Gas-Gas Separation in the Production and Application of Blue Hydrogen

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"Colours" of Hydrogen

GREEN
Hydrogen produced by electrolysis of water, using electricity from renewable sources like hydropower, wind, and solar. Zero carbon emissions are produced.

BLUE
Grey or brown hydrogen with **its CO_2 sequestrated or repurposed.**

YELLOW
Hydrogen produced by electrolysis using grid electricity.

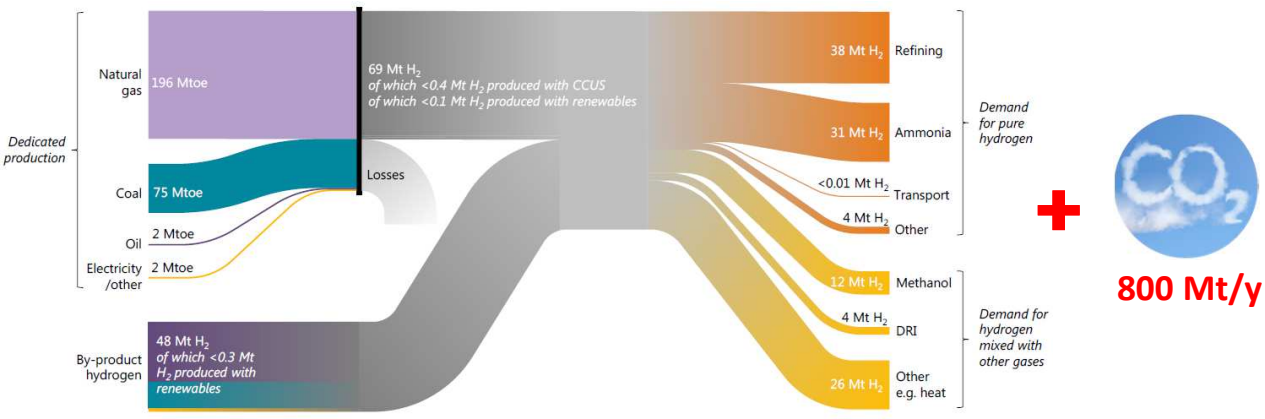
BLACK/GREY
Hydrogen extracted from natural gas using steam-methane reforming.

PURPLE/PINK/RED
Hydrogen produced by electrolysis using nuclear power.

BROWN
Hydrogen extracted from fossil fuels, usually coal, using gasification.

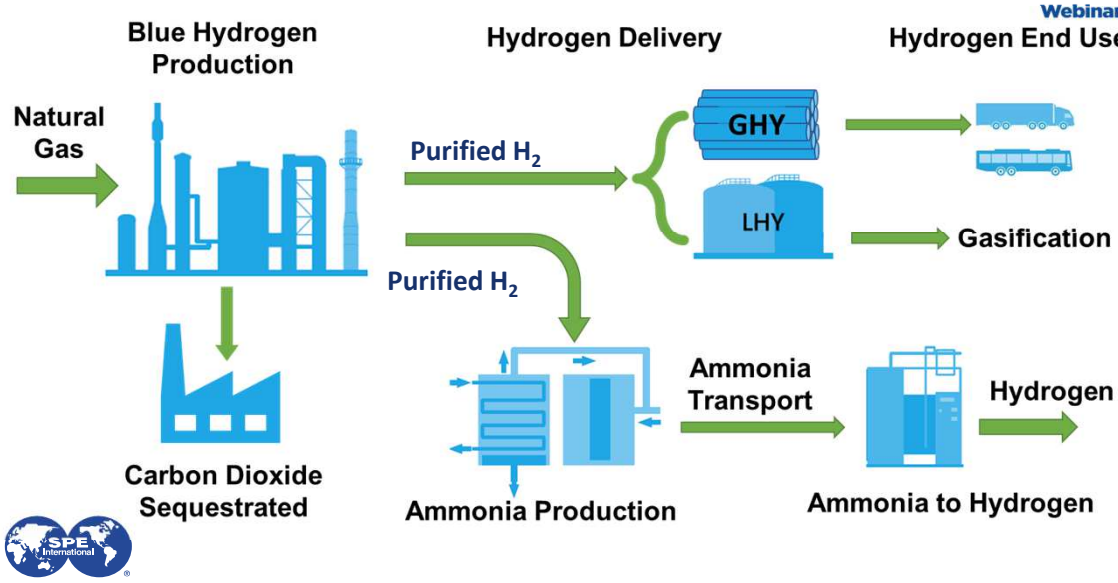
Making Sense of Heavy-Duty Hydrogen Fuel Cell Tractors - North American Council for Freight Efficiency (nacfe.org)

