



Hydrogen and Energy 101: Role of CCUS

GWPC Annual Forum – Salt Lake City, UT – September 29, 2021 -
www.gwpc.org

Talib Syed, P.E.

www.talibsyed-assoc.com

Tel: 720.877.1272 (m)



OUTLINE OF PRESENTATION:

- Production and Uses of H₂
- Integration of Fossil Energy into the H₂ Economy
- H₂ as a Solution to a Carbon-Neutral Economy
- Health/Safety Aspects of H₂
- Geologic Storage of H₂
- Global CCS Projects
- Top Clean Energy Developments
- Concluding Remarks



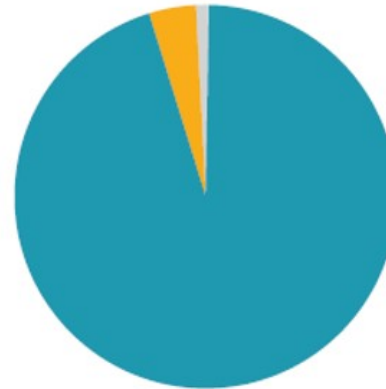
Hydrogen production: what colour?

	Commonly used term	Process	Carbon output
	"Grey" hydrogen	<ul style="list-style-type: none"> Fossil fuel-to-hydrogen conversion Electrolysis based on high-carbon electricity 	<ul style="list-style-type: none"> Fossil CO₂ is emitted
"CLEAN/LOW-CARBON"	"Blue" hydrogen	<ul style="list-style-type: none"> Fossil fuel-to-hydrogen conversion with CCS 	<ul style="list-style-type: none"> Fossil CO₂ is captured and stored
		<ul style="list-style-type: none"> Methane pyrolysis 	<ul style="list-style-type: none"> No CO₂ is emitted, solid carbon is produced
	"Green" hydrogen	<ul style="list-style-type: none"> Sustainable biomass-to-hydrogen conversion 	<ul style="list-style-type: none"> Biogenic CO₂ is emitted
		<ul style="list-style-type: none"> Water-splitting (electrolysis/photoelectrocatalytic) based on renewable electricity 	<ul style="list-style-type: none"> No CO₂ is emitted
	Carbon negative hydrogen	<ul style="list-style-type: none"> Sustainable biomass-to hydrogen-conversion with CCS 	<ul style="list-style-type: none"> Biogenic CO₂ is captured and stored
		<ul style="list-style-type: none"> Biomass pyrolysis 	<ul style="list-style-type: none"> No biogenic CO₂ is emitted, solid carbon is produced

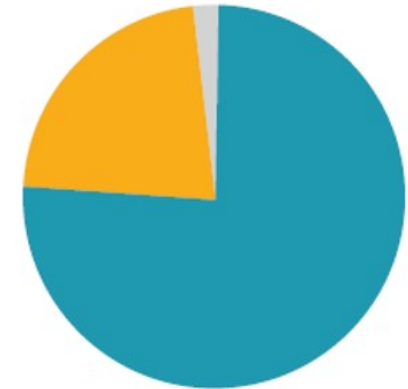
- REF: Hydrogen Strategy: Enabling A Low-Carbon Economy, USDOE, July 2020

