Carbon Neutral Fuel: Leading the Way to Net Zero Greenhouse Gas Emissions

Christine Ehlig-Economides

University of Houston

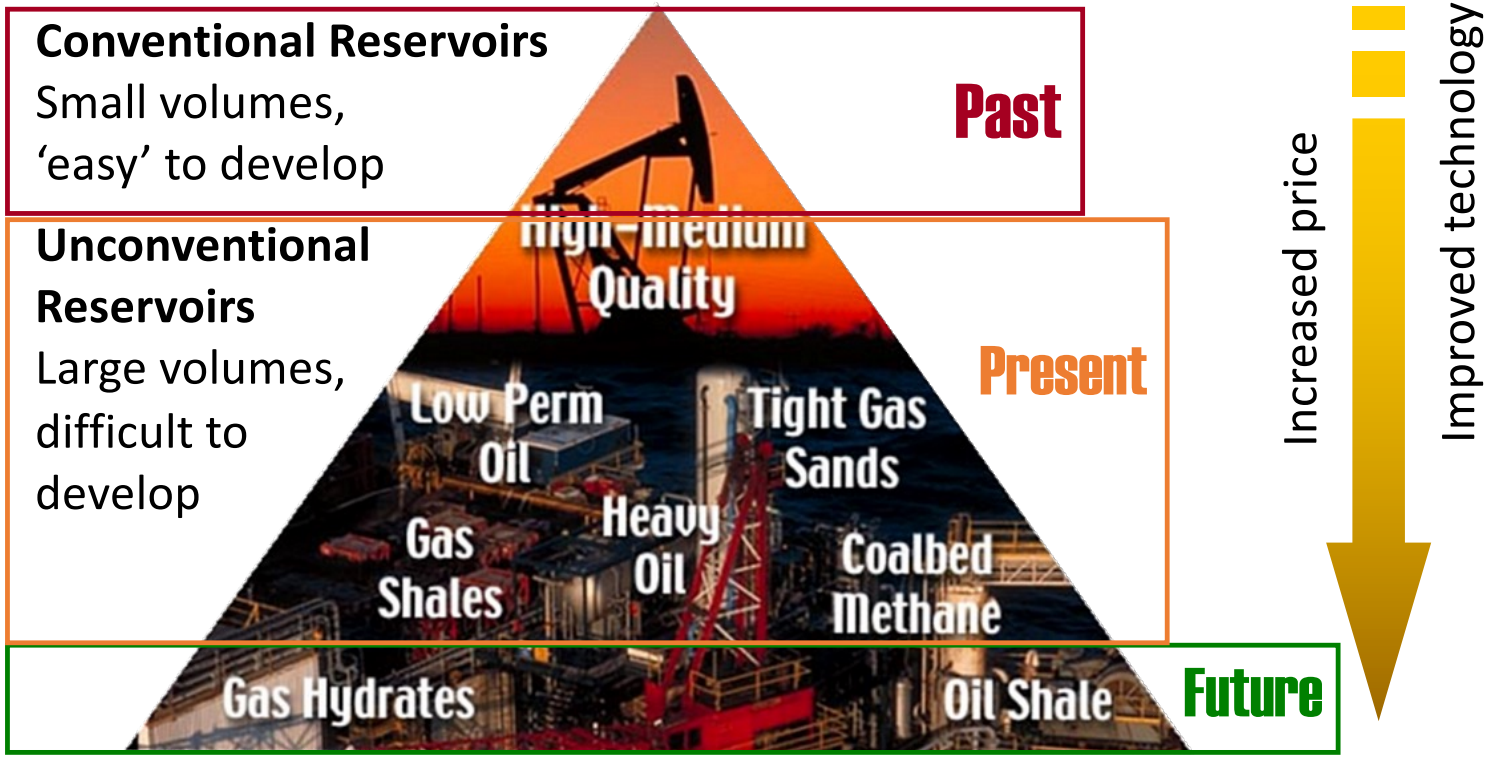
Highlights

- Carbon Neutral Crude Oil (CNCO)
- Carbon Neutral Natural Gas
- Synthetic fuel

Highlights

- **Carbon Neutral Crude Oil (CNCO)**
- **Carbon Neutral Natural Gas**
  - **better known as Blue Hydrogen**

