

HONEYWELL CO₂ AND H₂ SOLUTIONS

Powering the CO₂ Countdown

WILLIAM BLASKO
SENIOR OFFERING MANAGER, HYDROGEN

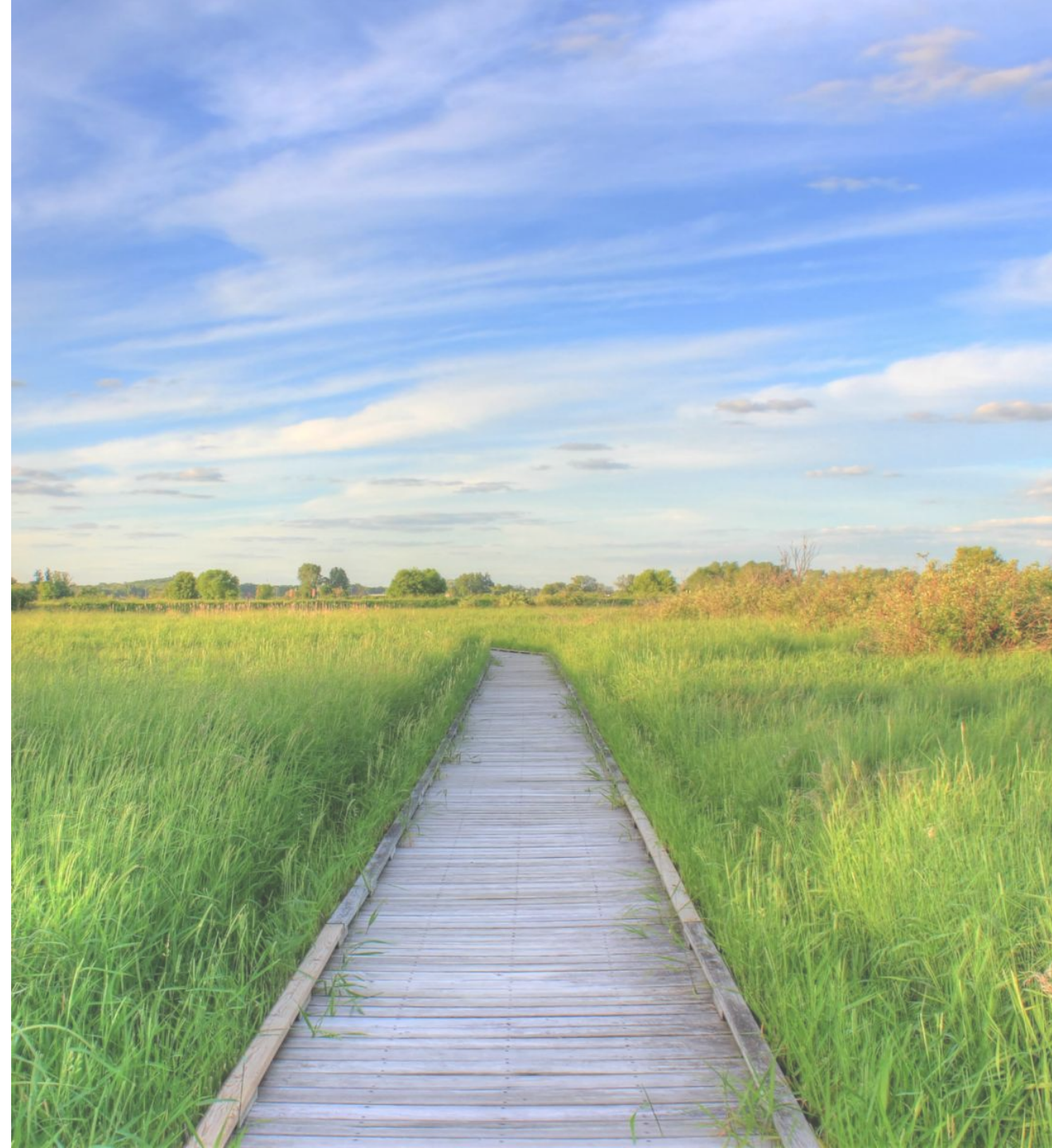


HONEYWELL CO₂ SOLUTIONS

CO₂ EMISSION REDUCTION

Capturing and Sequestering Carbon

- UOP has delivered technologies with capture capacity that will **enable up to 33 Mt/yr CO₂ capture** for CCUS projects*
- Industry leading **capture capacity** of CO₂ and H₂S emissions with potential for additional sequestration



*Results calculated based on design capacity of delivered technology using multiple UOP solutions: Separex™ Membrane Systems, Amine Guard™ FS Process, SeparALL™ Process.

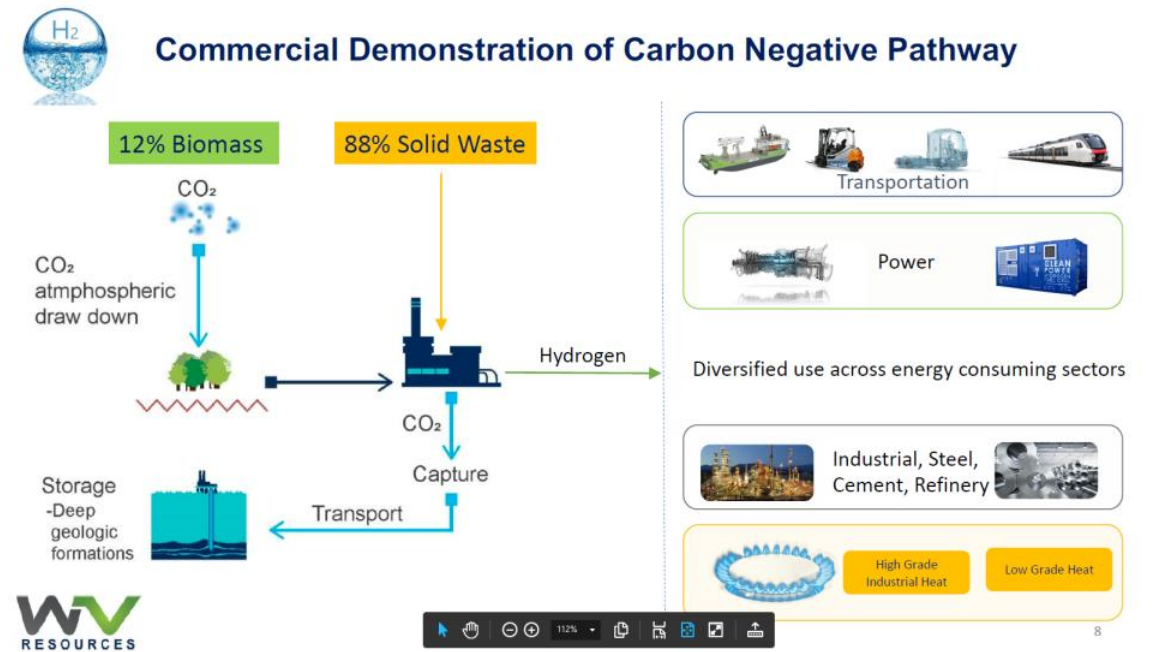
WABASH VALLEY RESOURCES

Project Overview: UOP selected as technology provider for carbon capture and H₂ purification for clean H₂ production from gasifier at WVR in West Terra Haute, Indiana

Why it Matters:

- One of the largest CCS project (1.65 Mt/yr CO₂)
- Second US project to sequester CO₂ in permanent geologic storage (not EOR)
- Demonstrates large-scale commercially viable CCS project under current regulatory and policy framework

Technology: Integration of Modular Molsiv, Modular Ortloff CO₂ Fractionation System, Modular PSA