Figure 3. U.S. and Global Production of Hydrogen

U.S. H₂ Production 10 MMT-
Percent by Source



Global H₂ Production 70 MMT-
Percent by Source



● Natural Gas SMR

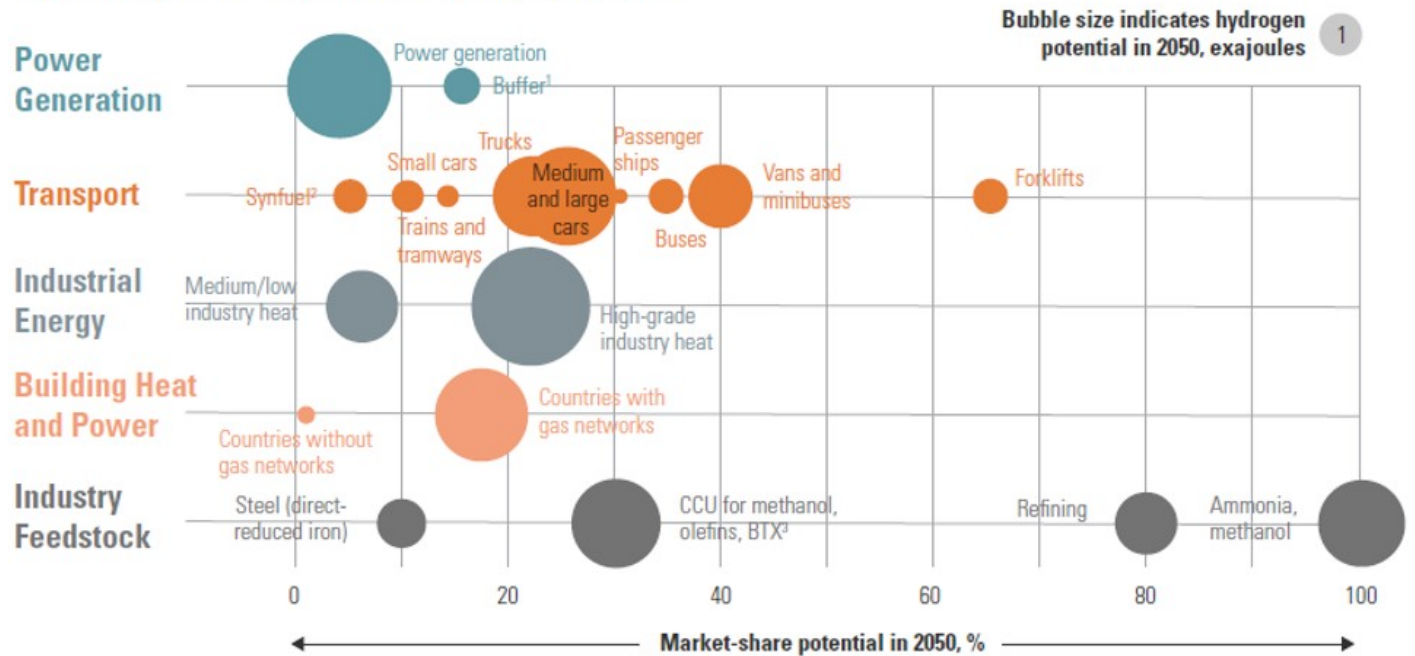
● Coal Gasification

● Electrolysis

- REF: Hydrogen Strategy: Enabling A Low-Carbon Economy, USDOE, July 2020

Figure 8. Global Potential for Future Use of Hydrogen