Hydrogen Today



Source: International Energy Agency: The Future of Hydrogen

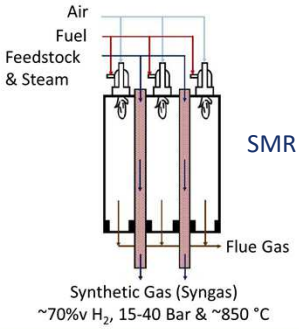
Blue H_2 Production and Transport



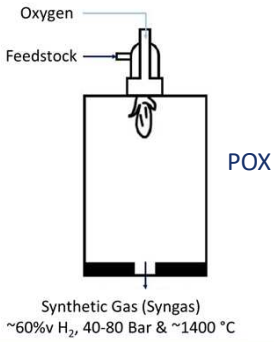
Adapted from https://investors.airproducts.com/static-files/25a35a56-22f6-47e7-9c5a-1e7eda6e8ea1

H_2 Generation Processes

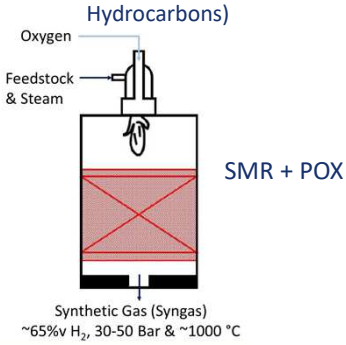
Steam Methane Reformer (SMR)
(Natural Gas or Other Light Hydrocarbons)



Partial Oxidation (POX)
(All Feedstock – NG to coal)



Autothermal Reformer (ATR)
(Natural Gas or Other Gaseous Hydrocarbons)



SMR reaction (SMR)

$CH_4 + H_2O \rightarrow CO + 3H_2$

$\Delta H = 206\ kJ/mol$

endothermic

Partial Oxidation of CH_4 (POX)

$CH_4 + 1/2\,O_2 \rightarrow CO + 2H_2$

$\Delta H = -36\ kJ/mol$

exothermic

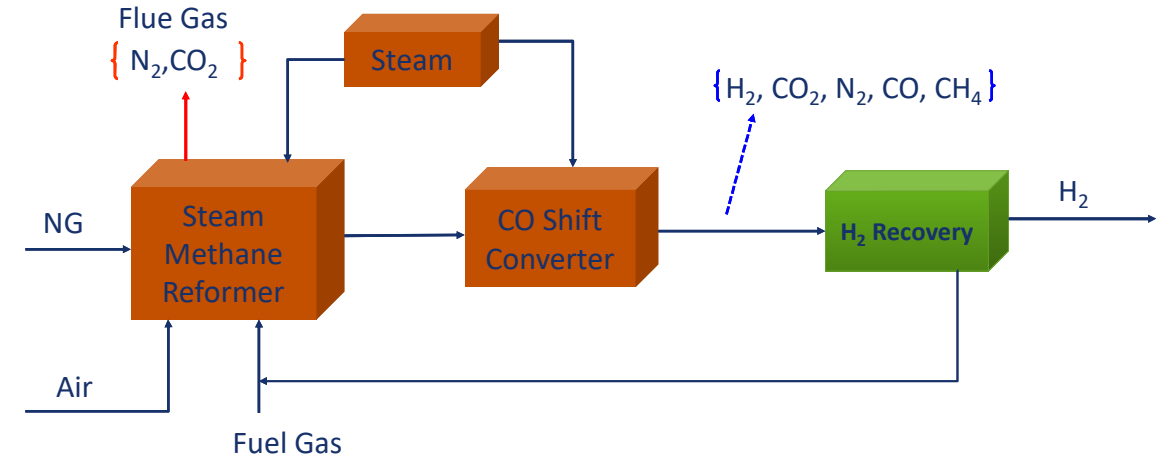
Water Gas Shift (WGS)

