Pushing to Zero Carbon Hydrogen

Michelle Schoonover

Manager – Syngas Technology

KAUST Research Conference: Hydrogen-Based Mobility and Power

24-26 October 2022

AIR PRODUCTS

Air Products

…a leader in the global industrial gas industry

$10.3 billion in FY21 sales	20,000+ employees	50 countries
~$55B market cap	80 years in business	170,000+ customers
1,800 miles of industrial gas pipeline	750+ production facilities	30+ industries served

Air Products: World Hydrogen Leader

The world's largest hydrogen producer with proven reliability

1100+ kilometers of pipeline

> 32 billion Nm3/year

H_2 The world's longest H_2 pipeline system and world-class liquid hydrogen supplier

15+ years safe fueling

250+ Hydrogen fueling projects worldwide

30+ H_2 Electrolyzer projects

20+ countries Unique product offering for H_2 fueling

1,500,000 fueling per year

10 million Total fueling

~50 patents for hydrogen fueling

Production	SMR, Gasification, Off-gas, Electrolyzer, Liquefier
Distribution	Pipelines, Liquid trucks, Gaseous trucks, Mobile fuelers

Hydrogen Will be Key to the Energy Transition

FINANCIAL TIMES

Hydrogen: can the lightest gas turn heavy industry green?

Steel, cement and chemicals industries must cut carbon footprints to meet EU emissions deadlines

TECH > HYDROGEN | 14 May 2021 | updated 05 Nov 2021 9:31am

Hydrogen vital for decarbonisation of heavy industries – report

The decarbonisation of hard-to-abate industrial sectors will hinge on the widespread use of hydrogen, confirms a study by Aurora Energy Research.

By Energy Monitor Staff

REUTERS EVENTS
RENEWABLES

Green hydrogen seen as best option for steel decarbonization

Mar 8, 2022

Global steel manufacturing is responsible for quarter of global industrial sector carbon dioxide emissions and decarbonizing the sector using green hydrogen is the most promising, though initially expensive, option, say industry heads and analysts.

RENEWABLE ENERGY MAGAZINE
At the heart of clean energy journalism

Heavy duty transport transition will rely more on hydrogen than batteries says new forecast

Thursday, 23 June 2022

BBC

The hydrogen revolution in the skies

By Caspar Henderson 7th April 2021

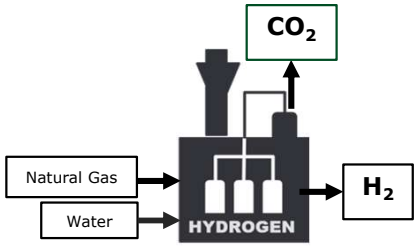
A record-breaking commercial-scale hydrogen plane has taken off in the UK, with more set to join it soon. How far can such planes go in cutting the aviation industry's emissions?

AIR PRODUCTS

Hydrogen production is moving towards low-carbon

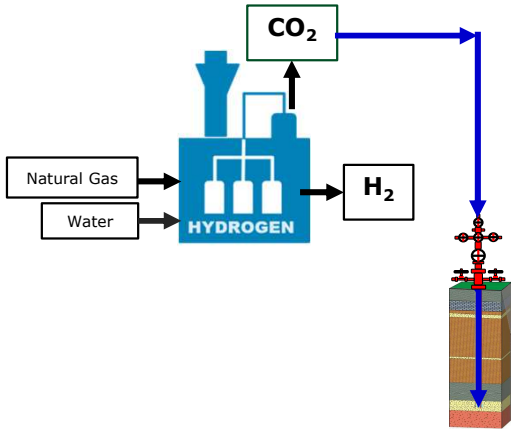
Grey Hydrogen

- Steam methane reforming (SMR): ~95% of world's H_2 production
- Large installed base: **need retrofit solution**



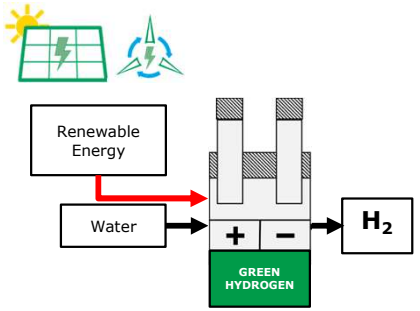
Blue Hydrogen

- SMR / ATR / Gasification with CO_2 capture and storage
- Can achieve negative carbon emissions



Green Hydrogen

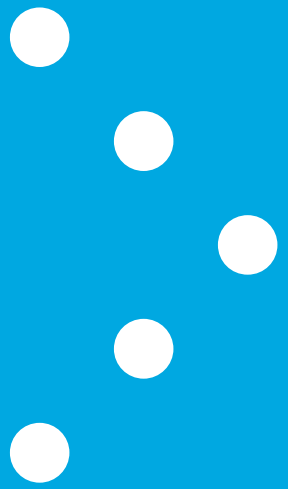
- Electrolysis of water with renewable energy
- CO_2-free, requires new construction and low-cost renewable energy