Hydrogen potential by market in 2050, %, exajoules

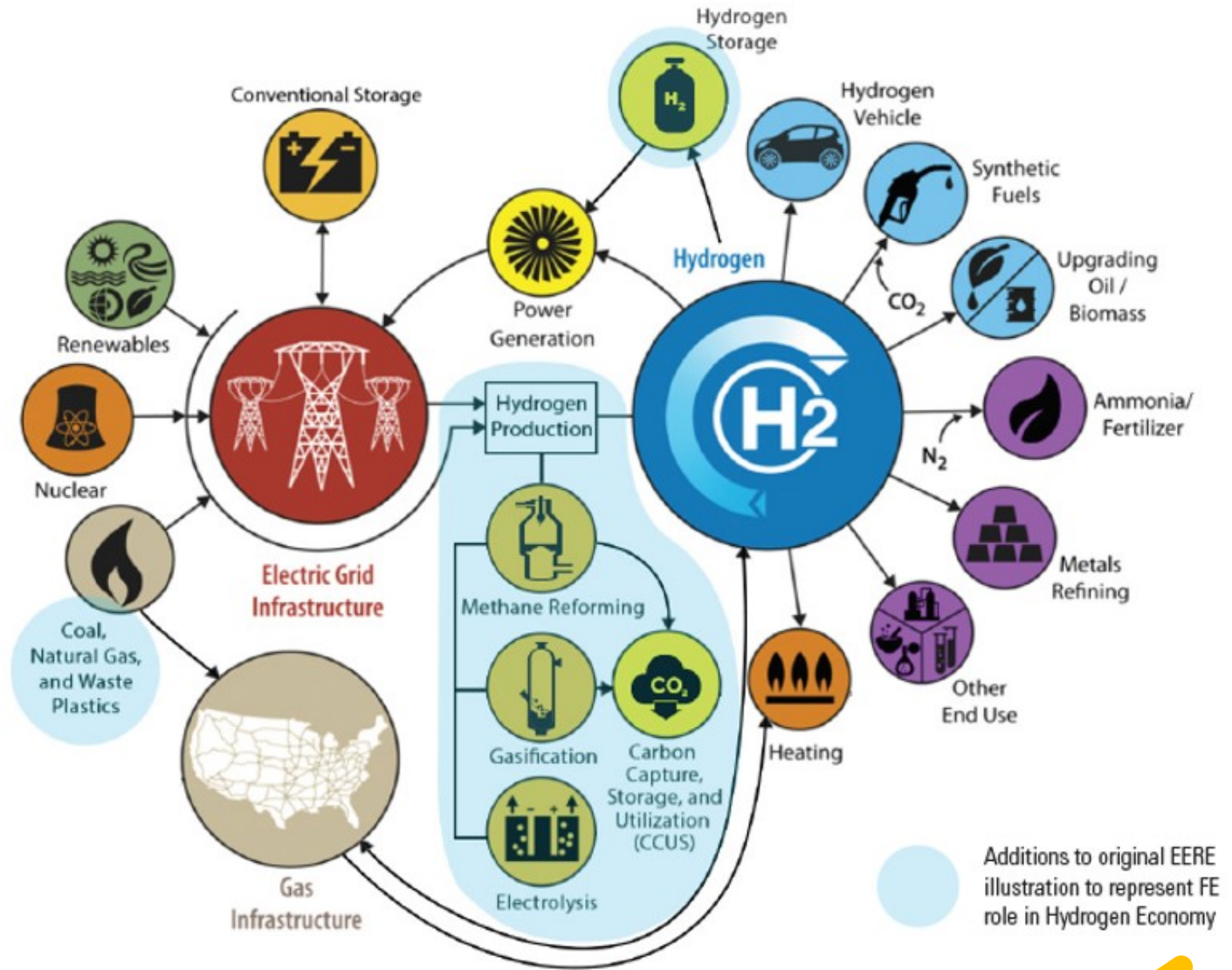


¹ % of total annual growth in hydrogen and variable renewable-power demand.

² For aviation and freight ships.

³ Carbon capture and utilization; % of total methanol, olefin, and benzene, toluene, and xylene (BTX) production using olefins and captured carbon.