$CO + H_2O \rightarrow CO_2 + H_2$

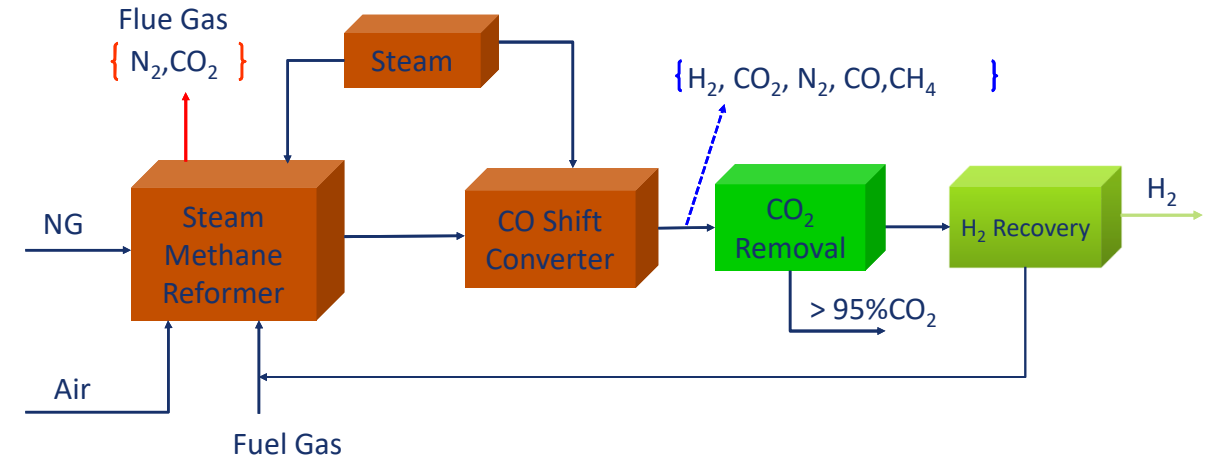
$\Delta H = -41\ kJ/mol$

exothermic

Conventional H_2 Production

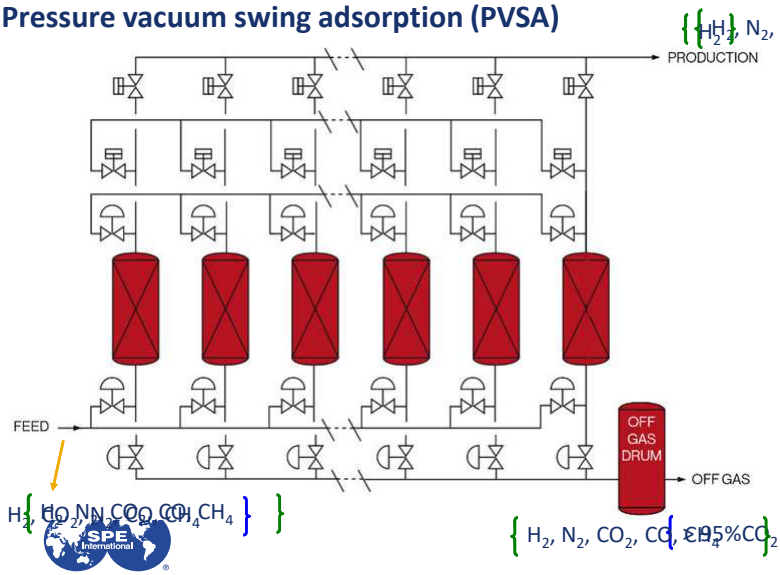


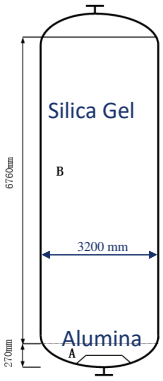
CO_2 Capture Before H_2 Purification



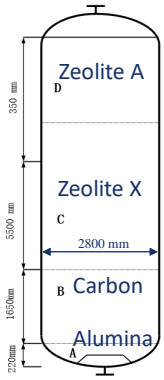
CO_2 Capture And H_2 Purification

Pressure vacuum swing adsorption (PVSA)