UOP announced as CCS technology provider for large project in early April

HONEYWELL CO₂ SOLUTIONS

Chemical Solvents

- **AmineGuard™ Process** - Largest licensor of high concentration MEA based systems
- **AmineGuard FS Process** - For industrial CO₂ capture projects, even at low partial pressures; lower opex vs MEA
- **Benfield** - Totally inorganic solvent for pressurized flue gas & industrial processes
- **Advanced Solvent for Carbon Capture** - Direct CO₂ capture from flue gas for refining, power, steel, cement, and natural gas industries

Physical Solvents

- **SeaparALL™ Process** - H₂S/CO₂ selectivity using Selexol solvent for sources containing sulfur
- Stable under oxidative conditions
- Can be used in hybrid cycles with other technologies like PSA, membranes, cryogenics to optimize CO₂ capture

Adsorbents

- **Polybed™ Pressure Swing Adsorption (PSA) System** – Optimized adsorbents and

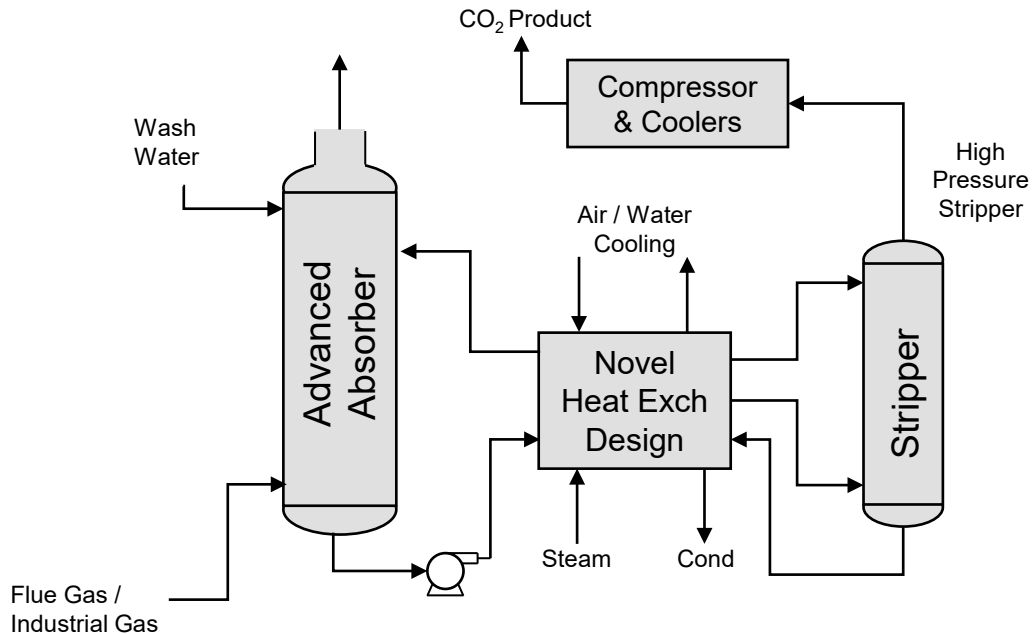
Cryogenics & Membranes

- Capture of CO₂ at pressure
- **Separex™ Membrane Systems** - Significant experience in Petrobras Presalt capturing & sequestering CO₂
- **Ortloff CO₂ Fractionation** - not only captures but also provides CO₂ as a high purity liquid product
- Membranes and cryogenics can be combined with other technologies to lower overall capture costs

Significant track record in CCS with vast suite of technology

ADVANCED SOLVENTS

Advanced Solvent for Carbon Capture



Applications include: Refining, Hydrogen Plants, Power, Steel, Cement, Natural Gas

Patented Solvent with Optimal Properties

- High mass transfer rate – smaller absorber
- Low heat of regeneration
- High stability
 - Enables higher pressure stripper & lower solvent makeup rates

Process & Equipment Design

- Advanced Absorber with proprietary internals
- Novel heat exchange tailored to solvent
 - Reduced solvent regeneration heat duty and lean solvent cooling
- High stripper pressure → reduced CO₂ compression

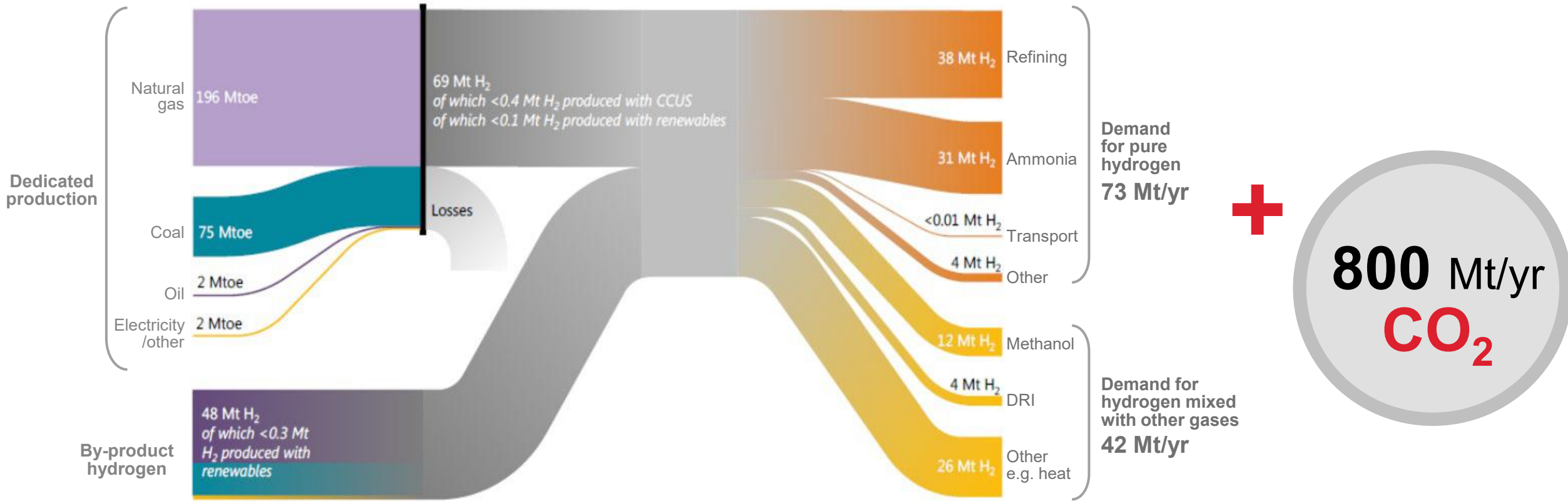
Development Status

- Technology demonstrated at pilot scale
- Exploring first commercial unit applications

