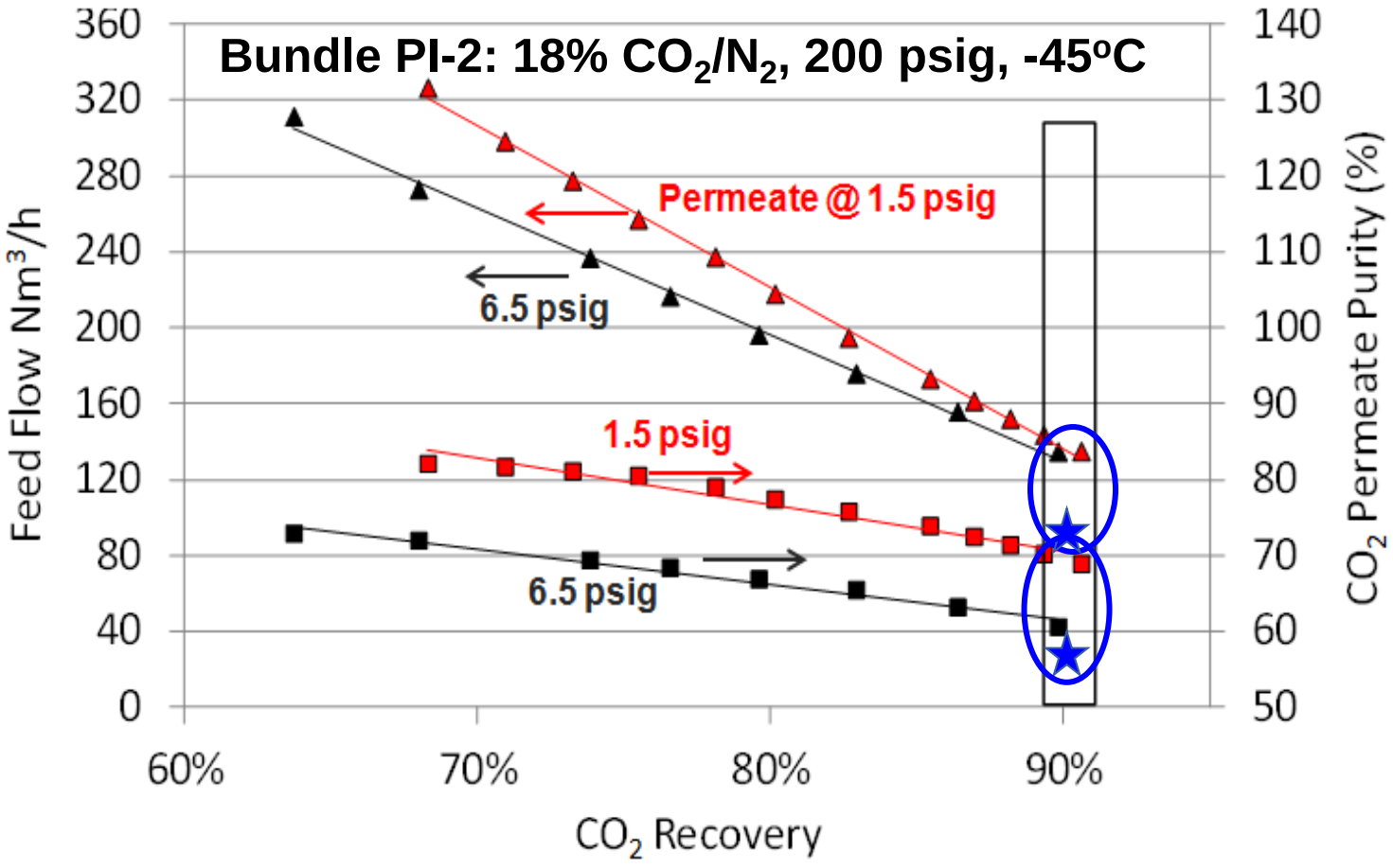

**Pilot mixers**

**DSU unit**
**Multi-filament spin line**

**Two prototype bundles**

**Development spin unit (DSU) - representative of commercial spin line**

# 4” Bundles tested with synthetic flue gas




★ ***Exceeding the project target:*** > 90 $Nm^3/h$ feed at 90% $CO_2$ recovery, >58% $CO_2$ purity