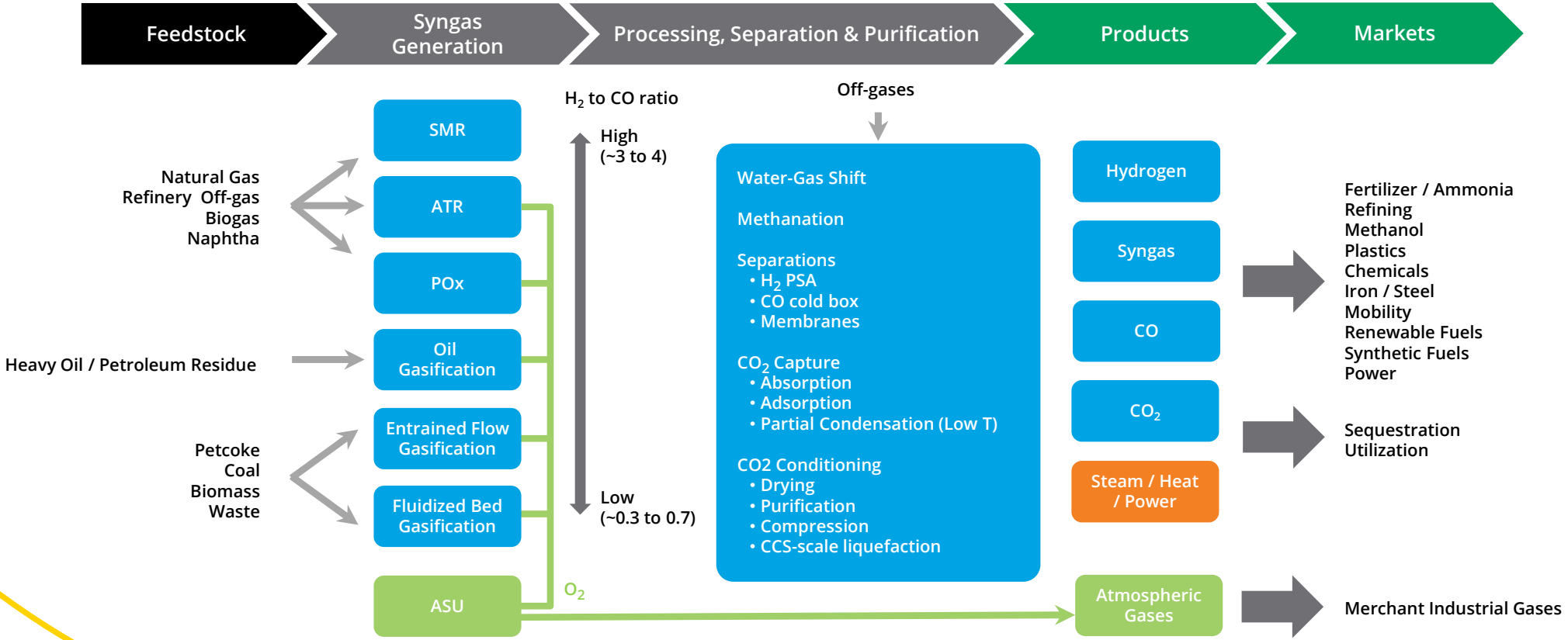
Current state
(~70 million tonnes H_2 annually)

Carbon-free future
(50–100+ % CO_2 reduction w/CC, carbon-free w/Electrolysis + Renewable Power)