HONEYWELL H₂ SOLUTIONS

**HYDROGEN IS KEY
TO THE CO₂ COUNTDOWN**

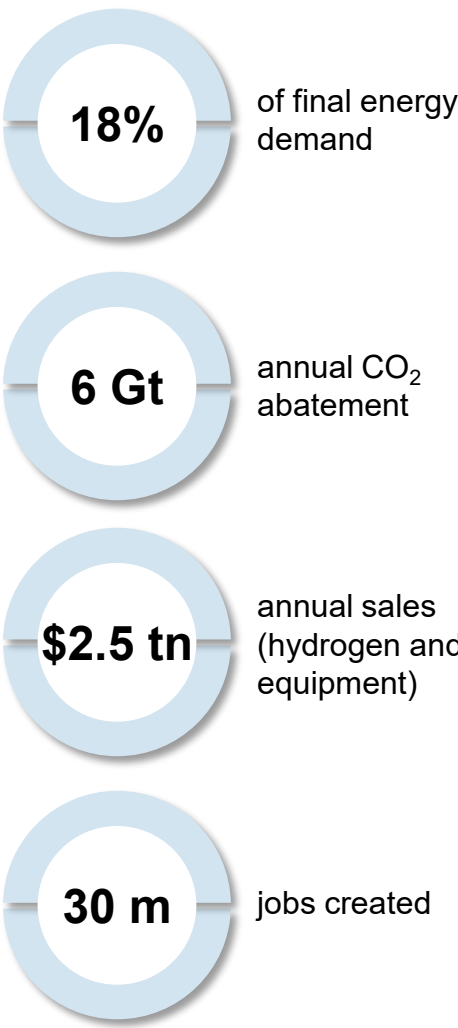
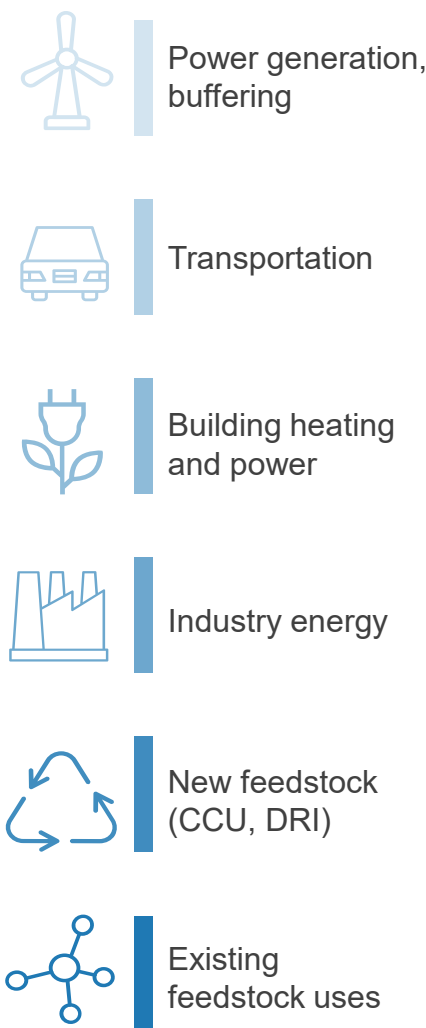
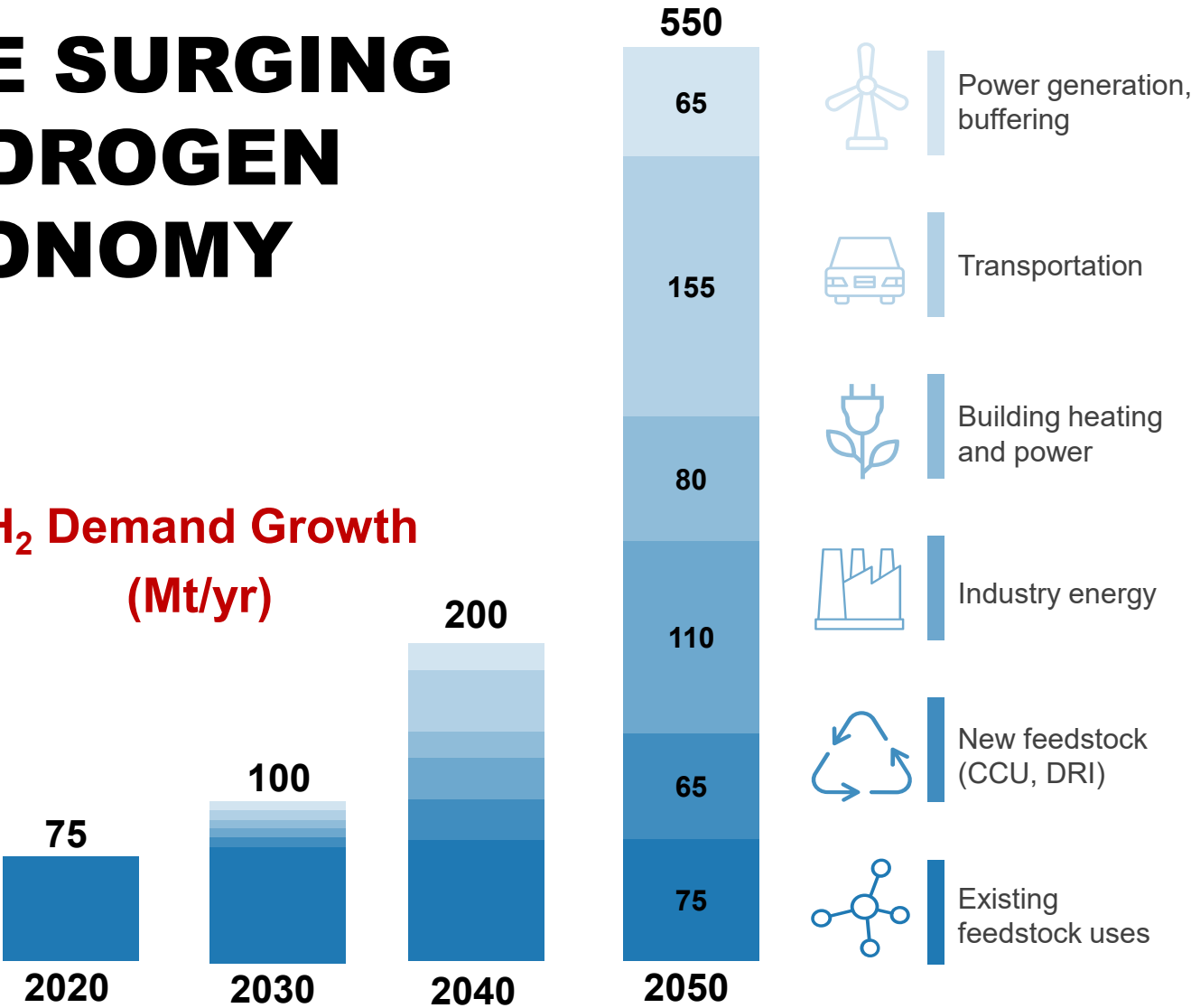
HYDROGEN TODAY



Today H₂ is a GHG emitting process, primarily used as industrial feedstock

THE SURGING HYDROGEN ECONOMY

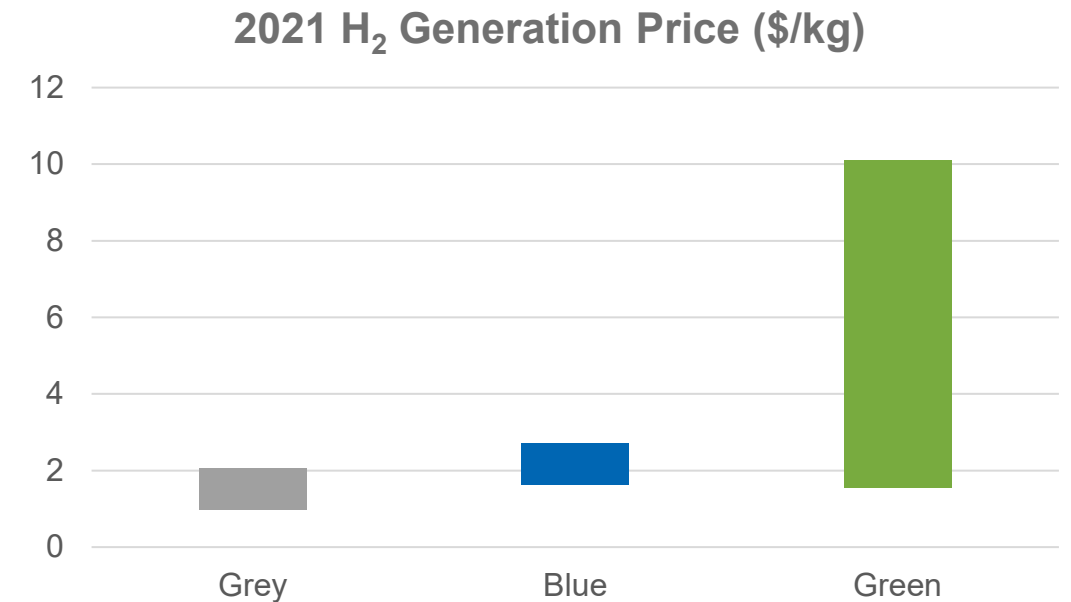
H₂ Demand Growth (Mt/yr)



