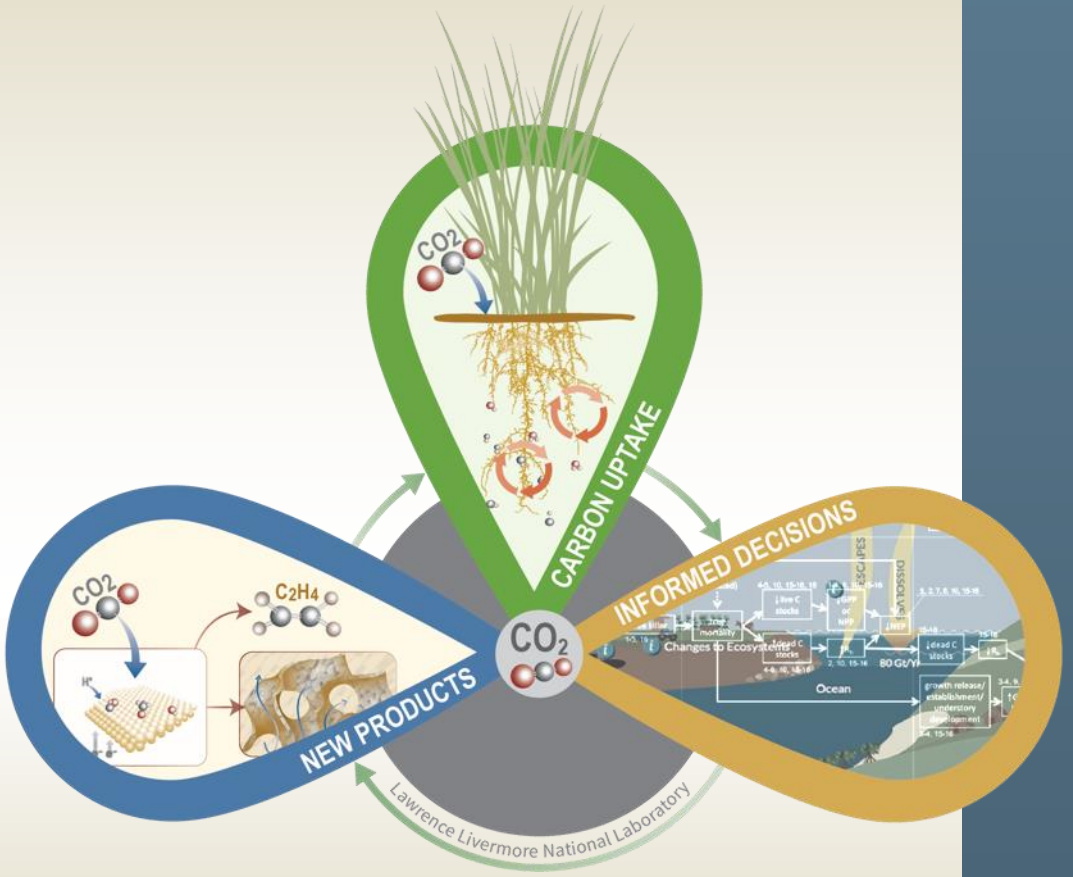

THE LLNL CARBON INITIATIVE

Opportunities for Blue Hydrogen in California

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Blue Hydrogen:

Hydrogen created from fossil sources, with some or all carbon permanently kept of out the air.