Adsorber for CO_2 removal



Adsorber for H_2 purification

https://www.engineering-airliquide.com/cn/bian-ya-xi-fu-psa-qing-qi-ti-chun

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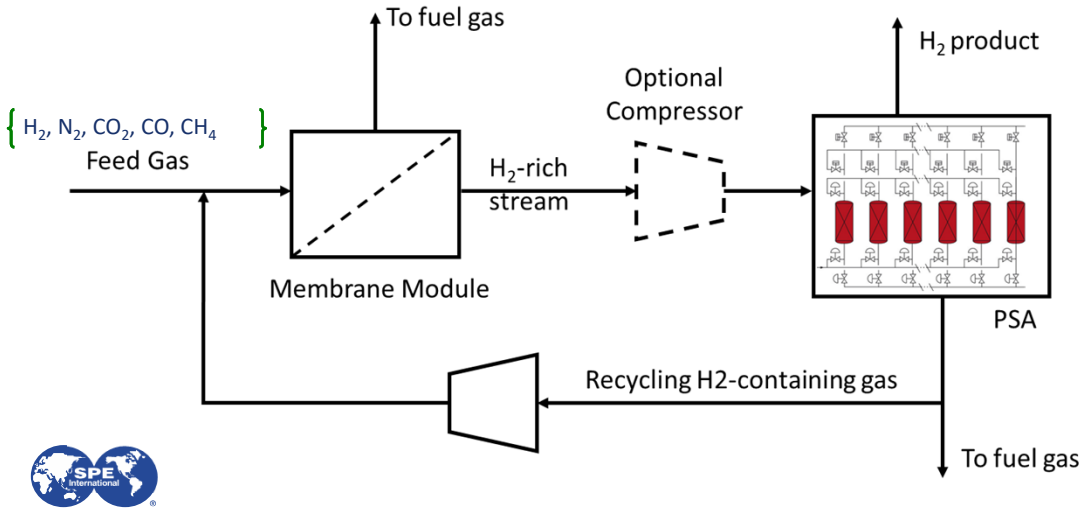
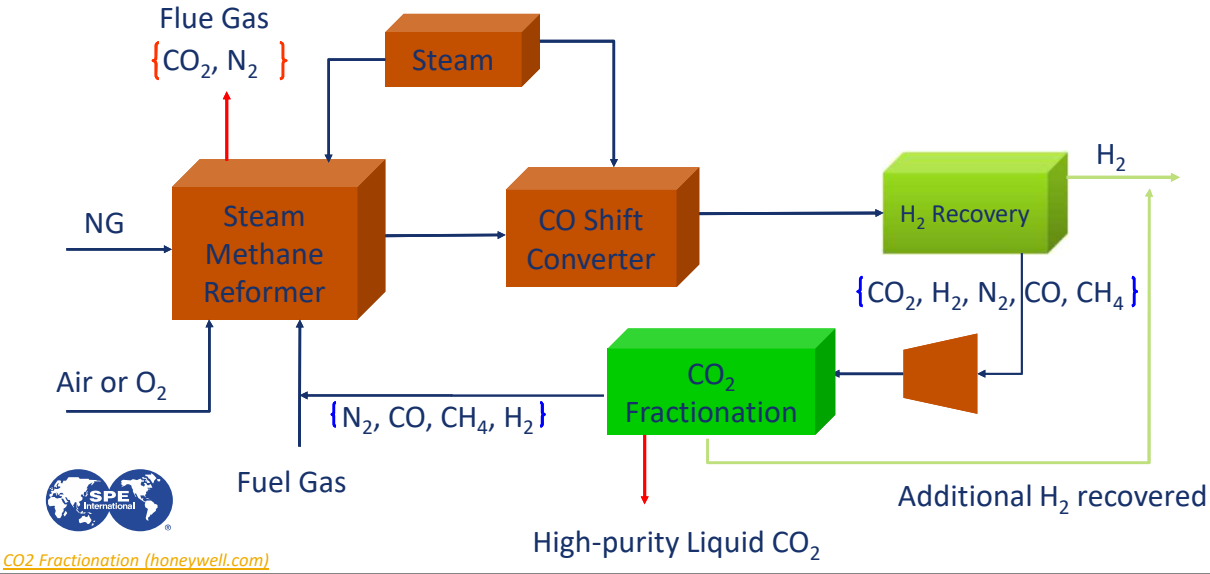
Enhanced H_2 recovery