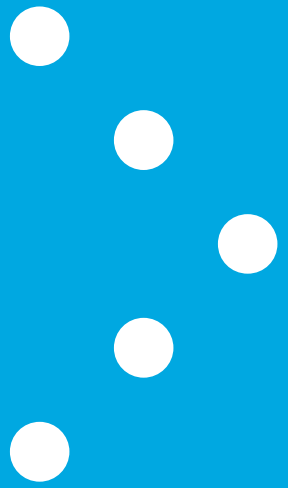
Blue Hydrogen



Air Products' Blue H_2, Syngas & CCUS Portfolio



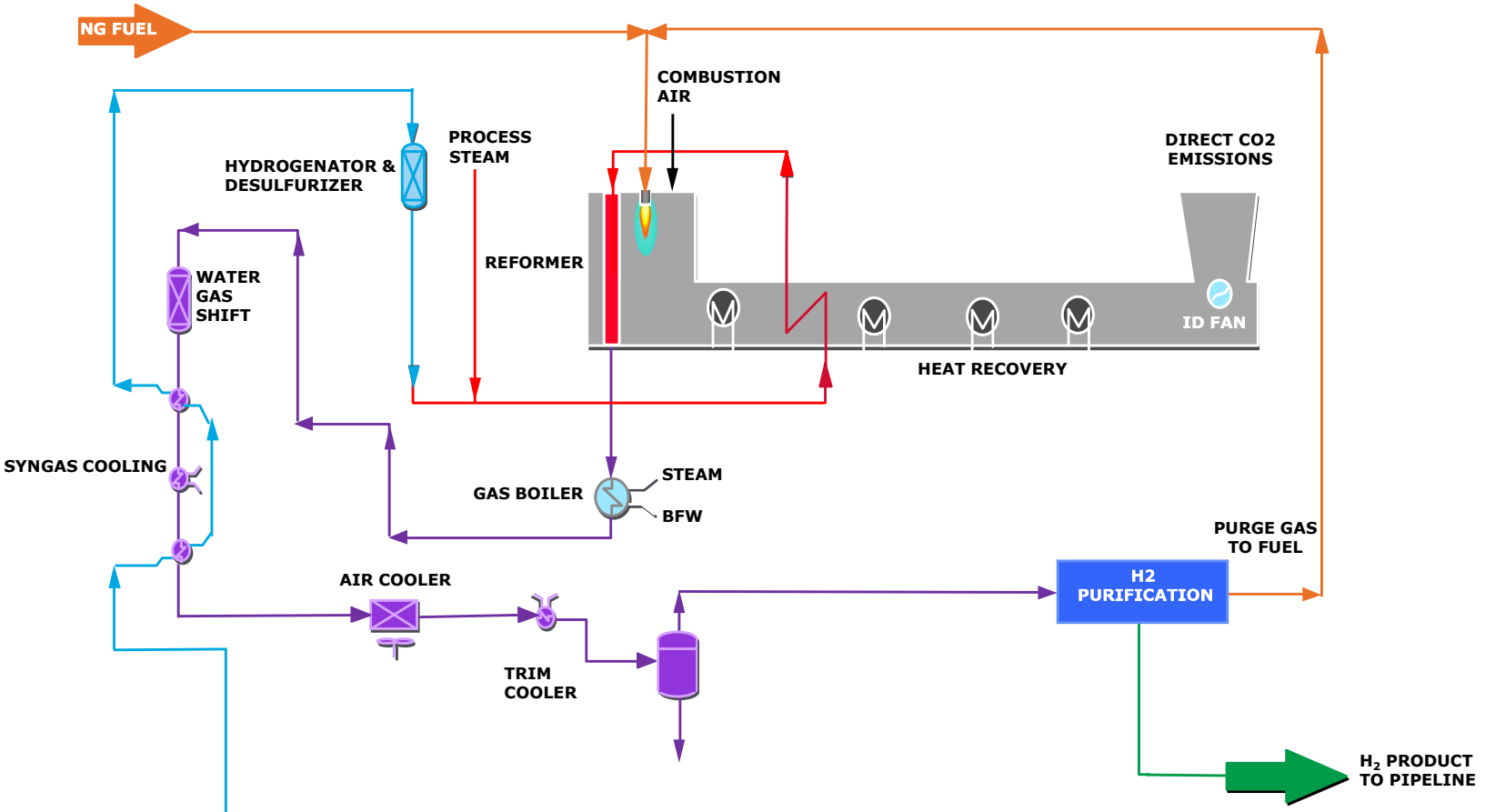
Steam Methane Reforming



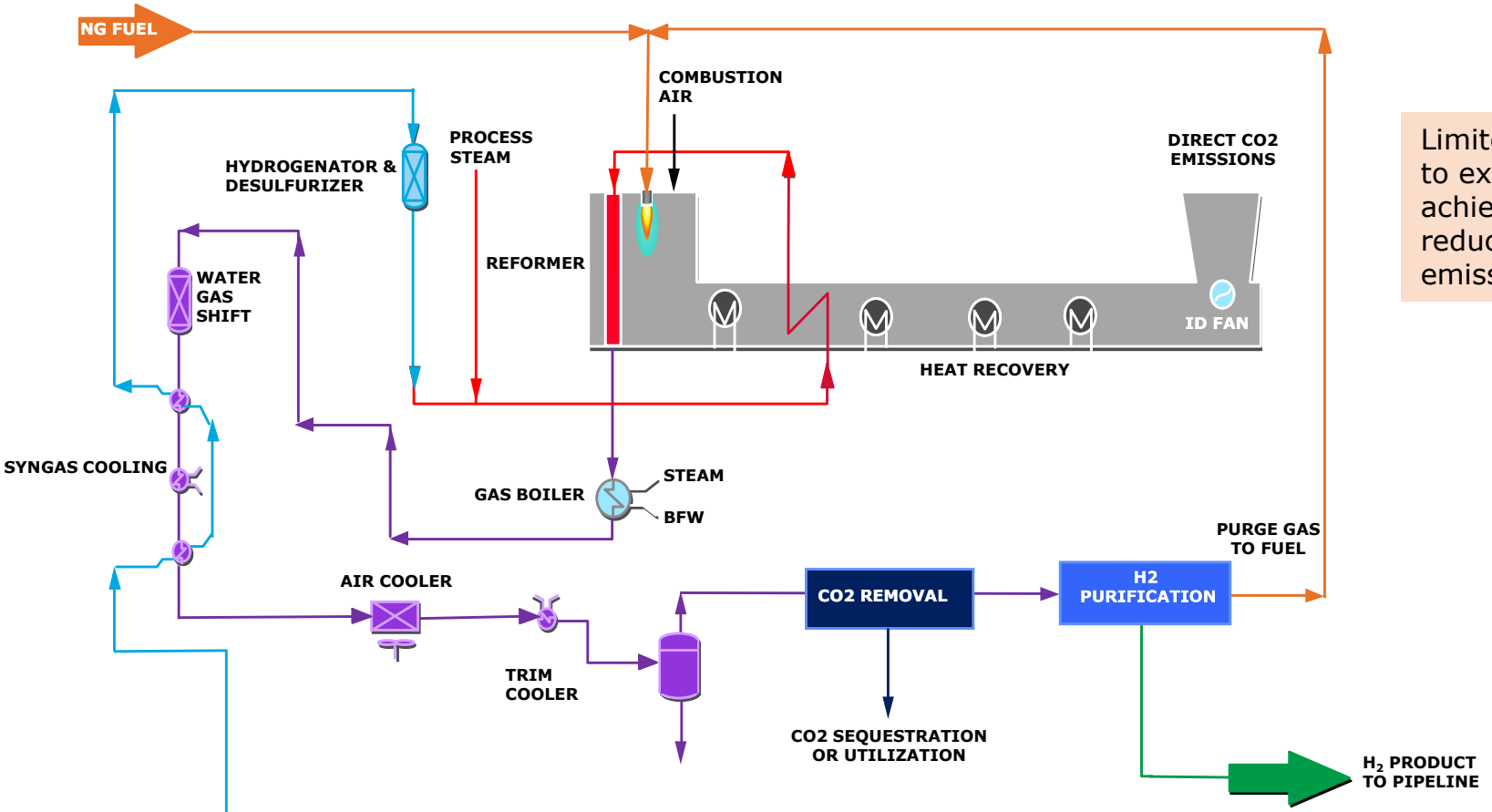
Steam Methane Reformer for Blue Hydrogen