This requires carbon storage

2019 added geologic storage to the California Low Carbon Fuel Standard

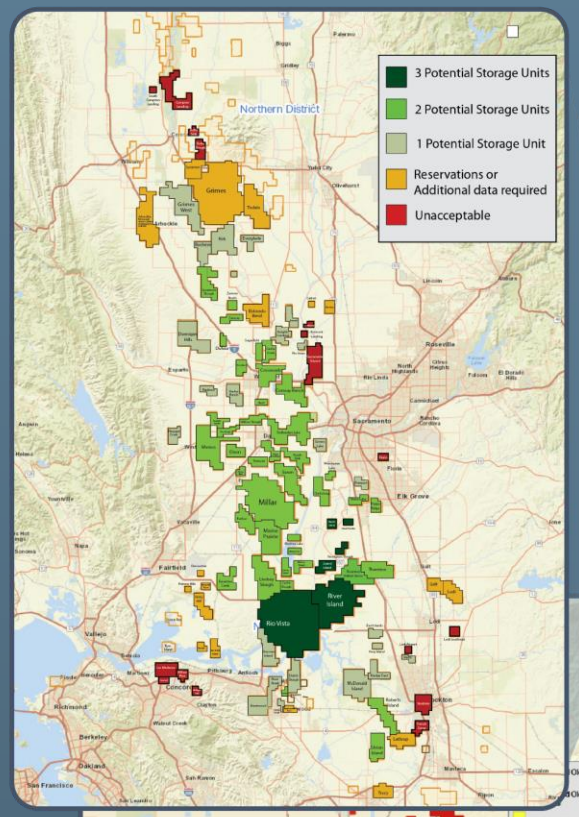
Most reductions in carbon intensity were already allowable (efficiency, renewable power, better feedstock).

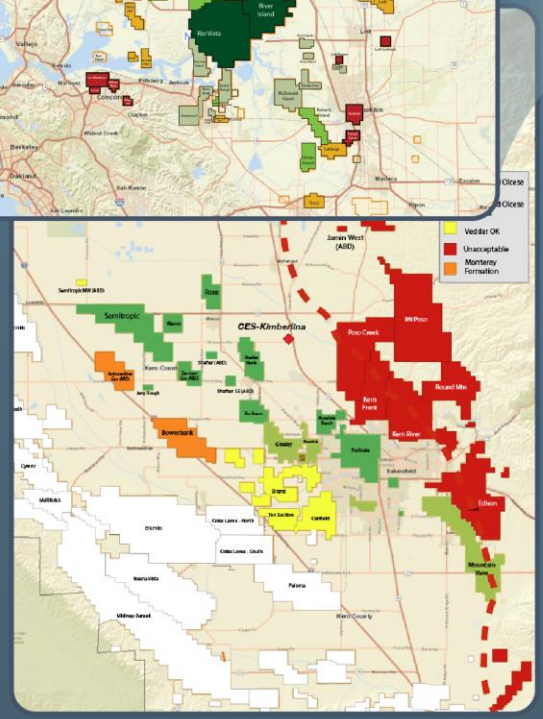
Finalized for 2019, carbon capture and storage ***on any process that yields a fuel sold in California*** will generate a credit that can be traded or used.

The accounting and storage rules are rigorous.

There is **plenty of safe space in California** to store CO_2 underground—in the same rocks that have held oil and gas for millions of years.

We have identified **17 billion tons** of safe storage in **just 2 areas** of the Central Valley.