Figure 1. Integration of Fossil Energy into the Hydrogen Economy⁴

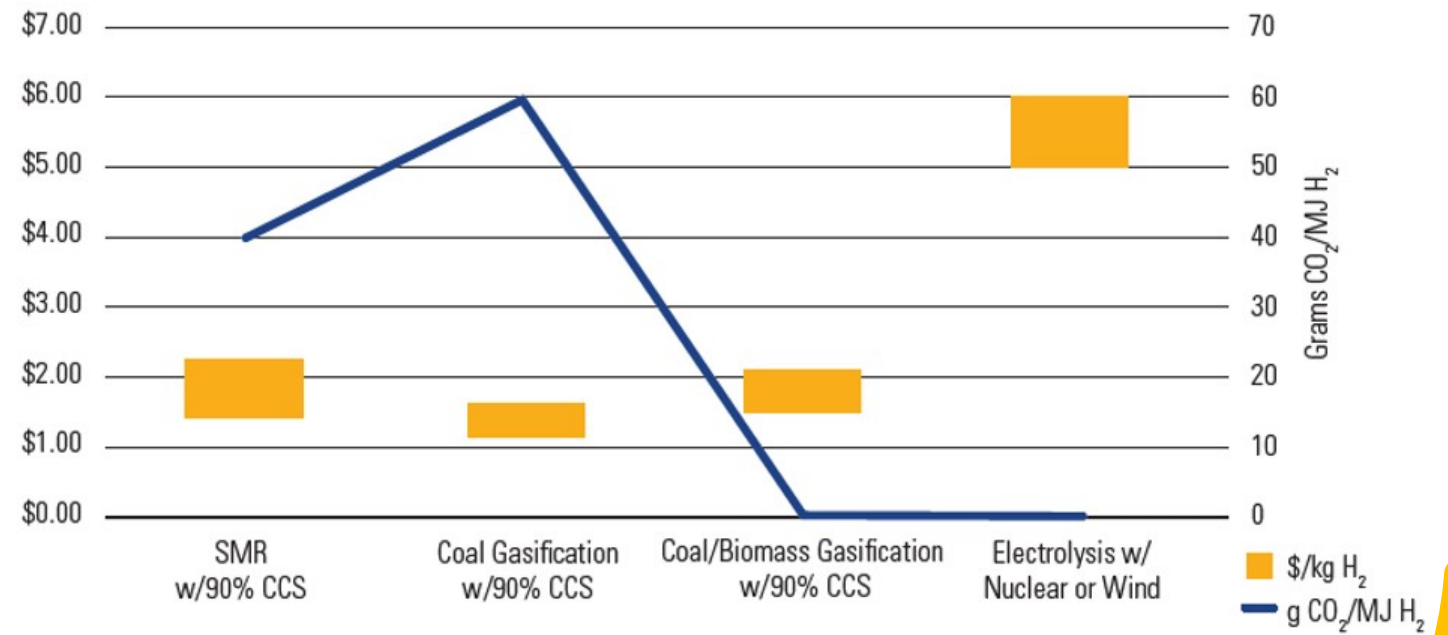


Integration of Fossil Energy into the Hydrogen Economy

REF: Hydrogen Strategy: Enabling A Low-Carbon Economy, USDOE, July 2020

- Hydrogen Strategy: Enabling a Low-Carbon Economy, USDOE, July 2020

Figure 4. Current Cost of Hydrogen Production and CO₂ Intensity



(Source: IEA Roadmap for Hydrogen and Fuel Cell and DOE Baseline Studies)

Brief Look at the H₂ Economy



Deploying clean H₂ could reduce ~ 34% of GHG emissions from fossil fuels by 2050



Scaled-up H₂ industry can lower cost of renewable H₂ (\$ 2/kg -2030 and \$ 1/kg -2050 (current cost - \$ 7.50/kg for green and \$ 2.40/kg for blue H₂).



Steel industry – likely benefactor of H₂ economy (~ 9% of global carbon emissions)



Home heating and cooking – another benefactor by blending 5-20% with natural gas for transport through existing pipelines



H₂ will play a bigger role in transportation

Health and Safety Aspects of H₂



H₂ has more energy/unit of mass compared to natural gas or gasoline (attractive as transport fuel), however has low energy density/unit of volume (Requires larger H₂ volumes to meet identical energy demands as other fuels)



H₂ can be compressed, liquified, or transformed into H₂-based fuels with a higher energy density (but subsequent re-conversion uses some energy)



H₂ handling requires special equipment and procedures – widespread use would bring new challenges. Requires adequate ventilation, leak detection and special flame detectors



Health and safety considerations of H₂-based fuels and feedstocks are familiar in the energy sector - exceptions are NH₃ and liquid organic hydrogen carriers (LOHCs)