- **Typical feedstocks**
  - Natural gas
  - Light hydrocarbons (LPG, Off Gases)
- **Co-product (if required)**
  - Steam
  - Power
- **Size range**
  - 100 Nm3/h to 200,000 Nm3/h H_2
  - (0.1 to 175 MMSCFD)
- **Typical CO_2 recovery**
  - ~50% for SMR

Typical Gray SMR Flowsheet



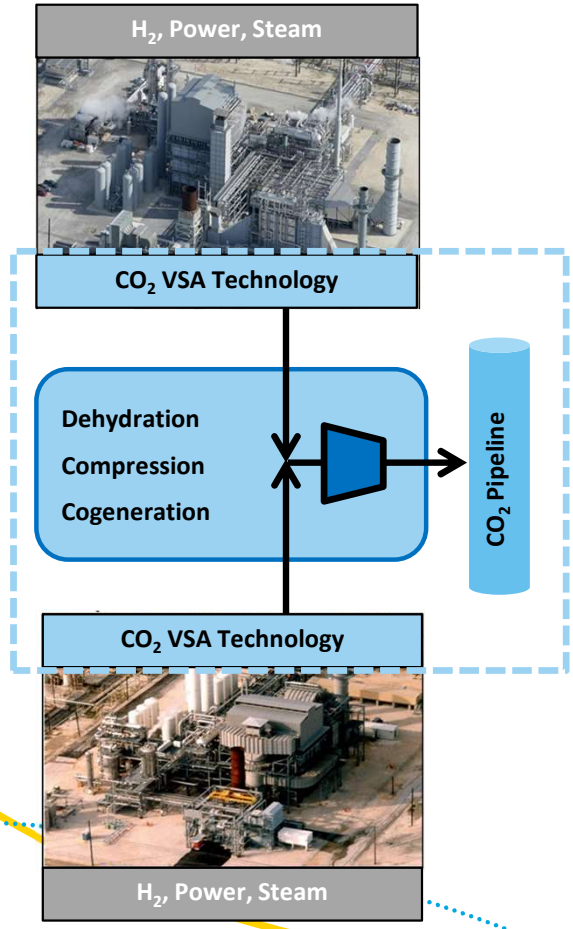
Typical Blue SMR Flowsheet



Limited modification to existing SMR will achieve ~50% reduction in CO2 emissions.

