



Advanced CO₂ and Storage Technologies

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Keynote Address

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Advanced Resources International, Inc.

Our history of services:

Since 1971*, we have added value to hundreds of oil and gas E&P projects in the U.S. and in over 30 countries, from Australia to Zimbabwe.

Our approach integrates geology and geophysics, petroleum engineering, and strategic and economic analysis.

We specialize in enhanced oil and gas recovery and the geological storage of CO₂.

*From 1971 – 1987, the company was called Lewin & Associates; from 1987 – 1991, the company was a subsidiary of ICF Consulting/Kaiser Engineers; since 1991, the company is stand alone and called Advanced Resources International, Inc.

Our clients include:



Introduction

Numerous studies and meetings are helping to define the role of Carbon Capture, Utilization and Storage (CCUS) for the oil, gas and coal industry.

- **National Petroleum Council Study-** “Meeting the Dual Challenge: A Roadmap to At-Scale Deployment of CCUS”
- **SPE Improved Oil Recovery Conference Plenary-** “Low Carbon Strategies and Future IOR Applications”
- **Annual SPE Conference Special Session-** “Meeting the Dual Challenge and Accelerating the Deployment of CCUS”
- **IEA Flagship Report-** “CCUS in Clean Energy Transition”

Importance of CCUS for the Oil, Gas and Coal Industry

Markets and the public are demanding low/net zero carbon fuels. CCUS will be essential for meeting this demand.



Source CAPP, 2017.

- Natural gas and CCUS for power generation
- Feedstocks for “blue” hydrogen
- Carbon neutral/negative oil with CO₂ EOR for transportation
- Lower carbon, “green” LNG import and exports

My view is that CCUS will be essential to ensure a viable future for the oil, gas and coal industry.

Picking the “Low-Hanging Fruit”

Revenues from EOR, augmented by recently passed 45Q tax credits, support a variety of “low-hanging fruit” CCUS projects that together store about 1 Bcfd (20 MMmt/yr).

Shute Creek Gas Processing Plant, SW Wyoming



Source: Exxon Mobil.

- Natural gas processing (Shute Creek, Lost Cabin, Century Plant, etc.)
- Chemicals, ammonia, and hydrogen (Coffeyville, Enid, Air Products SMR)

However, given today’s low oil prices, a more robust set of incentives and funding support are required for a “business case” for large-scale CCUS in key sectors.

Large-Scale CCUS Projects

In addition to numerous “low-hanging fruit” projects, a handful of larger-scale domestic CCUS are in progress:

Lake Charles Methanol

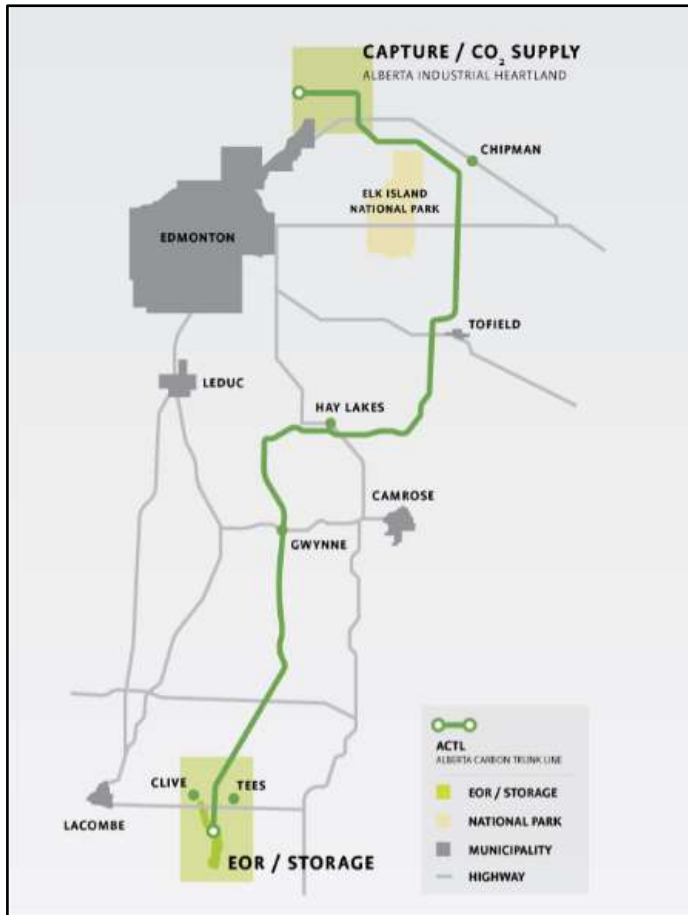


Source: Lake Charles Methanol.