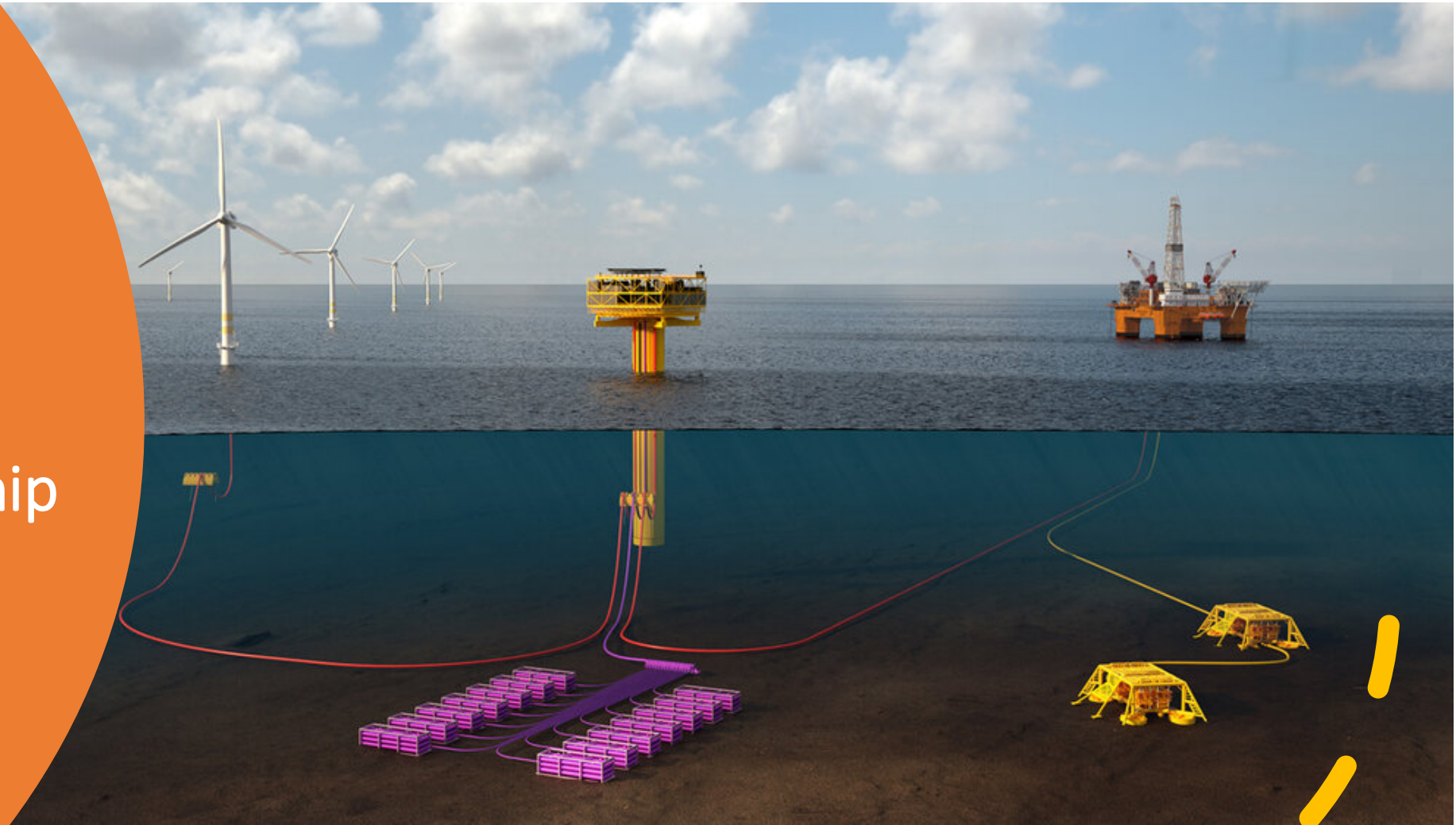
NH₃ raises more health and safety concerns than H₂ and will require professionally trained operators. It is highly toxic, flammable, corrosive and escapes from leaks in gaseous form

Geological Storage of H₂

- Geological storage best option for large-scale/ long-term storage and tanks for short-term/ small-scale storage
- Possible storage sites: Salt caverns, depleted O&G reservoirs and deep saline aquifers
- Salt caverns used for H₂ storage in UK and US since 1980s (Beaumont, TX, Delta, UT – hub and spoke model) - likely the lowest-cost option
- Depleted O&G reservoirs - Larger capacity, and more permeable. Will require contaminants removal prior to use in fuel cells (Greensand DK)
- Aquifers have least amount of experience. Both depleted O&G and aquifers have natural barriers that can provide containment. If can overcome challenges, attractive for large scale H₂ storage