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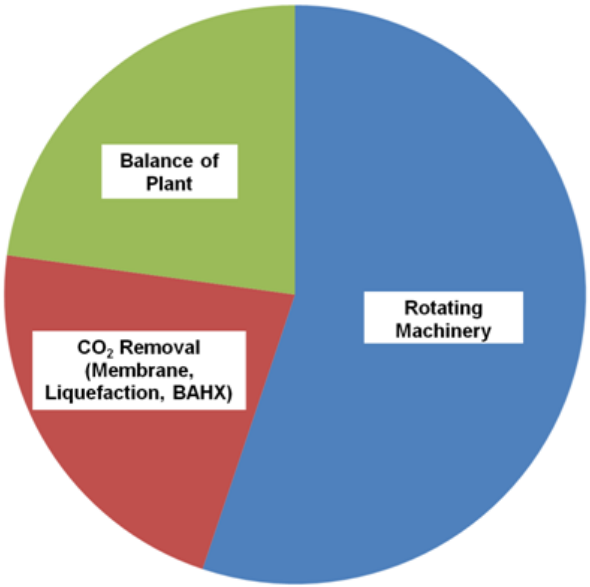
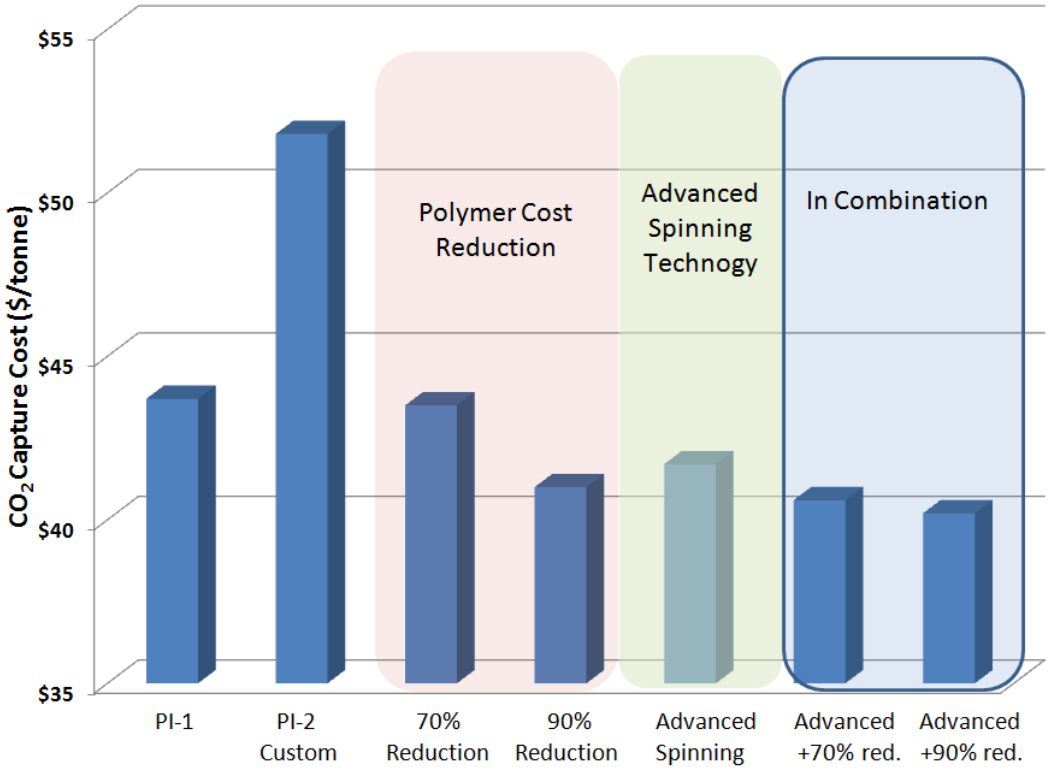
# Ongoing & future work

- **Reducing $CO_2$ capture cost with PI-2:**




**Projected 12'' PI-2 bundle cost breakdown**
(TEA study from Project 2)




★ **Reduced costs moving from lab production to bulk production**

★ **Advanced vs. traditional membrane formation method**

# Ongoing & future work

- **Field test of 6’’ PI-2 bundle at NCCC**

# Summary

★ Air Liquide is utilizing all existing techniques for the whole range of $CO_2$ feed and product purities from any $CO_2$ source

★ ***Exceeding the project target:*** > 90 $Nm^3/h$ feed at 90% $CO_2$ recovery, >58% $CO_2$ purity

★ Getting ready for the 0.3 MWe field test of 6'' PI-2 bundle

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# Acknowledgement / Disclaimer


- US DOE: José Figueroa, Sheldon Funk
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Research & Development

# Opening new ways

**THANK YOU FOR YOUR ATTENTION**