- **Lake Charles Methanol.** A \$4.4 billion project to produce 3.8 MMt/yr of methanol and capture/store 4 MMt/yr of CO₂, expected in operation in 2024.
- **White Energy/Oxy Ethanol.** Two 0.35 MMmt/yr West Texas CO₂ capture projects, with storage using EOR.
- **Numerous FEED Studies at Power Plants.** Project Tundra (ND), San Juan Generation, Plant Daniel (Miss.), and Dry Fork (Wyo), among others

International CCUS: Canada

Alberta Carbon Trunk Line



Source: Alberta Carbon Trunk Line, 2020.

Canada continues as a leader in Carbon Management with federal and provincial support for CCUS. (Petroleum Economist, October 2020)

- Weyburn-Midale CO₂ EOR, one of world's largest and longest-operating CCUS projects, with CO₂ storage of nearly 40 MMmt to date.
- Boundary Dam post-combustion capture from SaskPower's coal-fired power plant, with 1MMmt/yr of CO₂ sold for EOR.
- Project Quest, capture and geologic storage of 5 MMmt of CO₂ from a bitumen upgrader.
- Recent completion of **Alberta Carbon Trunk Line**, eventually transporting 14.6 MMmt per year of CO₂ to oil fields for EOR.

Other Major International CCUS Projects

- United Kingdom. Net Zero Teesside (NZT)**, industry consortium to decarbonize a cluster of carbon-intensive industries involving offshore CO₂ transport and storage of 10 MMmt/year.



Source: DNV-GL.

- Norway. Northern Lights**, a large-scale, widely accessible CO₂ storage facility in Norway's portion of the North Sea, expected ready by 2023-2024.
- Australia. A comprehensive onshore CO₂ EOR study**; initial field test at Cooper Basin/Moomba, a 1.7 MMmt/yr CCUS project; Gorgon LNG, a 4 MMmt/yr CCUS project, in operation.
- Netherlands. Port of Rotterdam (Porthos)** CCUS project, capturing 0.5 MMmt/yr of industrial CO₂ with storage offshore, expected ready by 2024.