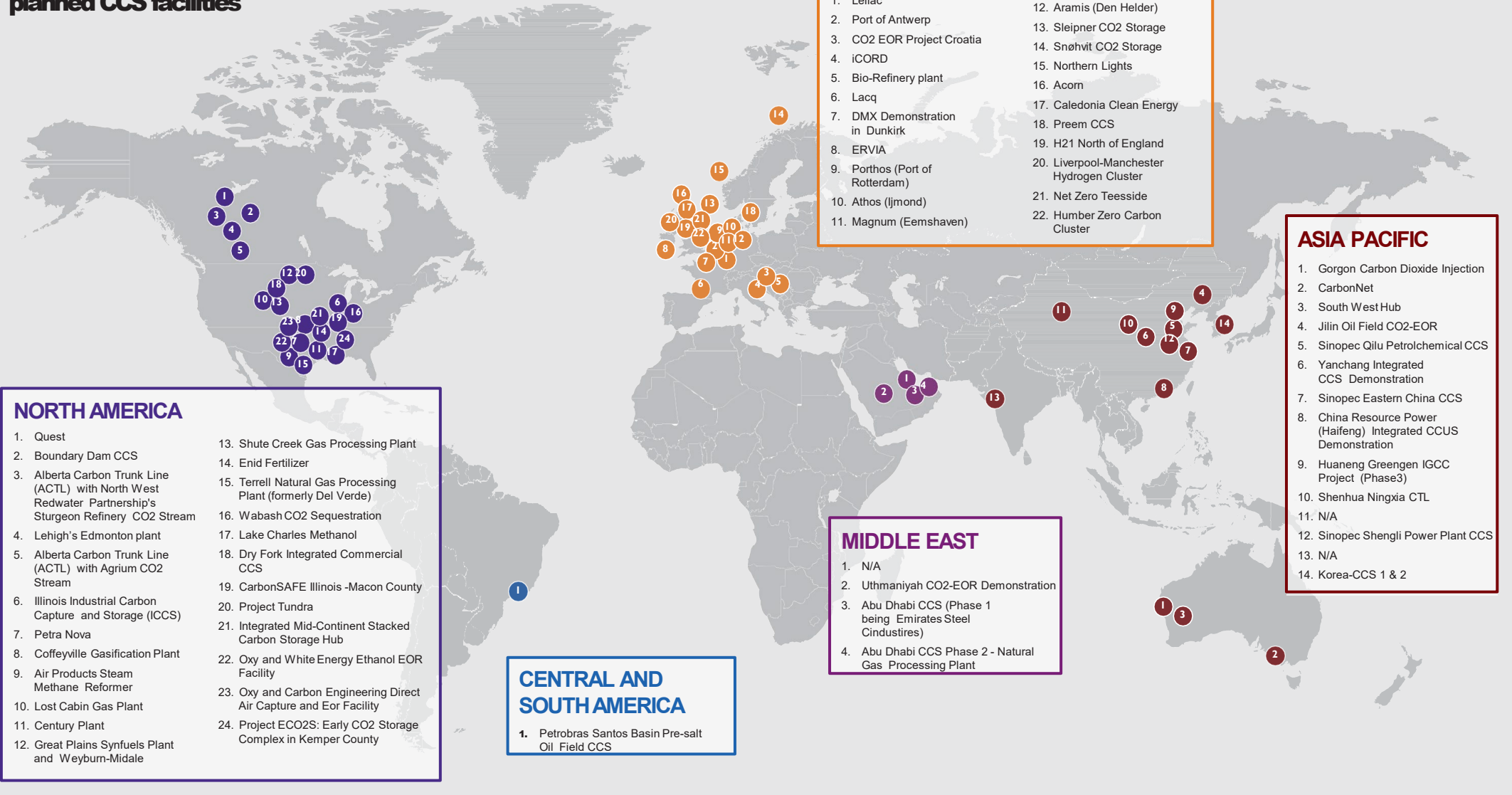
Offshore Hydrogen Storage

(Courtesy Technip
FMC – Deep
Purple)



Global CCS projects

Overview of existing and planned CCS facilities



- ### NORTH AMERICA
- | | |
|---|--|
| 1. Quest | 13. Shute Creek Gas Processing Plant |
| 2. Boundary Dam CCS | 14. Enid Fertilizer |
| 3. Alberta Carbon Trunk Line (ACTL) with North West Redwater Partnership's Sturgeon Refinery CO2 Stream | 15. Terrell Natural Gas Processing Plant (formerly Del Verde) |
| 4. Lehigh's Edmonton plant | 16. Wabash CO2 Sequestration |
| 5. Alberta Carbon Trunk Line (ACTL) with Agrium CO2 Stream | 17. Lake Charles Methanol |
| 6. Illinois Industrial Carbon Capture and Storage (ICCS) | 18. Dry Fork Integrated Commercial CCS |
| 7. Petra Nova | 19. CarbonSAFE Illinois -Macon County |
| 8. Coffeyville Gasification Plant | 20. Project Tundra |
| 9. Air Products Steam Methane Reformer | 21. Integrated Mid-Continent Stacked Carbon Storage Hub |
| 10. Lost Cabin Gas Plant | 22. Oxy and White Energy Ethanol EOR Facility |
| 11. Century Plant | 23. Oxy and Carbon Engineering Direct Air Capture and Eor Facility |
| 12. Great Plains Synfuels Plant and Weyburn-Midale | 24. Project ECO2S: Early CO2 Storage Complex in Kemper County |

