# Techno Economic Feasibility of a Hydrogen Supply Using In-situ Generation from Hydrocarbons with Catalysts and Electromagnetic Heating


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## Research Question

Is hydrogen generated within hydrocarbon reservoirs using catalysts and electromagnetic heat an economical and technically feasible source of hydrogen?

## Methods

Data based on:

- Primary data from TerraVent and Dr. Qingwang Yuan at TTU
- Secondary data from literature review

Research question broken down into four components:

- Production costs
- Input energy requirements
- Process efficiency
- Environmental Impacts

## Sustainable Development Goals



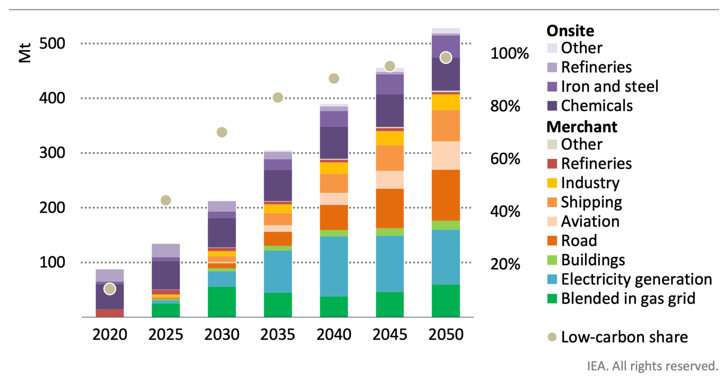




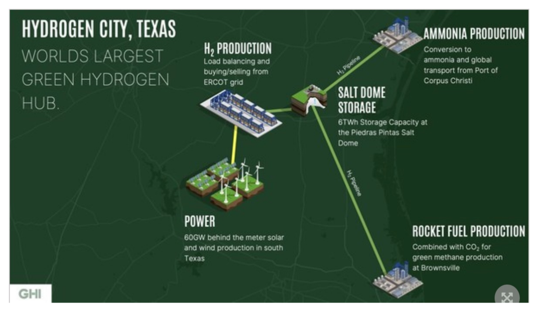



## Why Hydrogen?

- Importance of hydrogen to meet 2050 net-zero goals
  - Feasible way to convert existing infrastructure
    - Transportation, home heating
- Future regional hydrogen hubs
  - Edmonton hydrogen hub
  - Proposed Hydrogen City, Texas
- Government subsidies available



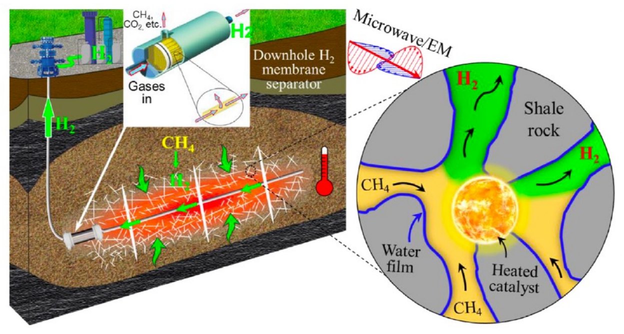

IEA Net Zero by 2050 Roadmap, p. 75, https://iea.blob.core.windows.net/assets/deebef5d-0c34-4539-9d0c-10b13d840027/NetZeroby2050-ARoadmapfortheGlobalEnergySector_CORR.pdf



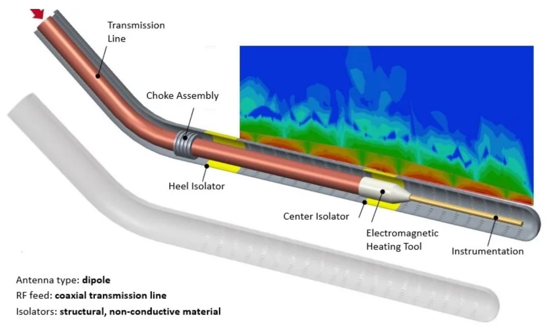

https://www.prnewswire.com/news-releases/green-hydrogen-international-announces-hydrogen-city-texas--the-worlds-largest-green-hydrogen-production-and-storage-hub-301494988.html#

## HOPE Process

- Sustainable, cost-efficient processes needed
- **H**ydr**O**gen from **PE**troleum Reservoirs - HOPE
- New low-carbon hydrogen generation process utilizing hydrocarbon reservoirs
- First proposed by Dr. Qingwang Yuan out of Texas Tech University in 2021
- TerraVent collaboration in 2022
- Heatwave® Technology




Yan et. al., 2023, International Journal of Hydrogen Energy, 48(41), p. 15423. Copyright 2023 by Elsevier Ltd