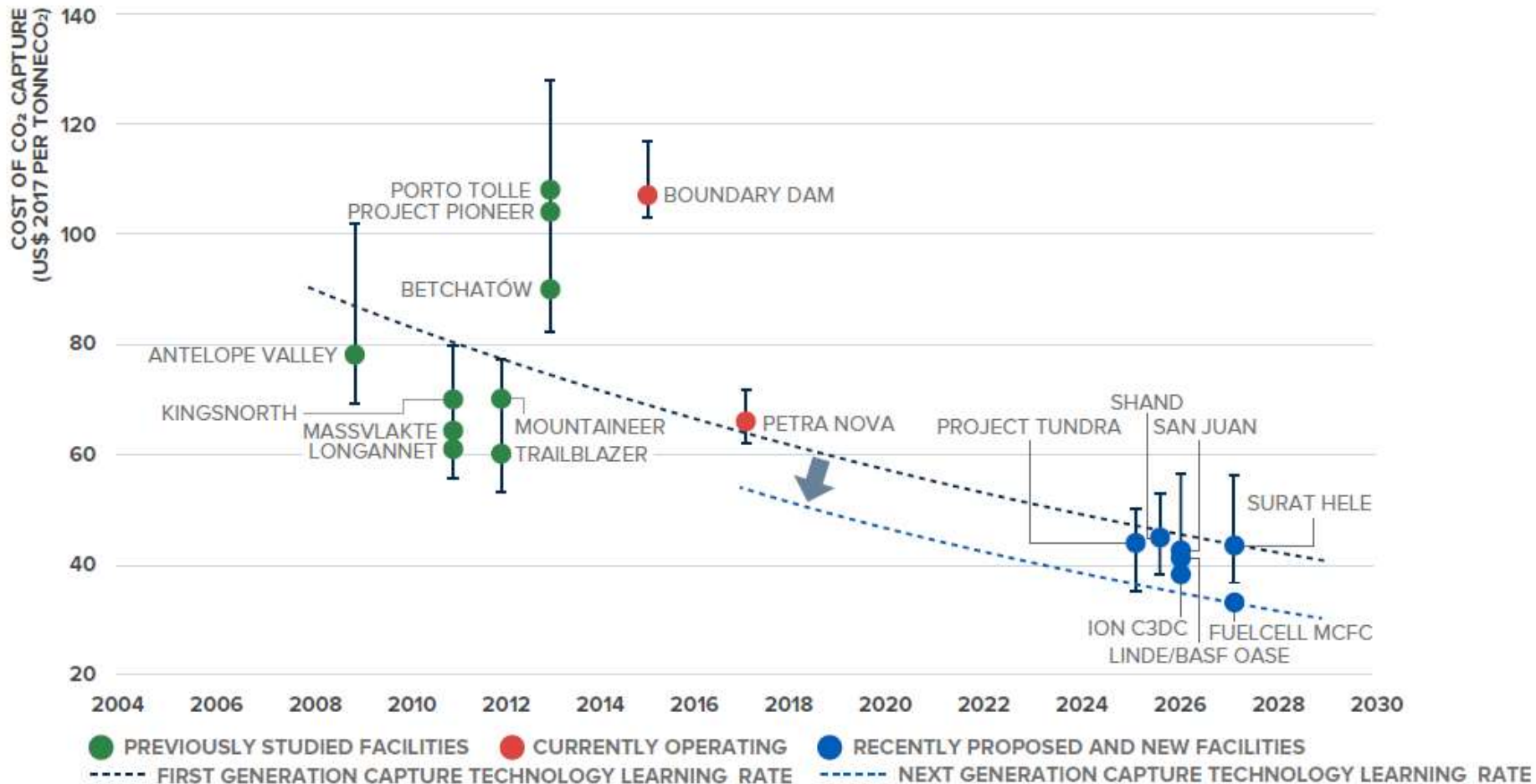
Building the Foundation for CCUS

After nearly three decades of studies, science, field pilots, and several false starts, four important cornerstones of CCUS are being put into place:

- Lower cost CO₂ capture technology
- Confidence about vast volumes of safe, secure CO₂ storage capacity
- Notable (but still too limited) financial and policy support (45Q, LCFS)
- Improving public acceptance

Lower Cost CO₂ Capture Technology

Costs of Post-Combustion CO₂ Capture for Large-Scale Coal-Fired Plants



Source: Global CCS Institute, 2019.

Regional CO₂ Storage Hubs

Industry and the US DOE/NETL are establishing large-scale regional CO₂ storage hubs.

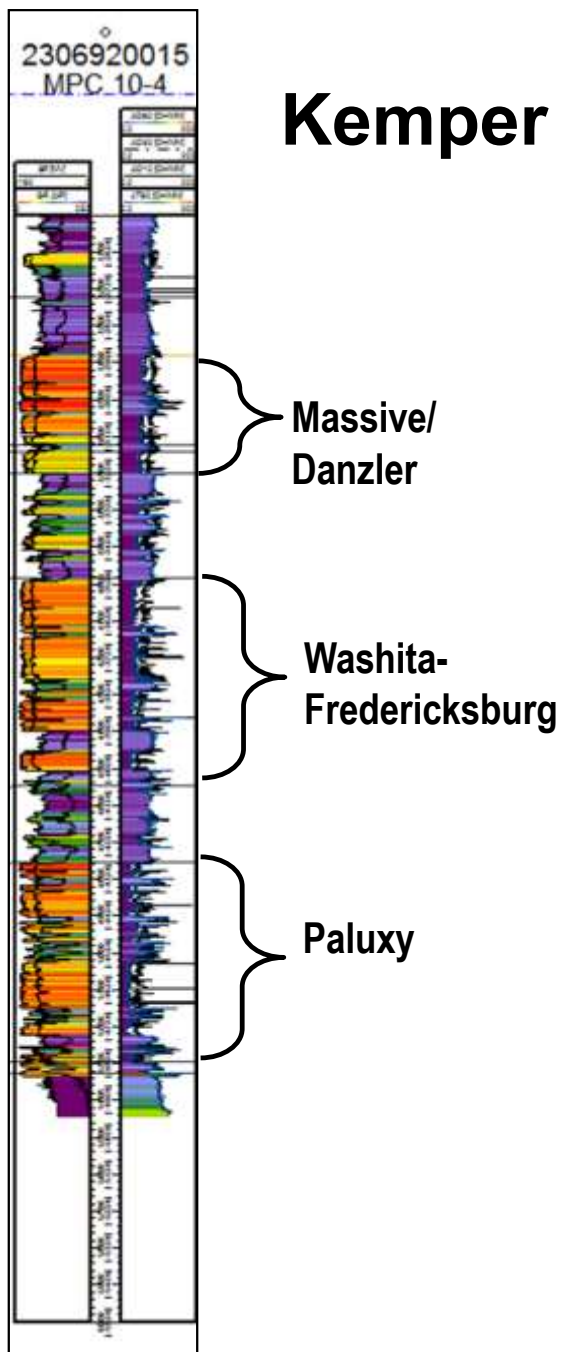
The US DOE/NETL's CarbonSAFE program is supporting the development of six regional CO₂ storage hubs, including:

- A “world-scale” saline storage facility in Kemper County, Mississippi.
- A storage hub at the Dry Fork power plant in Campbell County, Wyoming.
- Four other facilities in North Dakota, Illinois, Indiana, and New Mexico.

Gulf Coast Sequestration Company is pursuing Class VI permit to build and operate an 80 MMmt capacity deep saline CO₂ storage facility (2.7 MMmt/ year) in western Louisiana Gulf Coast.

Kemper County ECO₂S Storage Complex

Three stacked storage reservoirs with over a gigatonne of CO₂ storage capacity.

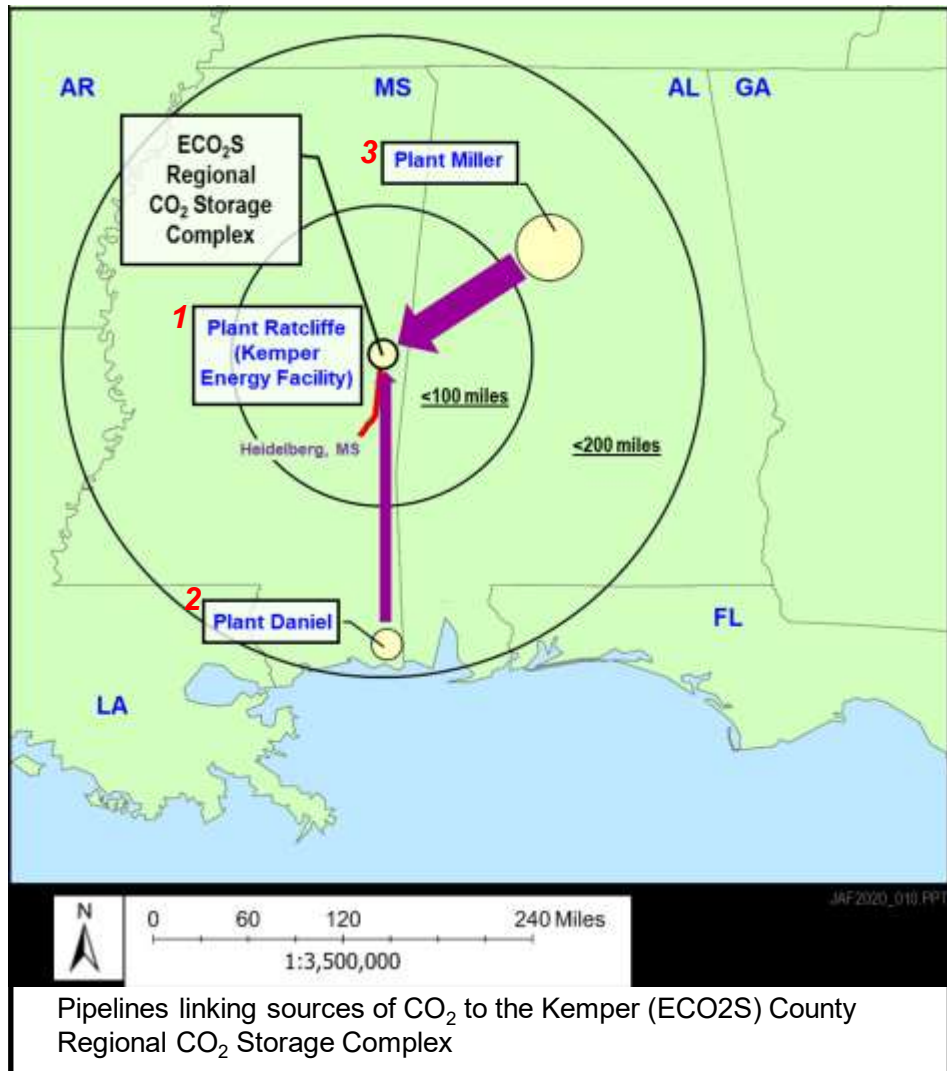


CO ₂ Storage Reservoir	P ₁₀ Capacity (MMmt)	P ₅₀ Capacity (MMmt)	P ₉₀ Capacity (MMmt)
Massive/Danzler	85	160	280
Wash.-Fred.	350	660	1,130
Paluxy	200	380	650
TOTAL	635	1,200	2,060