In a decarbonized world, H₂ demand could grow up to 10-fold

GREY, BLUE, AND GREEN H₂

H ₂	“Grey” Hydrogen from fossil fuels without CO ₂ capture				
	CO ₂ intensity	██████	██████	██████	██████
	Cost	██████	██████	██████	██████
	Scale Available	██████	██████	██████	██████
H ₂	“Blue” Hydrogen from fossil fuels with CO ₂ capture				
	CO ₂ intensity	██████	██████	██████	██████
	Cost	██████	██████	██████	██████
	Scale Available	██████	██████	██████	██████
H ₂	“Green” Hydrogen from water by electrolysis using renewable power				
	CO ₂ intensity	██████	██████	██████	██████
	Cost	██████	██████	██████	██████
	Scale Available	██████	██████	██████	██████



SOURCE: BloombergNEF

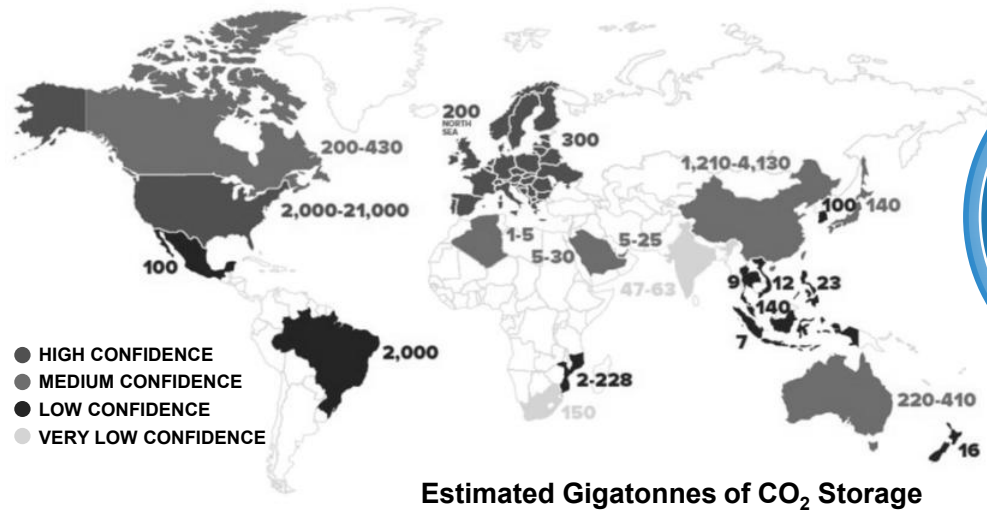
Decarbonization of grey H₂ and low-cost green H₂ will be growth areas

BLUE AND GREEN H₂

Today

Blue H₂ technology is ready now

- Offers the lowest cost of production
- Commercially proven unit operations
- Enables H₂ infrastructure investment
- Requires CO₂ end use or sequestration



550 Mt/yr
of Blue H₂
generates about
5 Gt/yr
of CO₂

Future

Green H₂ becomes more competitive

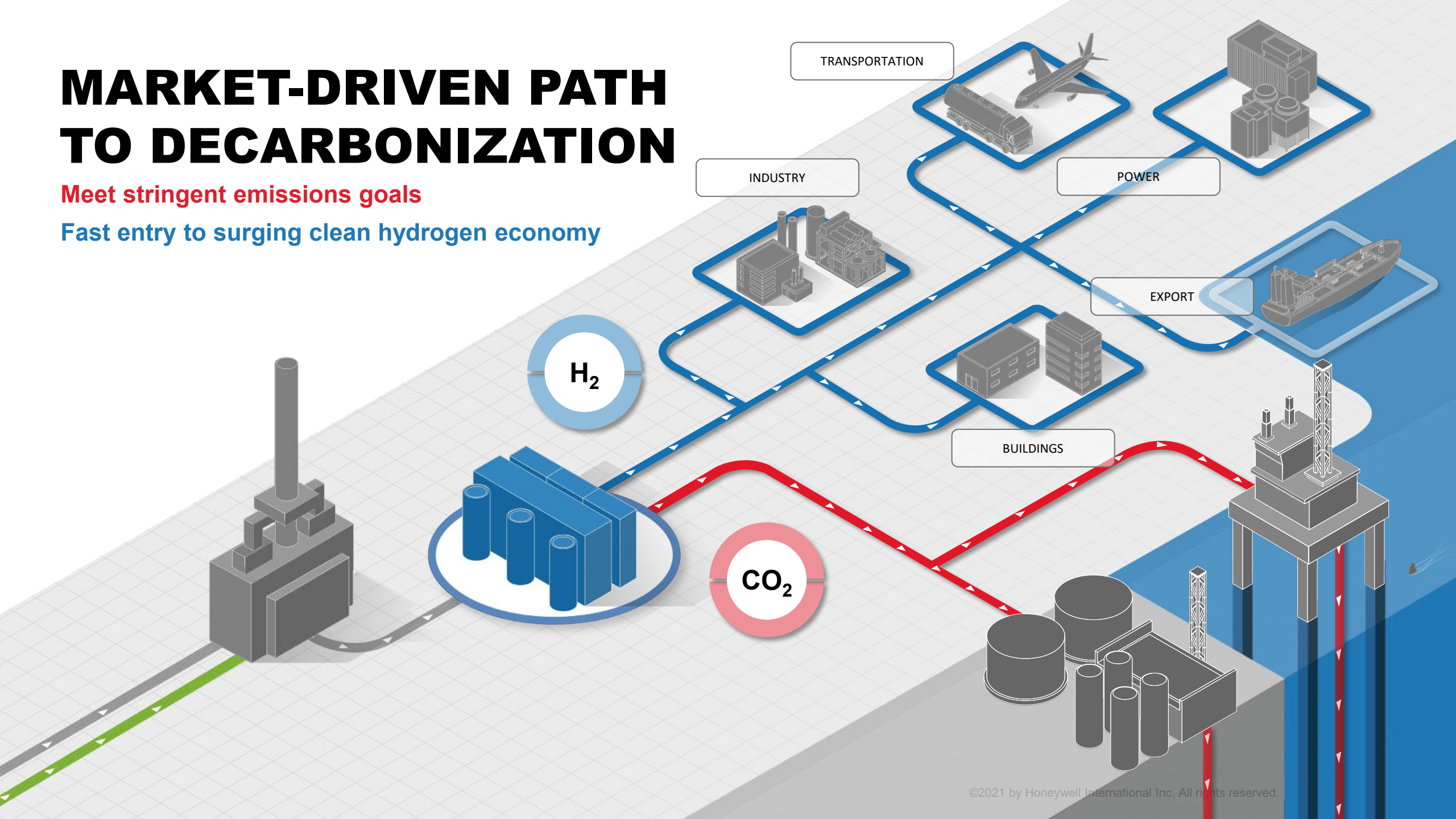
- Future segmentation depends on how quickly and significantly electrolyzer costs drop
- Development of infrastructure
 - Renewable electricity and electrolyzer capacity for green
 - CO₂ sequestration for blue
 - Transport from regions with cheap renewable electricity or sequestration

H₂

MARKET-DRIVEN PATH TO DECARBONIZATION

Meet stringent emissions goals

Fast entry to surging clean hydrogen economy



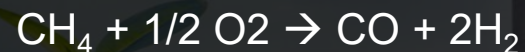
H₂ GENERATION PROCESS

Steam Methane Reforming (endothermic)



$\Delta H = 206 \text{ kJ/mol}$

Partial Oxidation of Methane (exothermic)