Hybrid Membrane and Adsorption

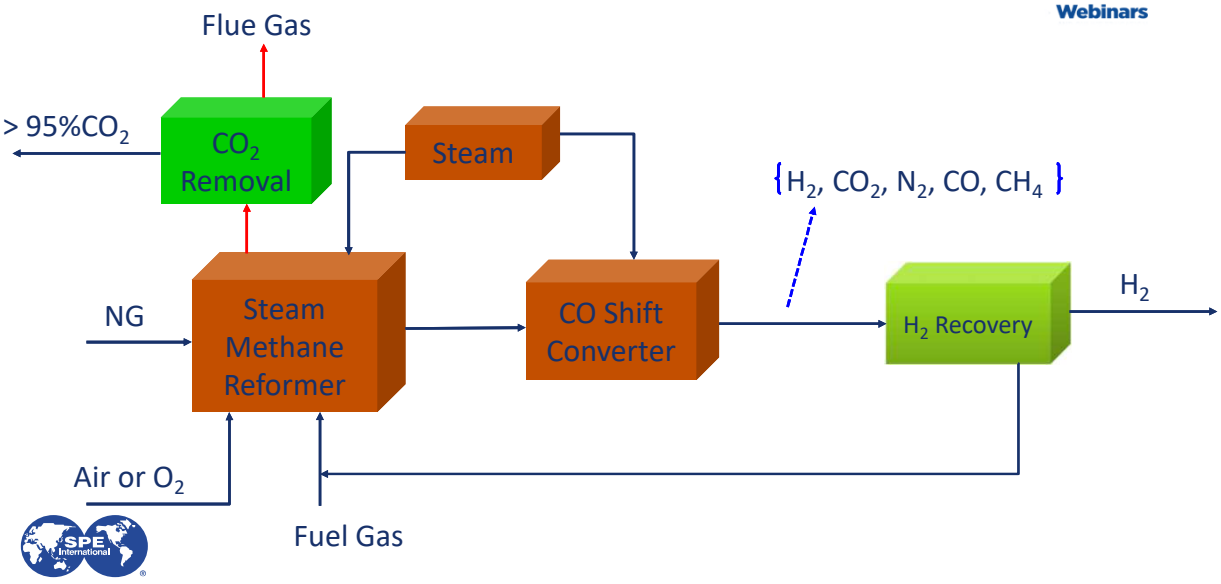


CO_2 Capture After H_2 Purification



CO2 Fractionation (honeywell.com)