USDOE methodology for site-specific saline storage efficiency calculation based on fluid displacement factors for clastic reservoirs where net pay, net thickness and net porosity are known of 7.4% (P₁₀), 14% (P₅₀) and 24% (P₉₀) (Goodman et al., 2011)



CO₂ Sources for Storage Hub



Kemper County Regional CO₂ Storage Hub

- CO₂ capture of up to **22.5 million metric tons per year** from three Southern Company plants.
- Pre-feed capture studies at APC's Plant Miller (coal) and MPC's Plant Ratcliffe (gas).
- FEED capture study at MPC's Plant Daniel NGCC power units.
- Pipeline transportation and surface facilities studies underway.



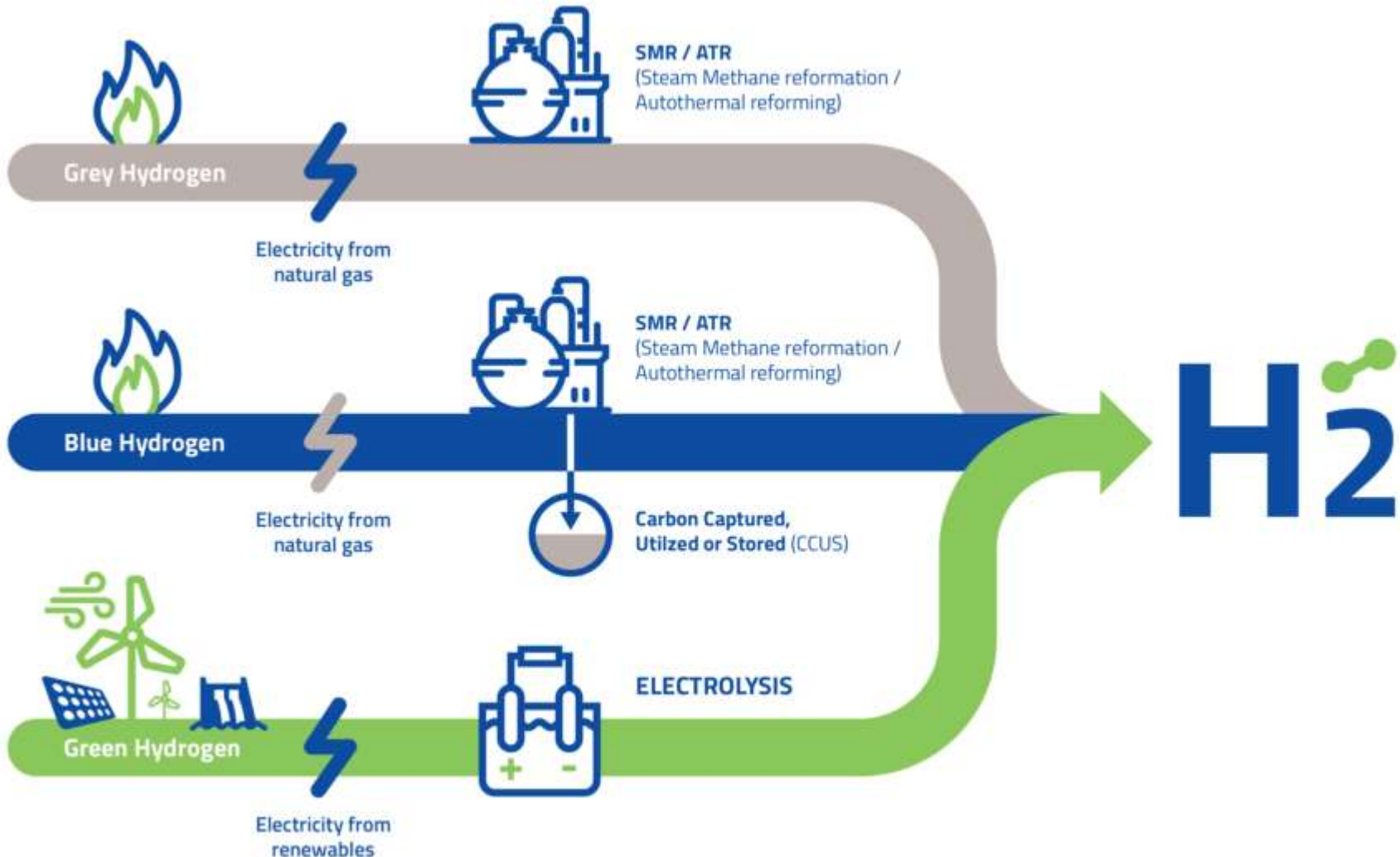
Incentives for Carbon Negative Transportation Fuels