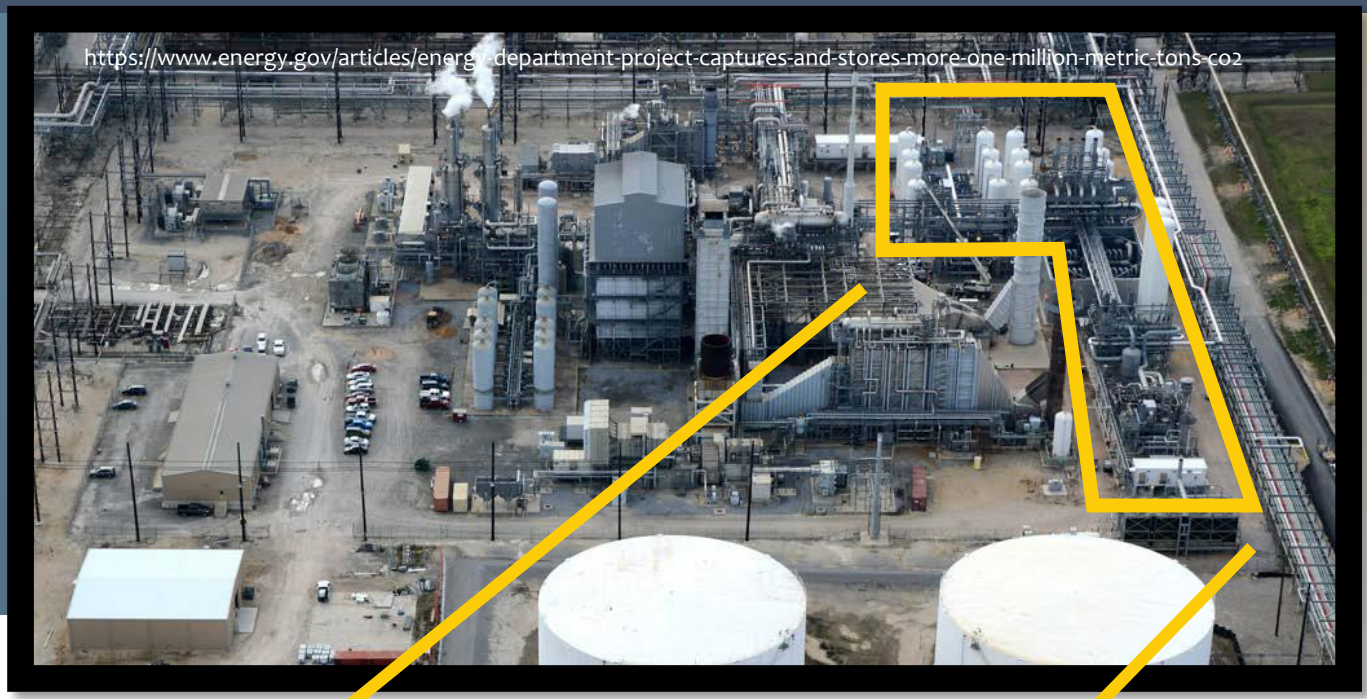
Permanent geologic storage is available

Transportation and permanent storage: less than $10/ton

https://www.energy.gov/articles/energy-department-project-captures-and-stores-more-one-million-metric-tons-co2`

Port Arthur: existing capture approach is surprisingly compact

Port Arthur 1 retrofit of carbon capture on existing SMR



PORT ARTHUR 1

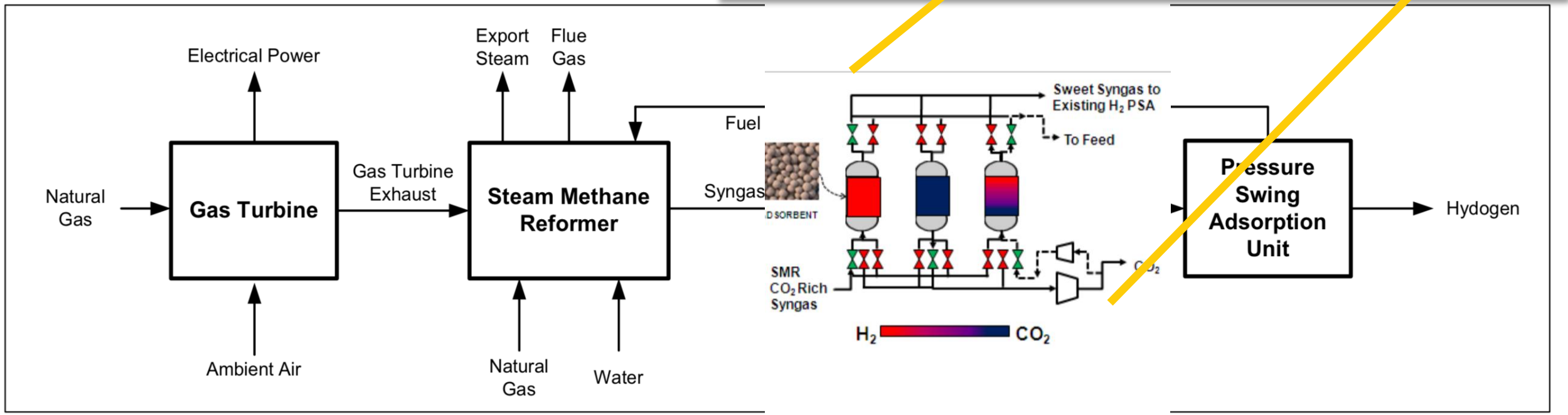


Figure 19. Port Arthur 1 basic process scheme (prior to CO_2 capture).