$\Delta H = -36 \text{ kJ/mol}$

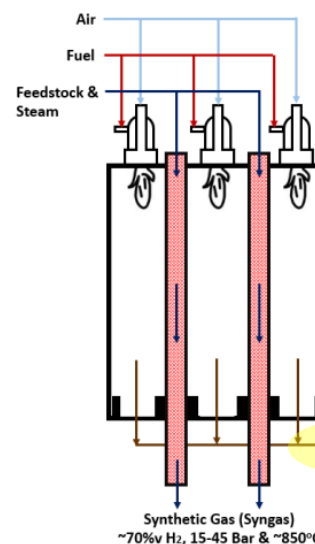
Water Gas Shift (exothermic)



$\Delta H = -41 \text{ kJ/mol}$

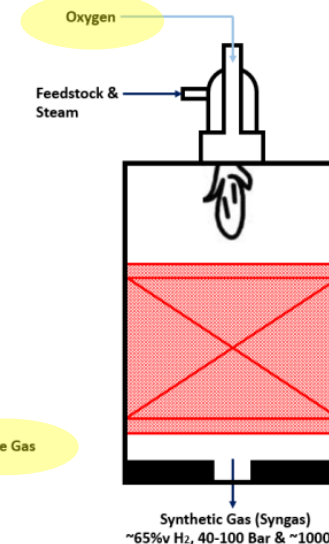
Source: IEAGHG

STEAM METHANE REFORMER (SMR)
(Natural Gas or Other Light Hydrocarbons)



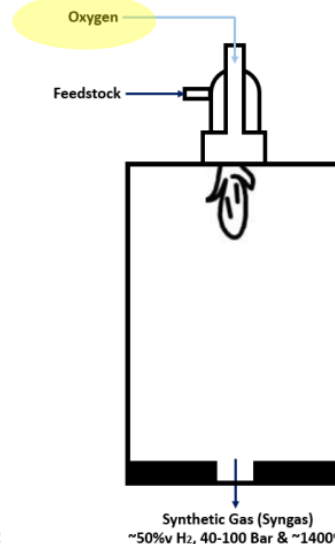
SMR

AUTOTHERMAL REFORMER (ATR)
(Natural Gas or Other Gaseous Hydrocarbons)



SMR + POX

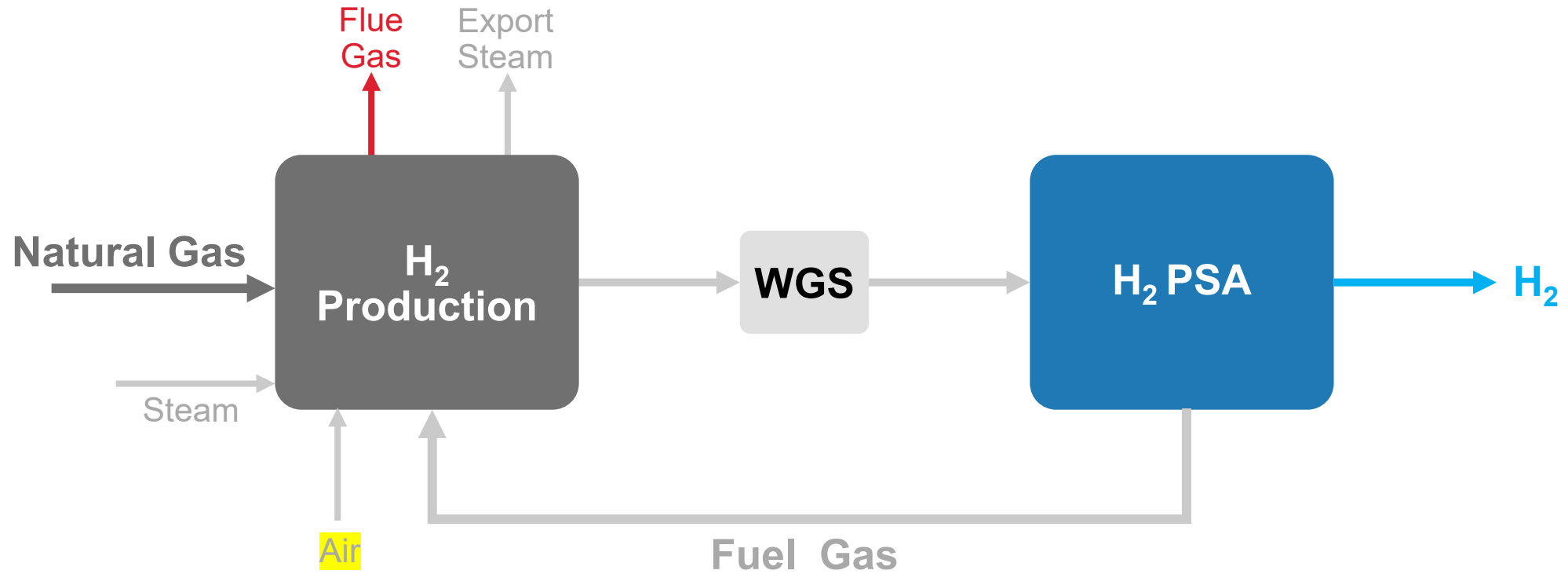
PARTIAL OXIDATION (POX)
(All Feedstock – NG to Coal)