Transportation is one of the most difficult sectors to fully decarbonize, but essential if the oil industry is to maintain a robust presence in its largest market.

- Evolve toward a natural gas and hydrogen/w CCUS (blue hydrogen) industry; Shell Oil strategy.
- Produce “carbon-negative” crude oil by storing more CO₂ (with EOR) than the CO₂ content in the produced oil.
- Pursue the methanol and bio-fuels LCTF market in California

A 45Q tax credit structure that gives double credit (beyond \$35/mt), similar to 2 credits per mt of CO₂ stored at Quest, for CO₂ storage of over 0.4 mt/bbl with EOR.

Green Hydrogen, Blue Hydrogen and Grey Hydrogen



Source: European Green Acceleration Center, 2020.

Producing Carbon Negative Oil

Over 100 billion metric tons (Gt) of CO₂ can be stored with EOR in a variety of “oil field” settings.

Oil Field Settings		Technical Potential		
		CO ₂ Storage (Billion mt)	Oil Recovery (Billion bbls)	CO ₂ /Oil Ratio (mt/bbl)
1	Conventional Onshore Oil Fields ⁽¹⁾	44	81	0.53
2	Residual Oil Zones ⁽²⁾	42	67	0.63
3	Shale Oil Formations ⁽³⁾	20 to 30	47	0.43 to 0.63
4	Offshore Oil Fields ⁽⁴⁾	Three case studies show significant potential		

In all four settings, more CO₂ can be stored than the CO₂ in the produced oil (if combusted) of about 0.4 mt/bbl.

Incentives for CO₂ Capture from NGCC

The single largest source of stationary CO₂ emission will soon be NGCC power plants. The “business case” for CCUS for these plants requires three critical next steps.

- Extend the “kick-off” date and the time of availability of the 45Q tax credits to 20 years.
- Increase the 45Q tax credit for CCUS from natural gas-fired power to \$75/mt. With 40% of CO₂ emissions and 60% of capture costs, NGCC plants need a higher level of support per mt of CO₂ than coal-fired power plants.
- Provide extra incentives (\$100/mt) for “first-of-a-kind”, higher CO₂ capture rate (95%+) systems, in operation by 2030.

Closing Comments

I have confidence that we are entering the “Dawn of the New Age for CCUS.”

- Markets, Public Policy, and Green Procurement Practices will increasingly demand low/carbon-neutral fuels.
- Wide-scale use of CCUS can enable the oil, gas and coal industry to meet these demands and remain viable during the transition to a carbon constrained world.
- A more robust set of incentives for: (1) carbon-negative production of oil (with EOR plus enhanced storage) and (2) capture and storage of CO₂ from coal and natural gas-fueled power plants are top priorities.



Sources for Slide #16:

1. “Improving Domestic Energy Security and Lowering CO₂ Emissions with “Next Generation” CO₂-Enhanced Oil Recovery (CO₂-EOR)”, DOE/NETL-2011/1504, July 2011, prepared by Advanced Resources International, Inc., updated in 2019 by Advanced Resources International, Inc.
2. A series of reports addressing the “San Andres ROZ Fairway Resources of the Permian Basin” prepared by Advanced Resources International for U.S. DOE, 2016-2018.
3. “The Next Phase of the “Shale Oil Revolution”: Storing CO₂ with Shale EOR”, USEA Webinar presented by Vello Kuuskraa, Advanced Resources International, September 23, 2020.
4. A series of offshore field case studies (Petronius, Cognac and Horn Mountain) prepared by Advanced Resources International for U.S. DOE, 2019-2020.

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