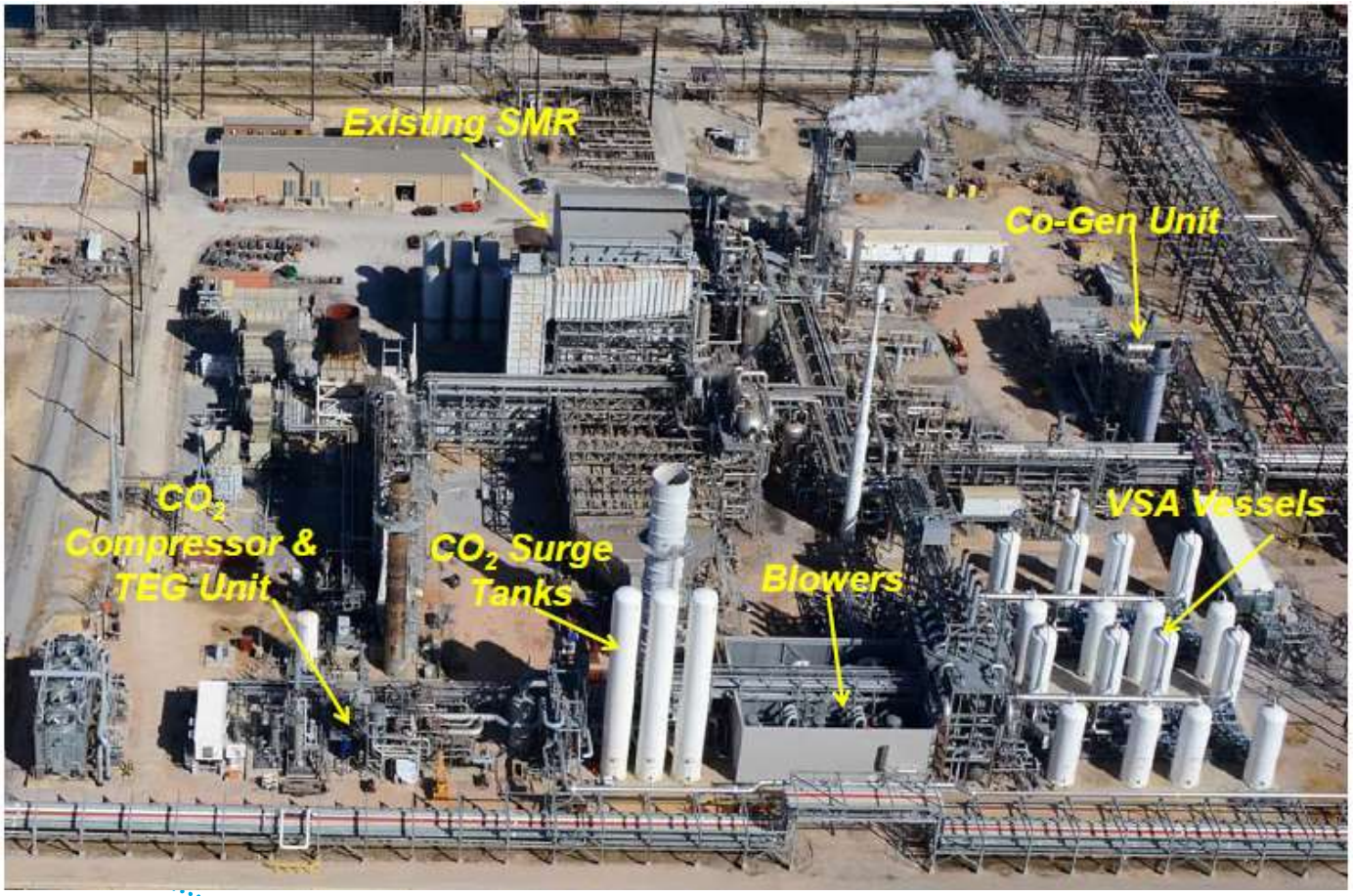
Air Products Port Arthur CO_2 Project

2012 onstream



- Retrofit of 2 Steam-Methane Reformers (SMR) that sit in the middle of a refinery
- Capture and purification of CO_2 from hydrogen plants (syngas) for EOR
- Technology developed by Air Products
- 90%+ capture of CO_2 in syngas (flue gas CO_2 not captured)
- 1 million tons per year of CO_2 to Denbury's Green Pipeline for West Hastings oilfield
- 30 MW Cogeneration unit to generate power and make-up steam
- Over 9 years of continuous operation

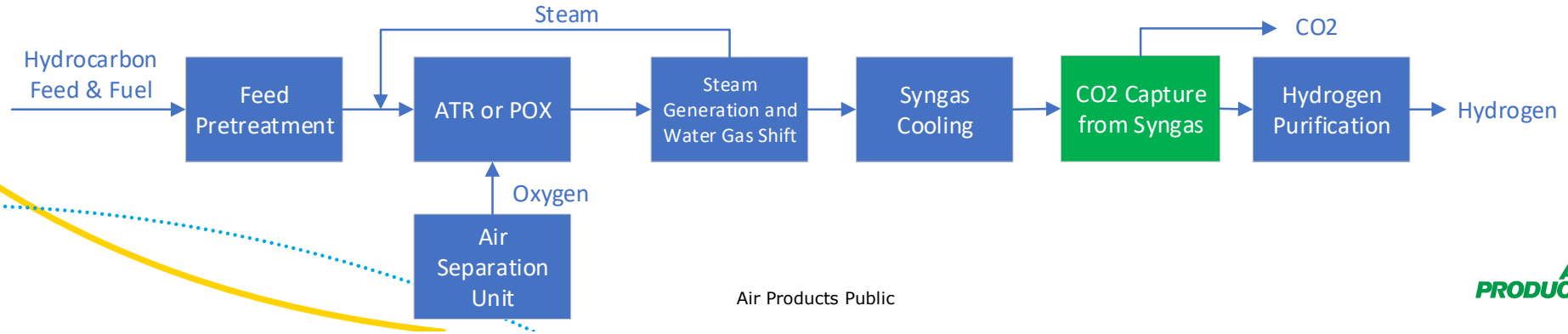
Overview of Air Products project site: Port Arthur, Texas