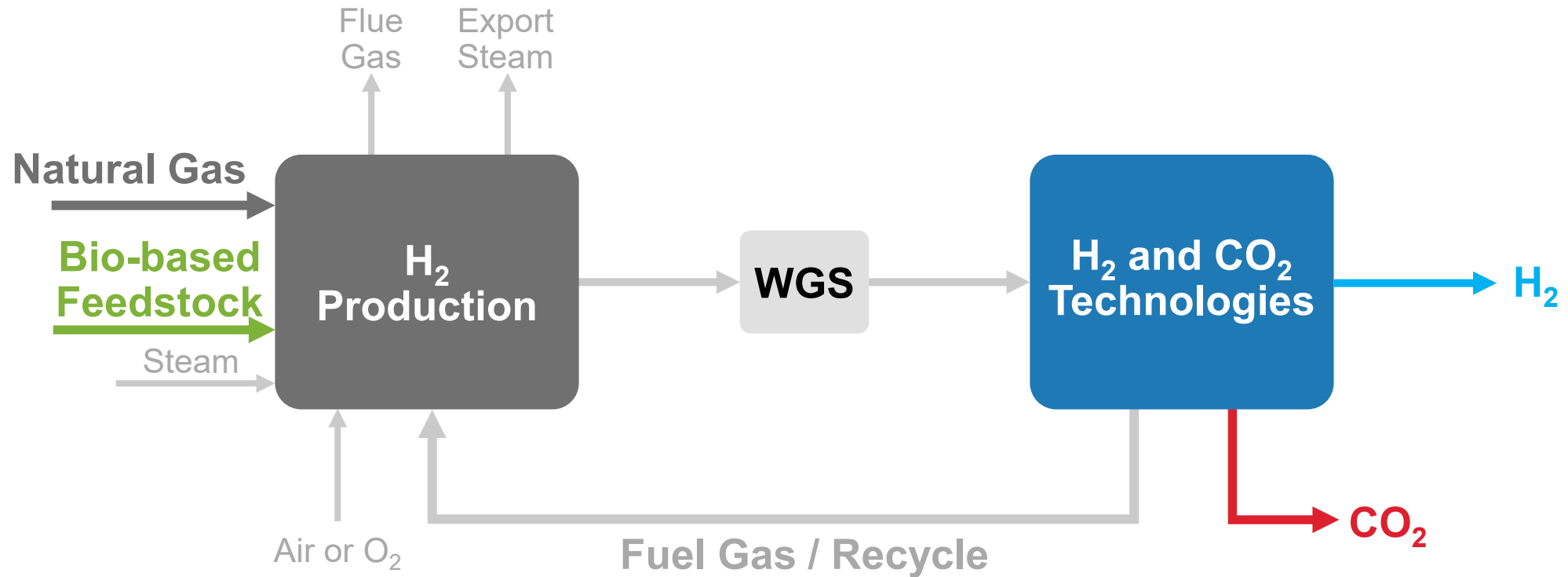
POX

SMR dominates H₂ market today, may shift toward ATR

CONVENTIONAL H₂ PRODUCTION



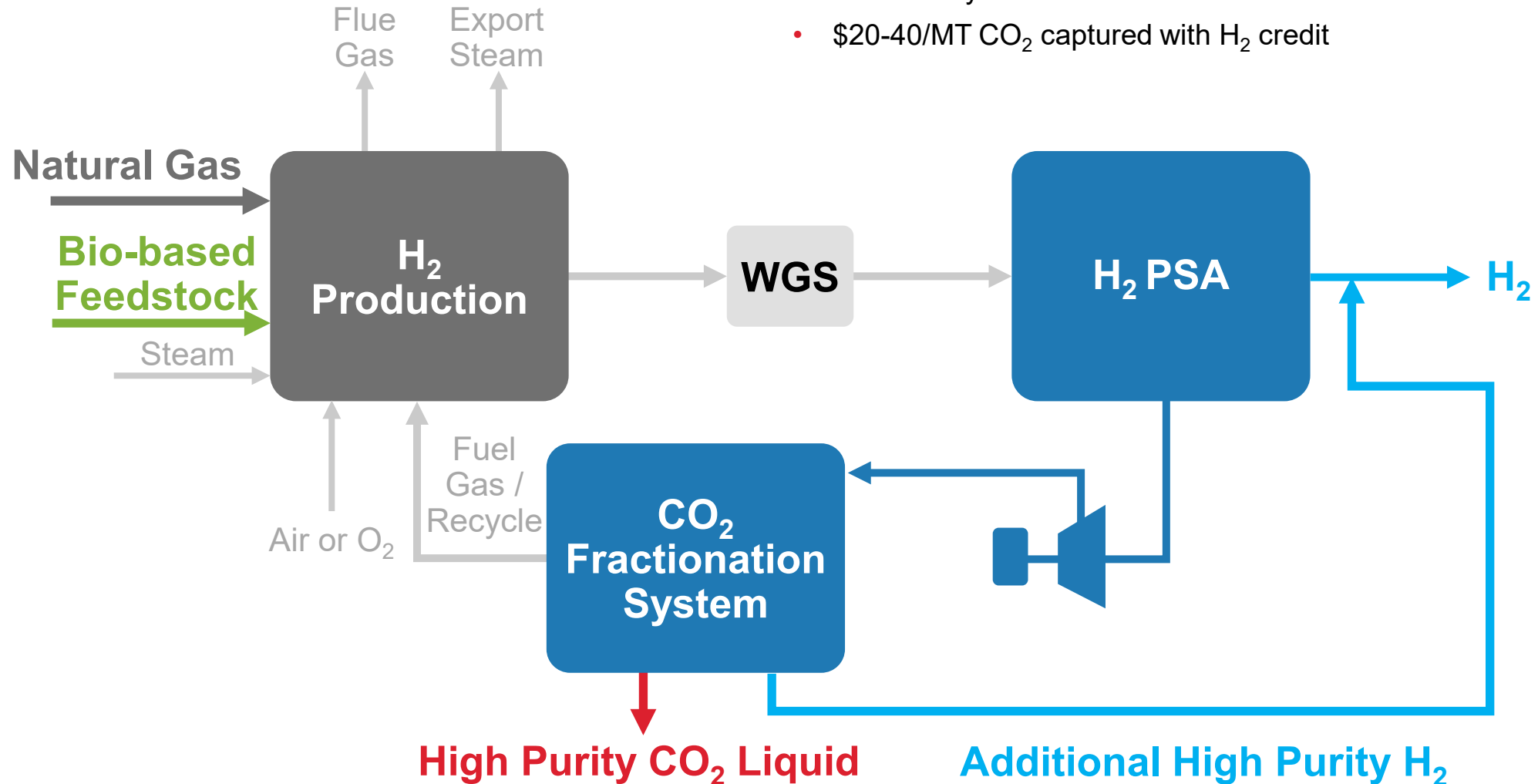
DECARBONIZED H₂ PRODUCTION



SMR RETROFIT

ORTLOFF™ CO₂ FRACTIONATION SYSTEM

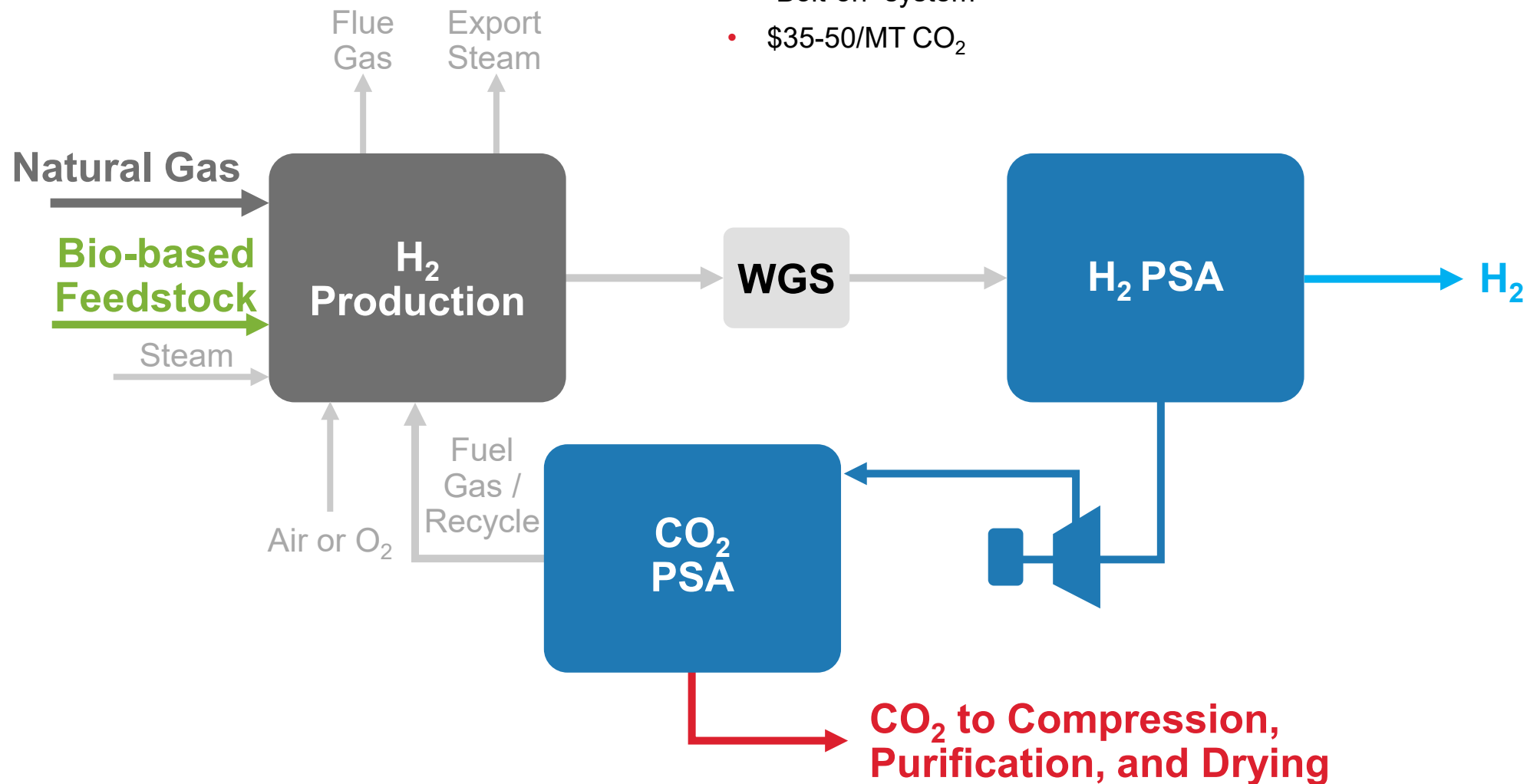
- 10-20% additional H₂ recovery
- >99% CO₂ recovery from PSA tail gas
- High purity, liquid CO₂ product
- No steam usage for carbon capture
- “Bolt-on” system
- \$20-40/MT CO₂ captured with H₂ credit