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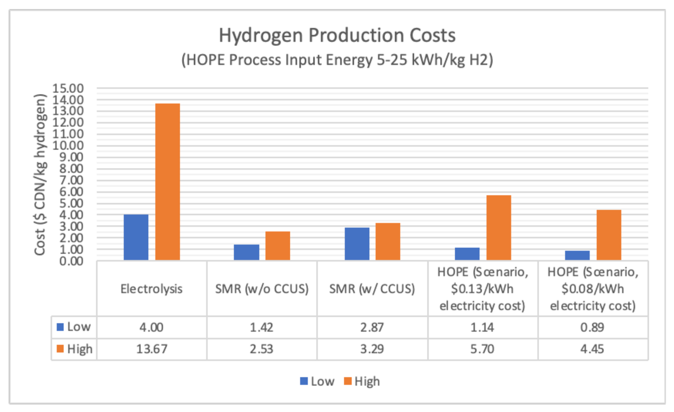
## Cost Analysis

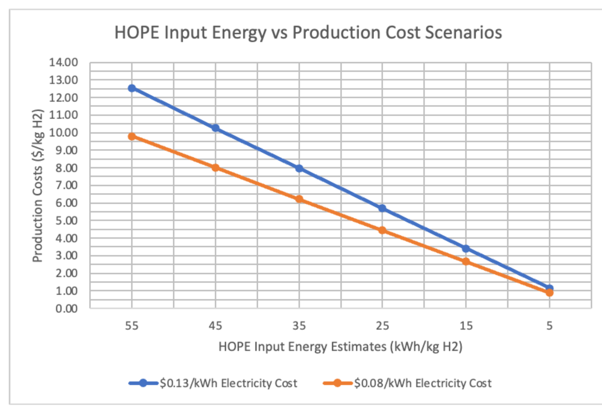
HOPE process driven by electricity

- Electricity cost is main component of O&M
- Two scenarios run:
  - Current grid price of $0.13/kWh
  - Non-peak rates, renewable mix of $0.08/kWh

HOPE energy input range of 5-25 kWh/kg $H_2$ result in costs competitive to electrolysis and SMR

| | | | | | | |
|---|---|---|---|---|---|---|
| Capital ($) | 10,000,000 | 10,000,000 | 10,000,000 | 10,000,000 | 10,000,000 | 10,000,000 |
| Debt split (%) | 60% | 60% | 60% | 60% | 60% | 60% |
| Capital split (%) | 40% | 40% | 40% | 40% | 40% | 40% |
| Capital Return Rate (%) | 10.0% | 10.0% | 10.0% | 10.0% | 10.0% | 10.0% |
| Debt Interest Rate (%) | 8.0% | 8.0% | 8.0% | 8.0% | 8.0% | 8.0% |
| Weighted Average Cost of Capital (%) | 8.8% | 8.8% | 8.8% | 8.8% | 8.8% | 8.8% |
| Project Life (years) | 20 | 20 | 20 | 20 | 20 | 20 |
| Capital Cost Factor (%) | 10.80% | 10.80% | 10.80% | 10.80% | 10.80% | 10.80% |
| | | | | | | |
| Antenna Size (m) | 1000 | 1000 | 1000 | 1000 | 1000 | 1000 |
| Heat rate (kW/m) | 2 | 2 | 2 | 2 | 2 | 2 |
| Capacity Factor (%) | 70% | 70% | 70% | 70% | 70% | 70% |
| Process Efficiency (%) | 90% | 90% | 90% | 90% | 90% | 90% |
| Annual Total Power (kWH) | 11,037,600 | 11,037,600 | 11,037,600 | 11,037,600 | 11,037,600 | 11,037,600 |
| Electricity Rate ($/kWh) | 0.130 | 0.130 | 0.130 | 0.130 | 0.130 | 0.130 |
| | | | | | | |
| Hydrogen Generation Rate (kWh/kg) | 55 | 45 | 35 | 25 | 15 | 5 |
| Annual Hydrogen Estimate (kg) | 200,684 | 245,280 | 315,360 | 441,504 | 735,840 | 2,207,520 |
| | | | | | | |
| **Hydrogen Production Cost ($/kg)** | **12.53** | **10.25** | **7.97** | **5.70** | **3.42** | **1.14** |