CO_2 Capture from Flue Gas



CO_2 Capture from Flue Gas

Chemical Scrubbing: Amine Solution

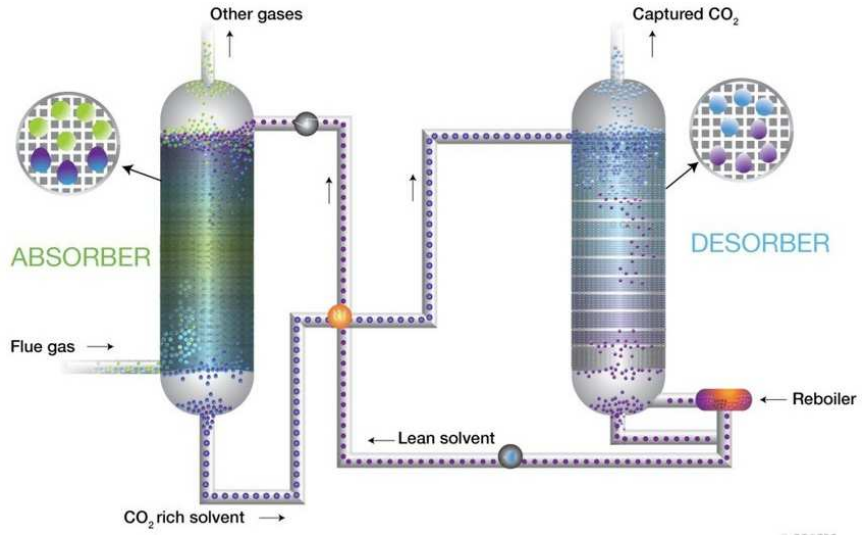
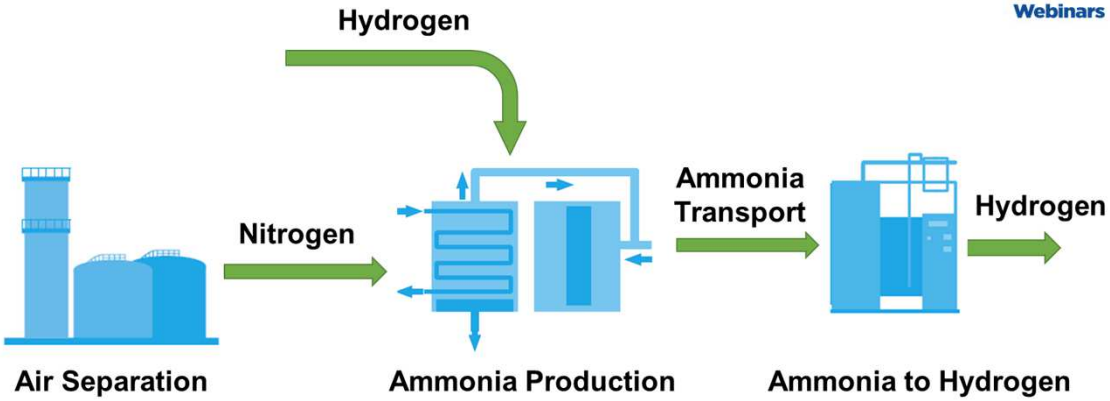


Image by CO2CRC

Amines:
- MEA,
- DEA,
- MDEA
- Other proprietary solvents

Ammonia as H_2 Carrier



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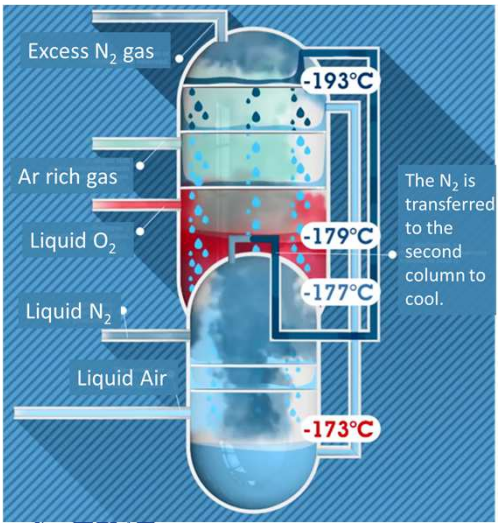
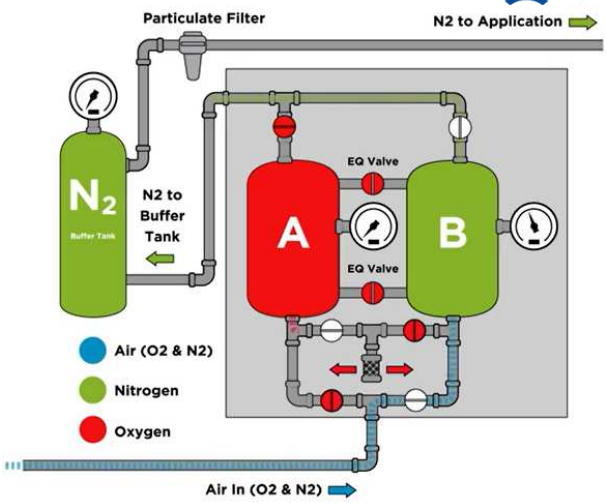
Air Separation