SMR RETROFIT

CO₂ POLYBED™ PSA

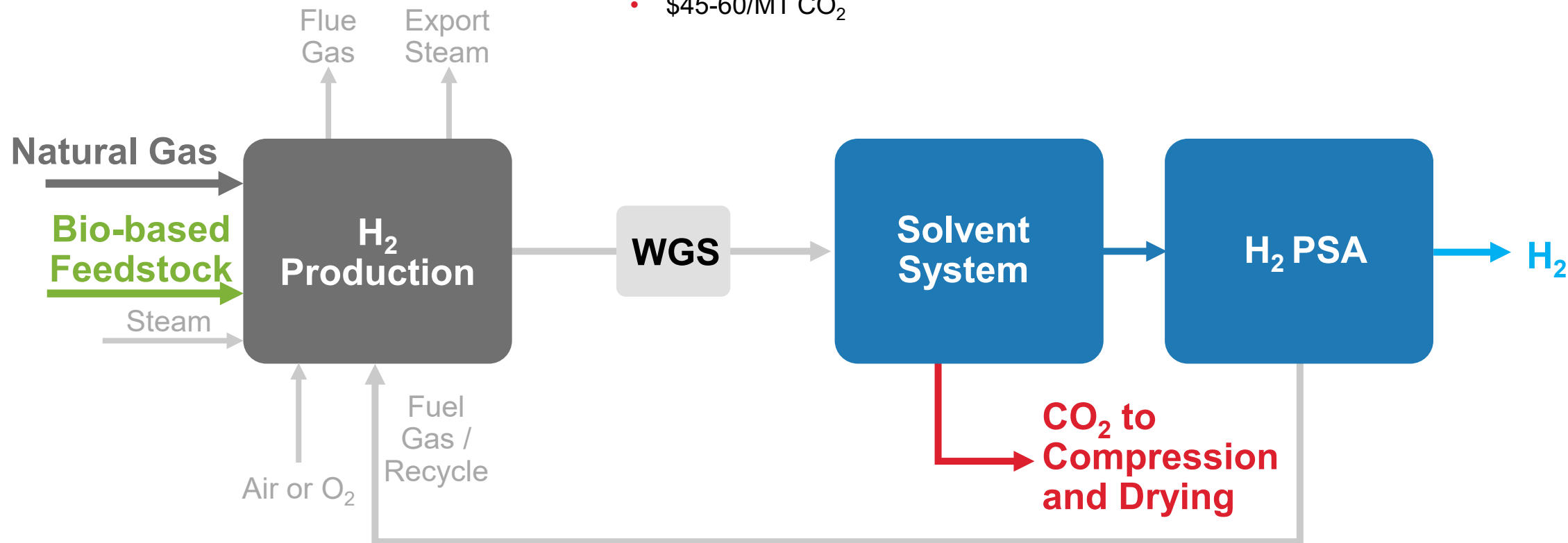
- Lowest capex and opex
- >99% CO₂ recovery from PSA tail gas
- Optimal for less stringent CO₂ purity specs
- No steam usage for carbon capture
- “Bolt-on” system
- \$35-50/MT CO₂



SMR RETROFIT

AMINE GUARD™ FS

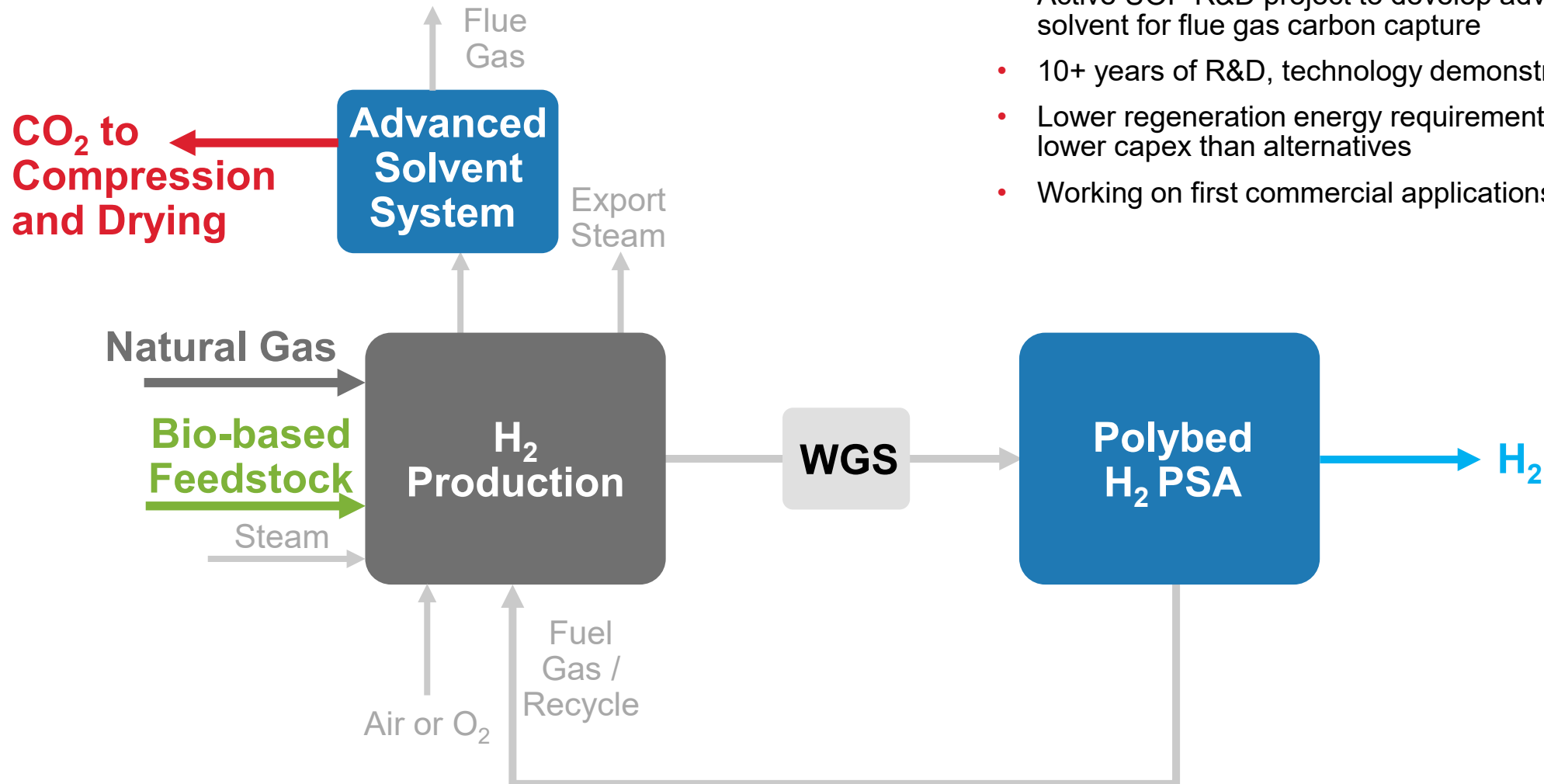
- Low capex and opex, but requires steam
- Up to >99% CO₂ recovery from syngas
- Extensive commercial experience in natural gas treating, synthesis gas treating, direct iron ore reduction, and ammonia plants
- \$45-60/MT CO₂



SMR RETROFIT

ADVANCED SOLVENT FOR CARBON CAPTURE

- Up to >95% CO₂ recovery from overall SMR
- Active UOP R&D project to develop advanced solvent for flue gas carbon capture
- 10+ years of R&D, technology demonstrated
- Lower regeneration energy requirements and lower capex than alternatives
- Working on first commercial applications now



