

Global Hydrogen Experience

- **Leadership position in outsourced Hydrogen production and recovery**
 - Hydrogen supplier since 1975 (first liquefier to NASA)
 - Supply >3.7 million Nm³/h of hydrogen (>7,500t/d)
- **Own and operate over 80 large hydrogen plants**
 - Over 1400 operating years for Hydrogen plants
 - Experience of various production methods from SMR, ATR, gasification and electrolysis
 - Reputation for reliability of operation
- **Lessons from supply to refining and chemicals industry are relevant to the Energy Transition including hydrogen for mobility**
 - Since 1993, > 250 H₂ station projects in 20+ countries
 - >1,500,000 fuellings/year / > 10,000,000 total fuellings
- **Member of the Hydrogen Council, a global CEO-led initiative with a united and long-term vision to develop the hydrogen economy**



Kochi (India): First-ever twin steam methane reformers designed and built by Air Products with a combined capacity of 16.4 tons per hour of hydrogen production.

World Largest Hydrogen Distribution Network

Air Products Gulf Coast Hydrogen

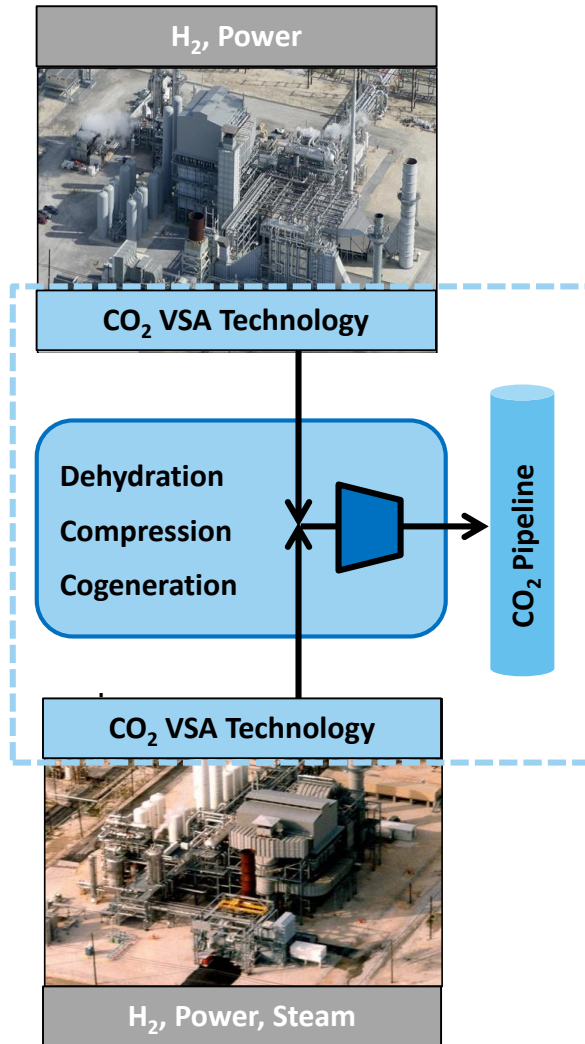


- ~700 Mile System
- >1.9 million Nm³/h Capacity
- 12 SMRs
- 2 H₂/CO/SG Plants
- 9 Off-gas Recovery Plants
- 1 SMR Under Construction

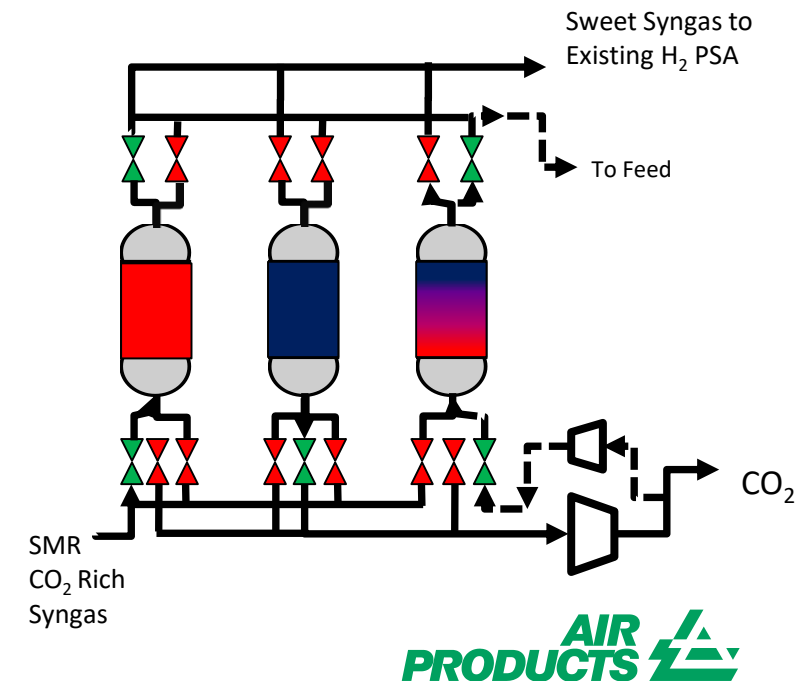
- Air Products H₂ Pipeline
- H₂ SMR
- H₂/CO/SG Plant
- Off-Gas H₂ Plant
- SMR Under Construction
- H₂ Satellite Facility