- ### CENTRAL AND SOUTH AMERICA
1. Petrobras Santos Basin Pre-salt Oil Field CCS

- ### EUROPE
- | | |
|---------------------------------|---|
| 1. Leilac | 12. Aramis (Den Helder) |
| 2. Port of Antwerp | 13. Sleipner CO2 Storage |
| 3. CO2 EOR Project Croatia | 14. Snøhvit CO2 Storage |
| 4. iCORD | 15. Northern Lights |
| 5. Bio-Refinery plant | 16. Acom |
| 6. Lacq | 17. Caledonia Clean Energy |
| 7. DMX Demonstration in Dunkirk | 18. Preem CCS |
| 8. ERVIA | 19. H21 North of England |
| 9. Porthos (Port of Rotterdam) | 20. Liverpool-Manchester Hydrogen Cluster |
| 10. Athos (Ijmuiden) | 21. Net Zero Teesside |
| 11. Magnum (Eemshaven) | 22. Humber Zero Carbon Cluster |

- ### MIDDLE EAST
1. N/A
 2. Uthmaniyah CO2-EOR Demonstration
 3. Abu Dhabi CCS (Phase 1 being Emirates Steel Cindustires)
 4. Abu Dhabi CCS Phase 2 - Natural Gas Processing Plant

- ### ASIA PACIFIC
1. Gorgon Carbon Dioxide Injection
 2. CarbonNet
 3. South West Hub
 4. Jilin Oil Field CO2-EOR
 5. Sinopec Qilu Petrochemical CCS
 6. Yanchang Integrated CCS Demonstration
 7. Sinopec Eastern China CCS
 8. China Resource Power (Haifeng) Integrated CCUS Demonstration
 9. Huaneng Greengen IGCC Project (Phase3)
 10. Shenhua Ningxia CTL
 11. N/A
 12. Sinopec Shengli Power Plant CCS
 13. N/A
 14. Korea-CCS 1 & 2