Cryogenic Air Separation

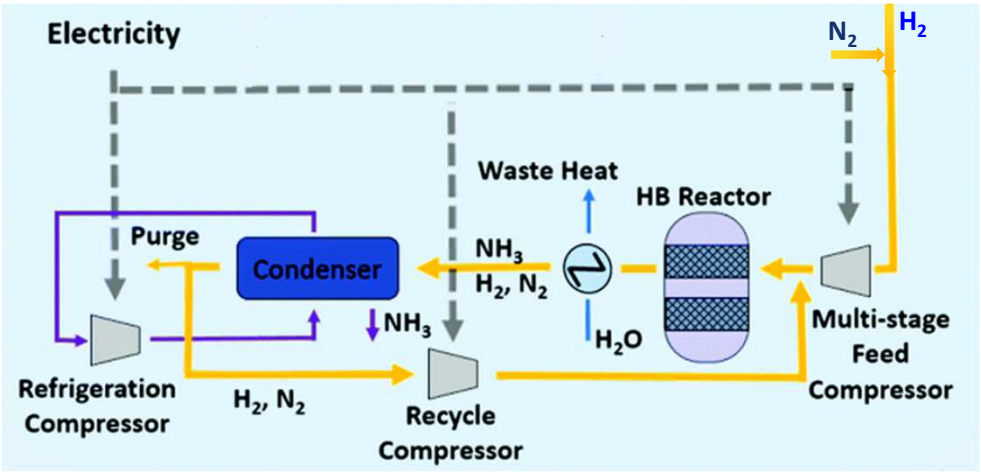
Air Liquide - Understanding the air separation process



Air Separation by VPSA

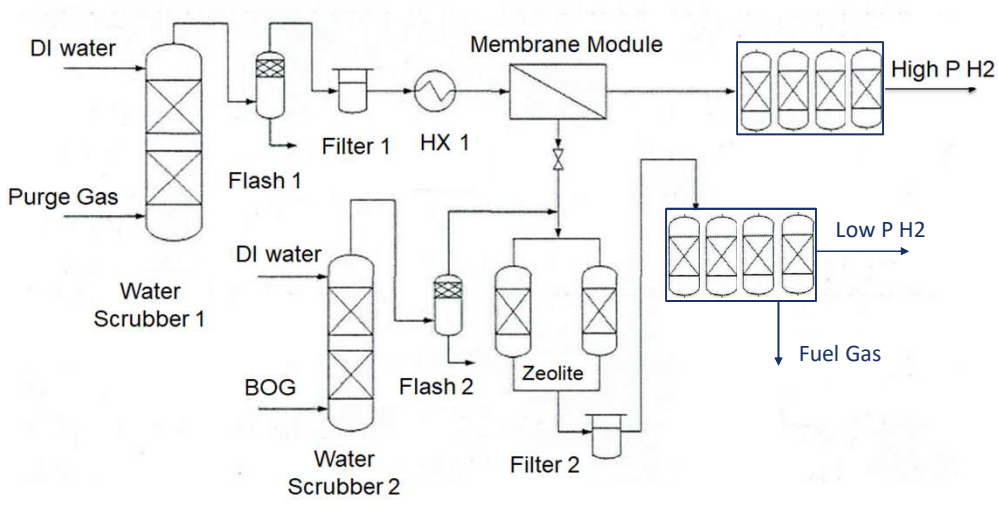
Pressure Swing Adsorption (peakscientific.com)

Ammonia Production



Adapted from Collin Smith, Alfred K. Hill, Laura Torrente-Murciano, Energy & Environmental Science 13 (2020) 331-344.

H_2 Recovery in Ammonia Production



For a 300,000 tonnes/year ammonia plant, the profit would be about 0.5 million AUD/y and payback period is about 1.5 years.

Key Takeaways

- Gas-gas separation is an enabler in the production and application of blue hydrogen.
- Desirable to capture CO_2 at high pressure as the cost is about half of that for CO_2 capture from flue gas.
- Hybrid membrane and adsorption process can increase H_2 recovery by > 5%.
- H_2 recovery in ammonia production can increase overall economics and reduce carbon emissions.