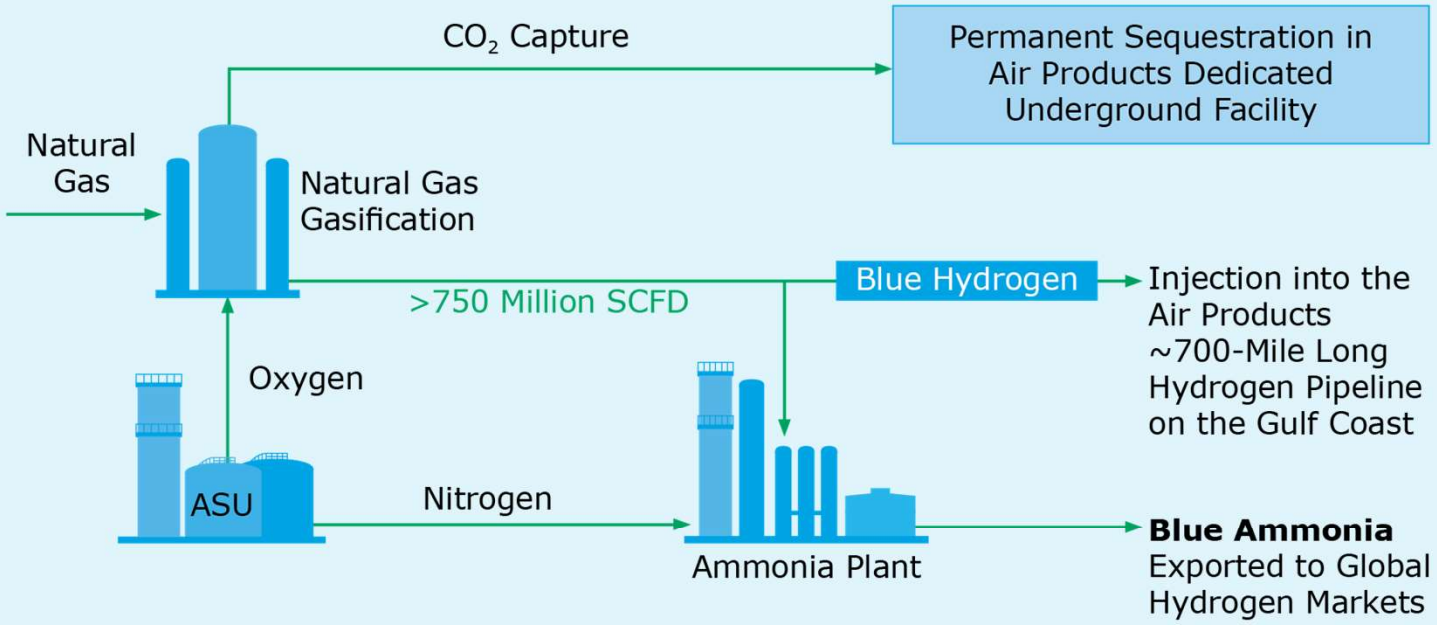
Auto Thermal Reforming (ATR) and Partial Oxidation (POX)