Courtesy:
Shell Quest
Canada



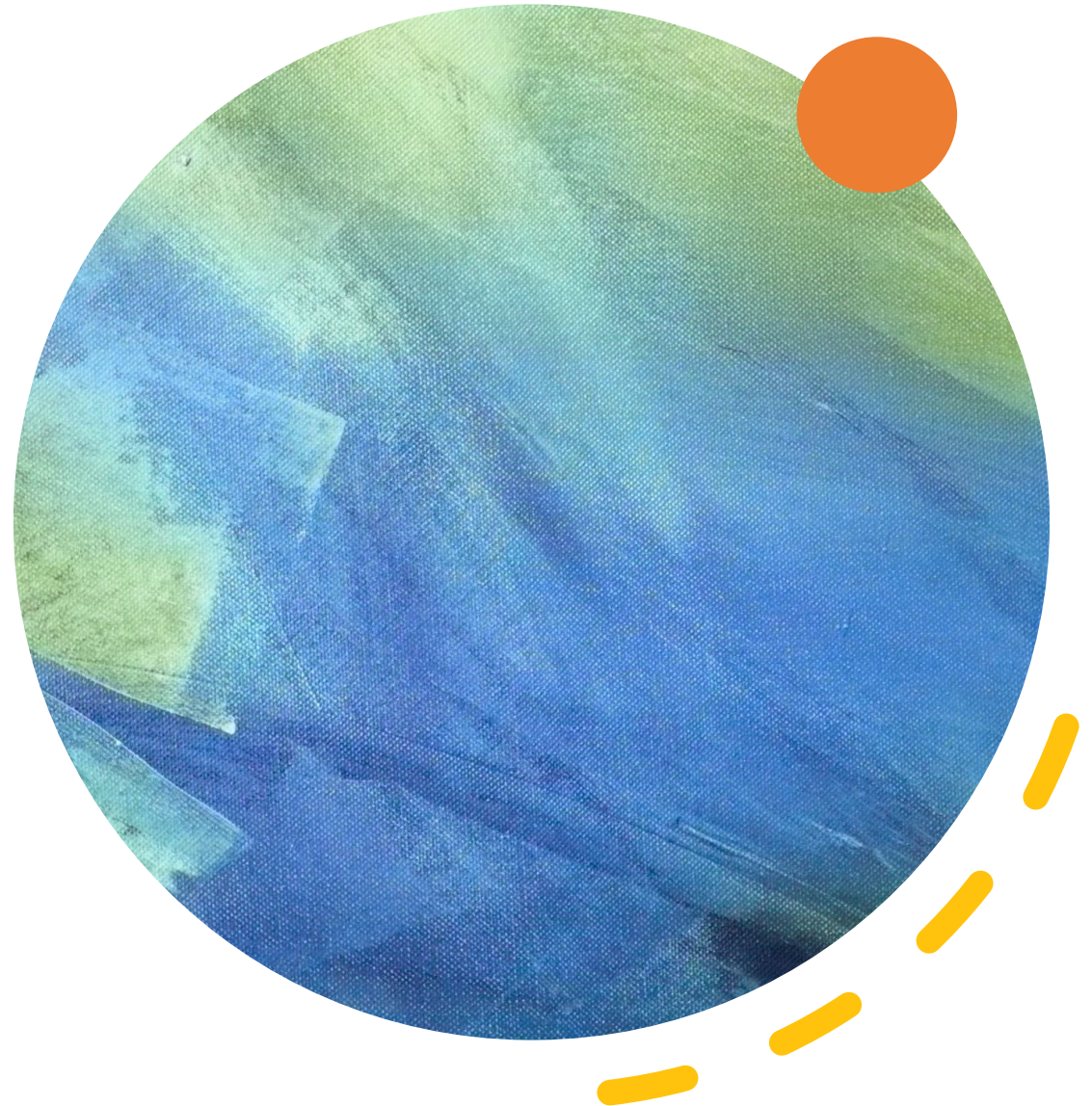
Top Clean Energy Developments of 2020/2021

- **Coal is on its way out:** (1) US and EU coal plants retirements outpaced new plants, (2) global coal consumption down
- **Gas also in decline:** Utilities not replacing coal with gas
- **China and carbon neutrality:** Plans to be carbon neutral by 2060 (will adopt more vigorous policies/measures)
- **Green Deals - carbon-free electricity goes mainstream:** (1) S&P Global Clean Energy index up 37% (in last 2 years), (2) EU stimulus package set aside 25% for clean energy technologies, (3) Biden administration proposed a carbon-free power sector by 2035
- **Big banks make climate commitments:** To reduce carbon intensity of entire portfolios over time
- **Financial Institutions and shipping decarbonization:** Poseidon Principles – finance initiative to decarbonize the maritime sector

(SOURCE: Laurie Stone/RMI/Energy Post – Jan 4, 2021)

Top Clean Energy Developments of 2020/2021 (Continued)

- Green H₂ taking off
- Increase in Blue H₂ projects in US and globally
- US rejoins Paris Agreement – CATCH Act – 45Q changes
- Bans on gas vehicles are growing
- Renewed focus on methane emissions
- Racial justice enters climate activism discussion



Concluding Remarks

- H₂ will play an important role for future energy needs globally
- CCUS will also play a bigger role in enabling transition to a low carbon economy
- Major challenges to massively scale-up the H₂ economy: government policies and financial incentives; global cooperation; buildup of infrastructure and commercial markets/hubs; technology challenges – transportation, potential use/blending of existing gas pipeline networks, decarbonizing major industry sectors – steel, cement etc.
- Industrial-scale production of low-carbon H₂ possible with today's technology with ability for substantial near-term emission reductions
- O&G industry with its unique skills, resources and experience can play a major role in this energy mix transition