Air Products Port Arthur CO₂ Project

6 million tonnes captured to date

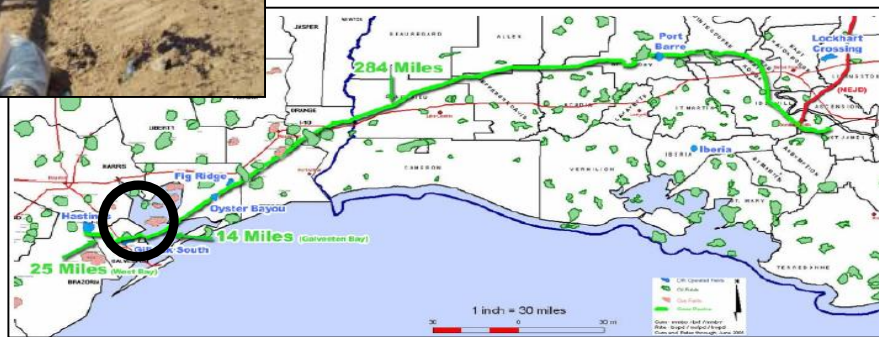


- Supplies 56,000 Nm³/h CO₂ compressed and purified CO₂ for injection into TX oilfields for enhanced oil recovery (EOR)
- Retrofit of 2 SMRs located in the middle of Valero refinery
- **AP CO₂ Vacuum Swing Adsorption** Technology selected as superior to Amine for this application
 - Installed upstream of PSA
- 90%+ capture of CO₂ from the process gas stream



Key Project Components

- Vacuum swing adsorption (VSA) vessels
- Tri-ethylene glycol (TEG) drier system
- CO₂ export compressor
 - 8 stages
 - Export pressure over 140 bar
- 13 mile (21 km) supercritical CO₂ pipeline connecting to Denbury's "Green" 300+ Mile CO₂ Pipeline



Map shows Denbury's Green CO₂ Pipeline. Data source is Denbury, December 2011,

	CO ₂ VSA (Upstream of PSA)	aMDEA (Upstream of PSA)
Relative Capex	Sensitive to location - high construction costs favor VSA, lower favor aMDEA	
CO ₂ recovery	~93-97% depending on CO ₂ specification	98% +
CO ₂ avoided	Typically higher for VSA; lower energy demand & lower carbon intensity of electricity vs steam	-
Efficiency (kJ/MT CO ₂ captured)	More efficient	Less efficient (~2 x energy demand or more) Uses lower-value energy (e.g. LP steam)
Intensity (indirect emissions/CO ₂ captured)	Lower, and decreasing as grid intensity reduces over time	Higher (typically ~1.5-2 x VSA)
Relative Reliability	Negligible impact on H ₂ availability with either system	
Operability	Faster to start up and shut down, simpler to ramp	-

Hydrogen and Syngas Production BAT Guidance

- Hydrogen/Syngas/ Carbon Monoxide plants (HYCO) are an Annex 1 activity under IED (4.2) and are used in several industry sectors and are covered in detail the following BREFS
 - [LVOC BREF](#) - Covering processes such as MDI
 - [LVIC BREF](#) -Covering process ammonia
 - [Refinery BREF and associated BAT conclusion's](#) – part of the refinery ‘bubble’
 - Waste Gas (WGC) BREF (in development but standalone SMR in scope)
- Industry guidance- [European Industrial Gases Association](#) Documents
 - [EIGA document 155 Hydrogen plant](#)*(covers SMR)
 - [EIGA document 183 HYCO plant](#) *(covers SMR, POX, ATR, etc)
- Suggestions on scope of CCS BAT Document**
 - BAT document should be looking at the impacts of adding CCS, not at the base SMRs/Processes themselves.
 - CO2 is not regulated under IED so BREF can not recommend standards for CO2 avoidance. Installations still require a GHG permit if listed as activities under EU ETS annex 1 (SMR>20 MWth)
 - Hydrogen production from raw materials other than methane?