Auto Thermal Reforming and Partial Oxidation

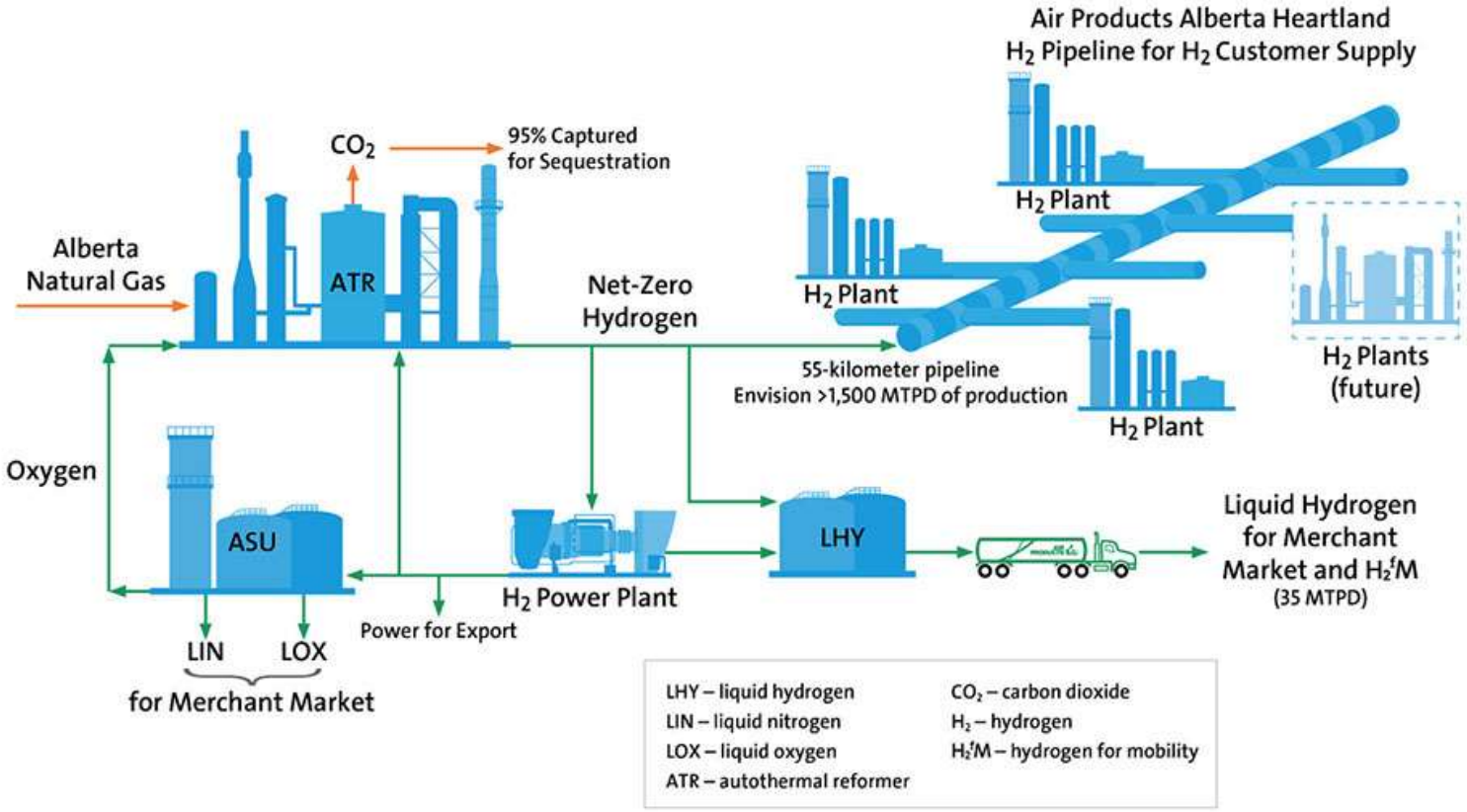
- **Typical Feedstocks**
  - ATR: Natural Gas, Light Hydrocarbons, treated as SMR
  - POX: Flexible Feedstocks (Non-catalytic Process)
- **Maximum size typically up to 500,000 Nm3/h H2**
- **Advantages of ATR/POX**
  - Larger plant sizes possible
  - Simple CO2 capture to > 95%
- **Disadvantages of ATR/POX**
  - Requires an Air Separation Unit (ASU)
  - 15,000 Nm3/h Hydrogen would require 3600 Nm3/h O2 (124MT/d)



World's Largest Blue Hydrogen Facility Louisiana, USA

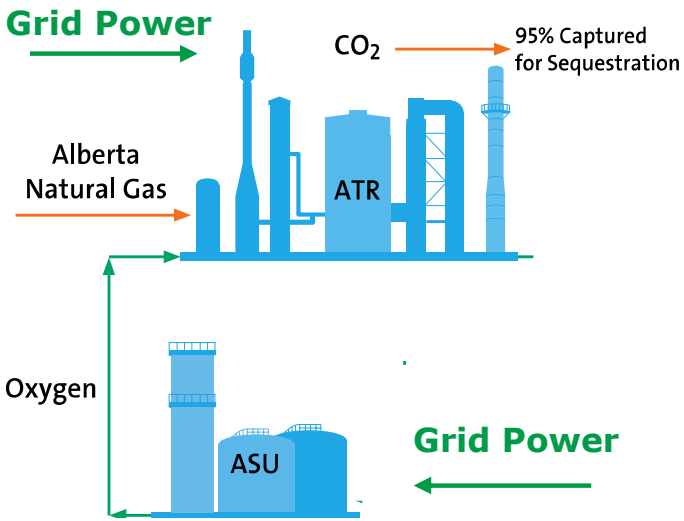


World-Scale Net-Zero Hydrogen Energy Complex
Alberta, Canada



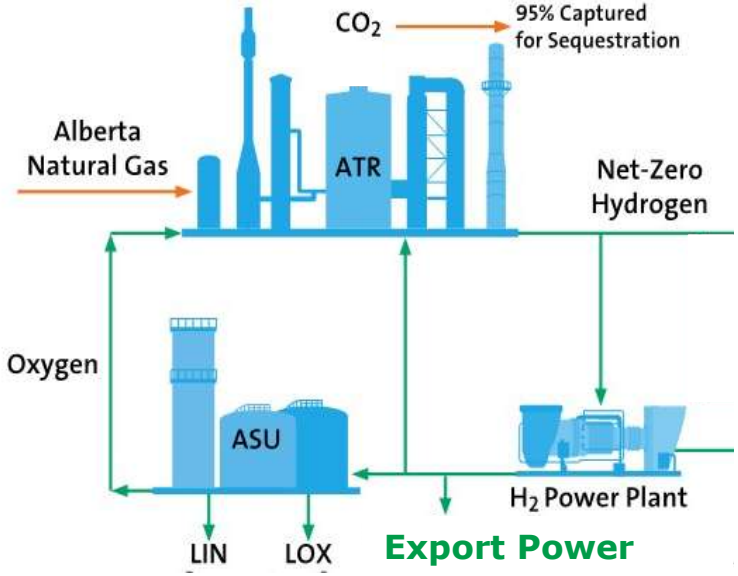
Paradigm Shift – H2 Plant as Power **Producer**