COMBUSTION EQUIPMENT

SMR Furnaces and Burners are the Engine that Drive Hydrogen Production

Essentials for Successful Decarbonized SMR Retrofit:

- Establish Combustion Equipment Condition
- Recommend Necessary Maintenance and Upgrades
- Verify Burners Are Flexible-Fuel Capable

Carbon Capture significantly changes the fuel composition and burner operating conditions

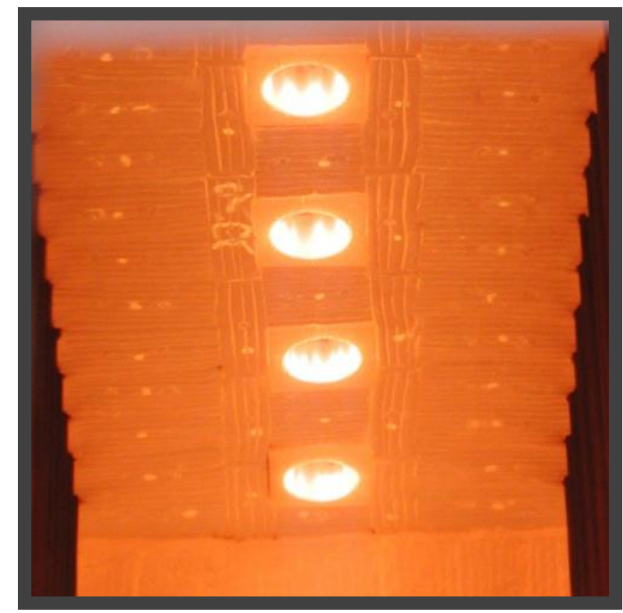
UOP successfully partners with every SMR licensor

Proven burner solutions for every configuration of SMR

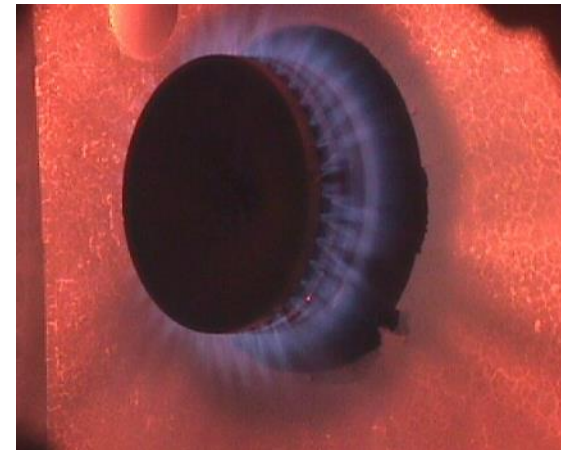
- UOP Callidus Proprietary CUBH Burner Platform
- Consistent performance for wide ranging conditions



CUBH Down-Fired Low NOx



Down-Fired Conventional



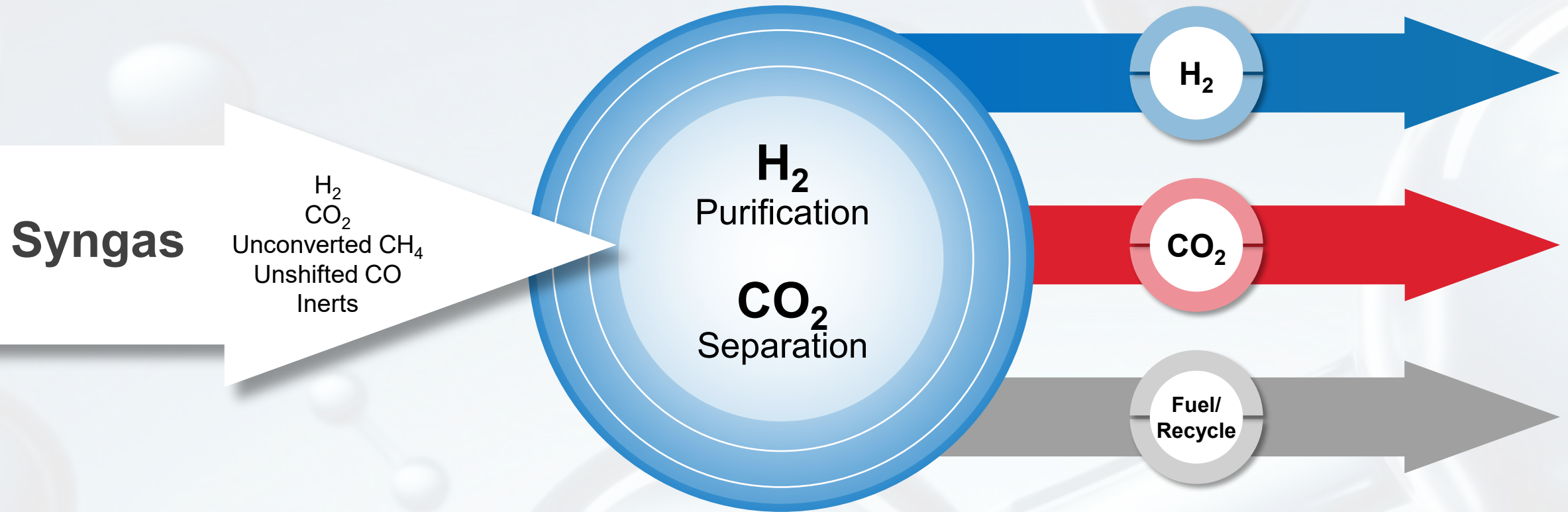
Premix Natural Draft Wall-Fired



Forced Draft Wall-Fired

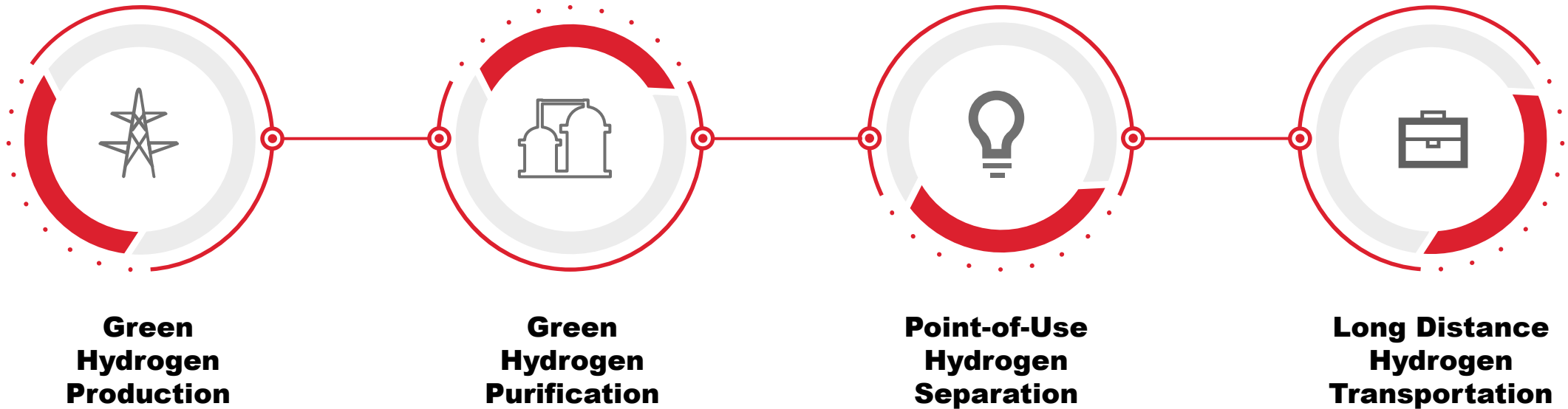
Combustion Capabilities are a Unique UOP Strength

H₂ AND CO₂ TECHNOLOGIES



Efficient and customized blue hydrogen solutions are required

H₂ ECONOMY GROWTH



Increased focus on reducing CO₂ footprints and growing H₂ economy

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