1st of a Kind: $76 per ton CO_2

Cost Category	USD/Metric Ton	Comments
Installed Capital Cost	$51.00	See Note 2
Natural Gas	$5.10	See Note 3
Miscellaneous Utilities	$0.90	
Property Tax	$5.00	
Labor and Maintenance	$4.50	See Note 4
Gross Total Cost	$66.50	See Note 5
Net Total Cost	$76.50	See Note 6

Notes:

1. All calculations assume a CO_2 production level of 1,000,000 metric tons per year.

2. Installed Capital Cost was approximately $300,000,000; this includes CO_2 capture equipment, the CO_2 pipeline to connect Port Arthur with Denbury Green Pipeline, the CO_2 compressor and the cogeneration unit. Calculation assumes an annual capital recovery factor of 0.17, based on a 15-year life and a 10% return on capital.

3. Natural Gas includes natural gas utilized by the cogeneration unit as well as efficiency impacts on the existing hydrogen plants. This assumes natural gas pricing of $3/MMBTU.

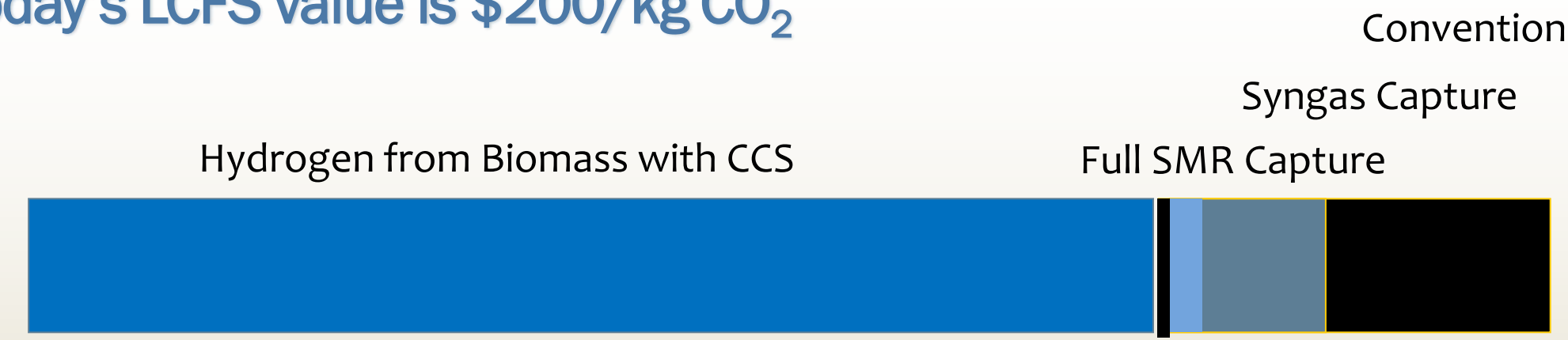
4. Labor and maintenance costs are incremental to those costs associated with pre-existing operations at the Port Arthur site.

5. Economics shown do not include any costs associated with Monitoring, Verification and Accounting (MVA) of sequestered CO_2 and exclude the effect of a new CO_2 source as a result of the energy used to capture the CO_2.

6. Economics shown do not include any costs associated with Monitoring, Verification and Accounting (MVA) of sequestered CO_2 and include the effect of a new CO_2 source as a result of the energy used to capture the CO_2.

Carbon Intensity of Blue Hydrogen: +7 to – 20 kg CO_2/kg H_2

Today's LCFS value is \$200/kg CO_2



- Blue hydrogen benefits from ~ $200 (LCFS) and $45 (45Q) policy support in California
- Geologic storage is required
- More CO_2 underground means more $$
- Adding biomass sources improves carbon footprint and LCFS value to as much as $5.40 per kg of hydrogen