Conventional – Grid power is *imported*

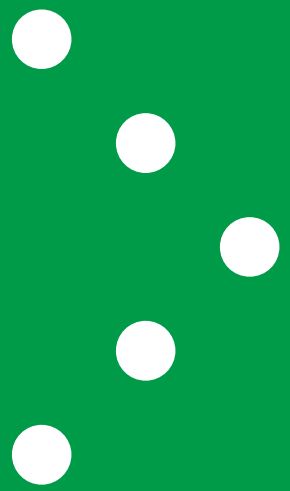


Air Products Blue H2: Power is *exported*

Much lower CO2 footprint

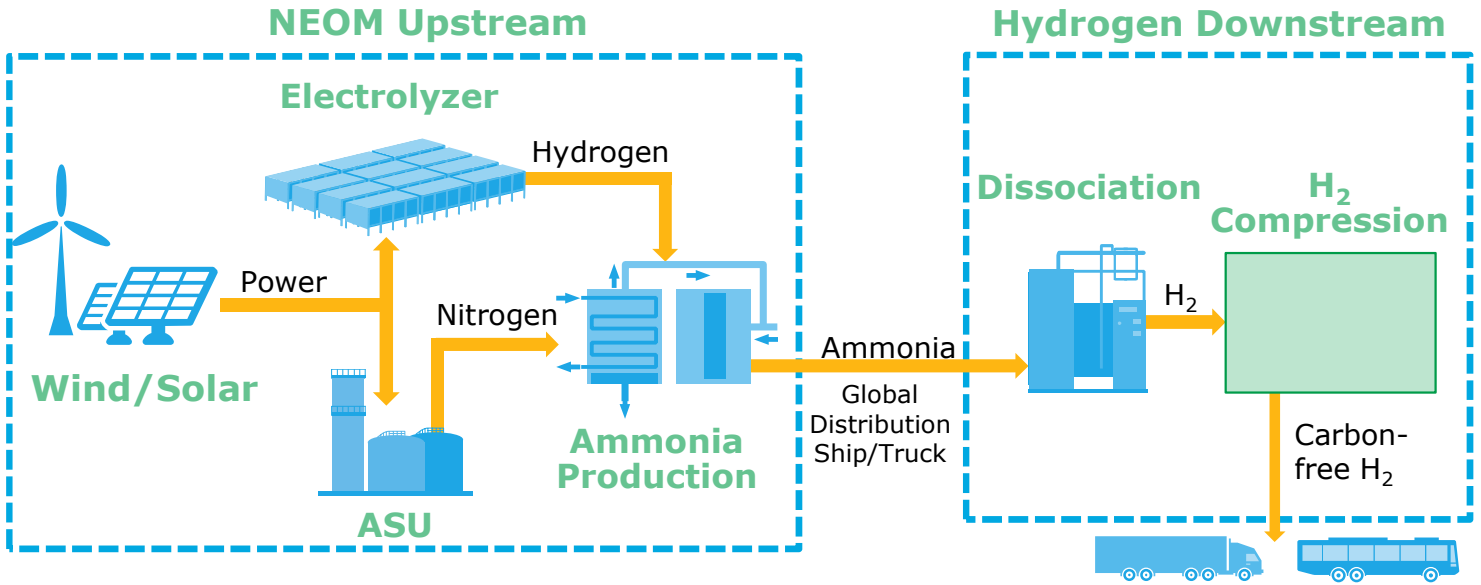


Green Hydrogen



NEOM Carbon-free hydrogen

Produced and delivered with world-class technology



650,000 kg/day of Carbon-free Hydrogen

- **Ownership:** 1/3 equal Air Products/NEOM/ACWA Power
- **Ownership:** 100% Air Products

Multi-billion-dollar total investment

Pushing to Zero Carbon Hydrogen

- Air Products, world leader in Hydrogen, is a first mover in both blue and green hydrogen
  - Louisiana and Alberta are the first of many world-scale blue hydrogen projects
  - NEOM is the first of many world-scale green hydrogen projects
- Investments in large scale projects will accelerate learning and drive technology development across the hydrogen supply chain
- Air Products is excited about our on-going work in Saudi Arabia, including hydrogen research at our Technology Center in Dharan Techno Valley
- Air Products is committed to further pursuit of collaboration projects in Saudi Arabia in the push to zero carbon hydrogen

Thank you
tell me more

AIR PRODUCTS