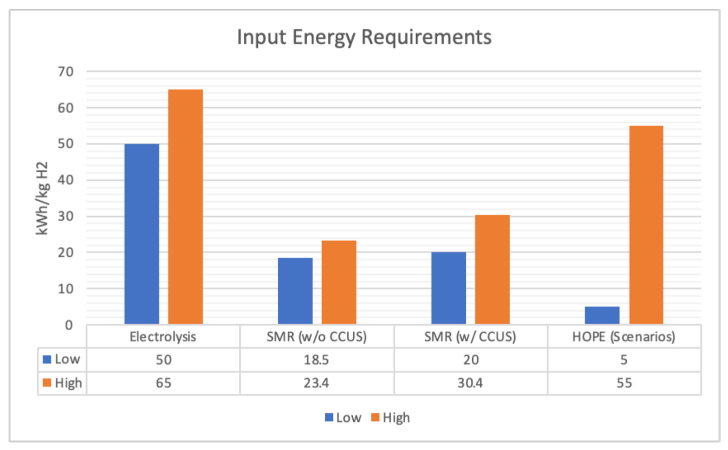

## Input Energy

Energy return on energy invested (EROEI)

- $E_{OUT}/E_{IN}$ ($E_{OUT}$ = energy of process output; $E_{IN}$ = energy of CAPEX, O&M, input fuels)

Simplified cost analysis run with range of input energy to determine input to make process competitive

- Electrolysis and Steam methane reforming (SMR)




## Process Efficiency

Hope Process

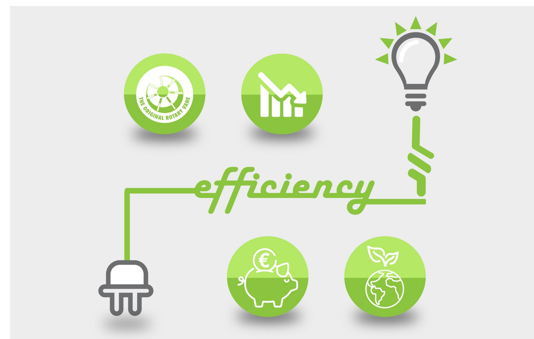
- Proof of concept research done to date
- Crude Oil – up to 63% (Yuan et. al., 2022)
- Shale Gas – up to 100% (Yan et. al., 2023)

Electrolysis

- Alkaline, Proton Exch. Membrane – low temp processes
- 56% - 70% (Hazrat et. al., 2022)

SMR

- 74% - 85% (Megia et. al., 2021)






## Environmental Impacts

Hope process

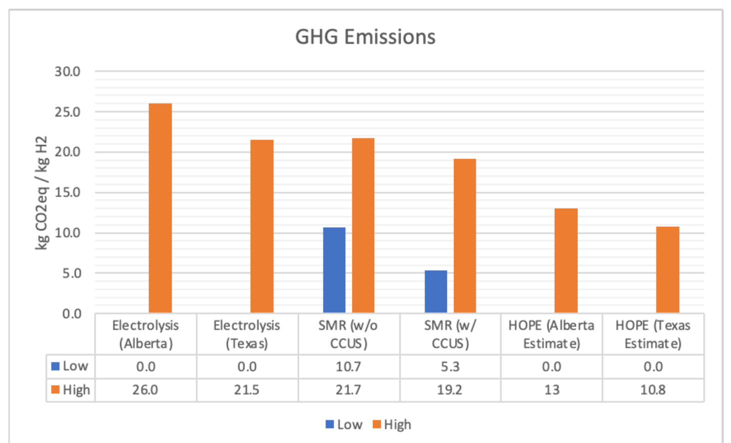
- GHG's generated remain in reservoir, downhole membrane allows selective $H_2$ production
- Grid vs renewable power
- No freshwater required for $H_2$ generation

SMR process

- SMR without CCUS – 10 to 13 kg $CO_2$eq/kg $H_2$ (incl. fugitive methane – up to 22) (Howarth & Jacobson, 2021)
- SMR with CCUS – 5 to 6 kg $CO_2$eq/kg $H_2$ (incl. fugitive methane – up to 19) (Howarth & Jacobson, 2021)
- Freshwater use ~13 – 19 litre H2O/kg $H_2$ (Tarun et. al., 2007)

Electrolysis

- Renewable vs grid power (AB 0.52 kg CO2eq/kWh, TX 0.43 kg CO2eq/kWh) (Sadikman et. al., 2022; U.S. EIA, 2022)
- Freshwater use ~9 litre H2O/kg $H_2$ (Katebah et. al., 2022)




- HOPE case shown assumes input energy of 25 kWh/kg $H_2$
- High cases for electrolysis and HOPE assume 100% grid power, low cases assume 100% renewable power

## Conclusions and Recommendations

Results show HOPE process can be feasible $H_2$ generation option

- 5-25 kWh/kg $H_2$ energy input
- ~$1.00-$4.50/kg $H_2$ (optimized power supply costs)
- Low GHG's
- No freshwater use

Continued research recommended:

- HOPE process energy efficiency
- Optimized catalyst use
- Field scale efficiency
- Detailed process economic analysis

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