Hydrocarbon Resource Triangle



Steve Holditch

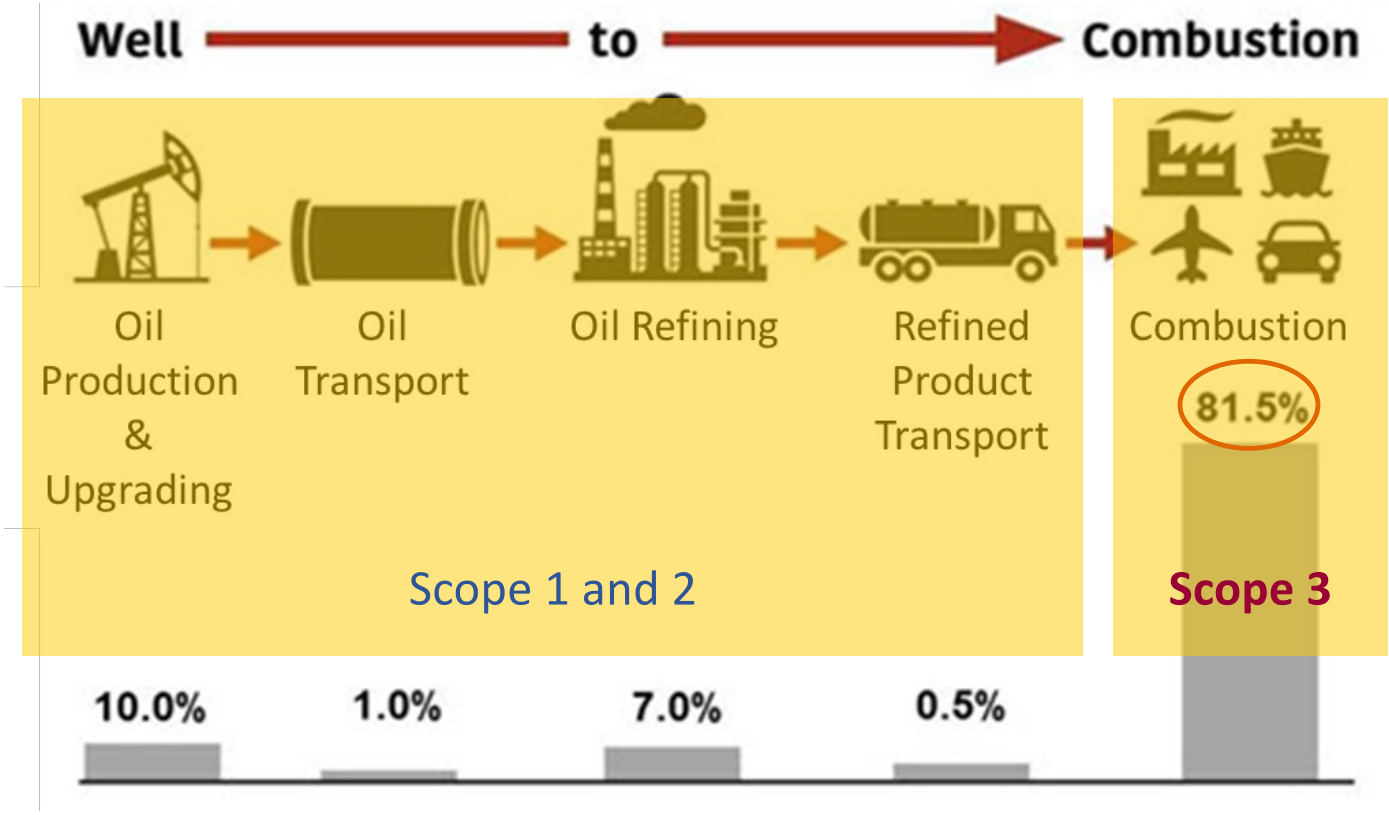
Definition

Carbon neutral fuel

emits no greenhouse gas (GHG) to the atmosphere by

- Eliminating GHG leaks
- Capturing and storing combustion GHG

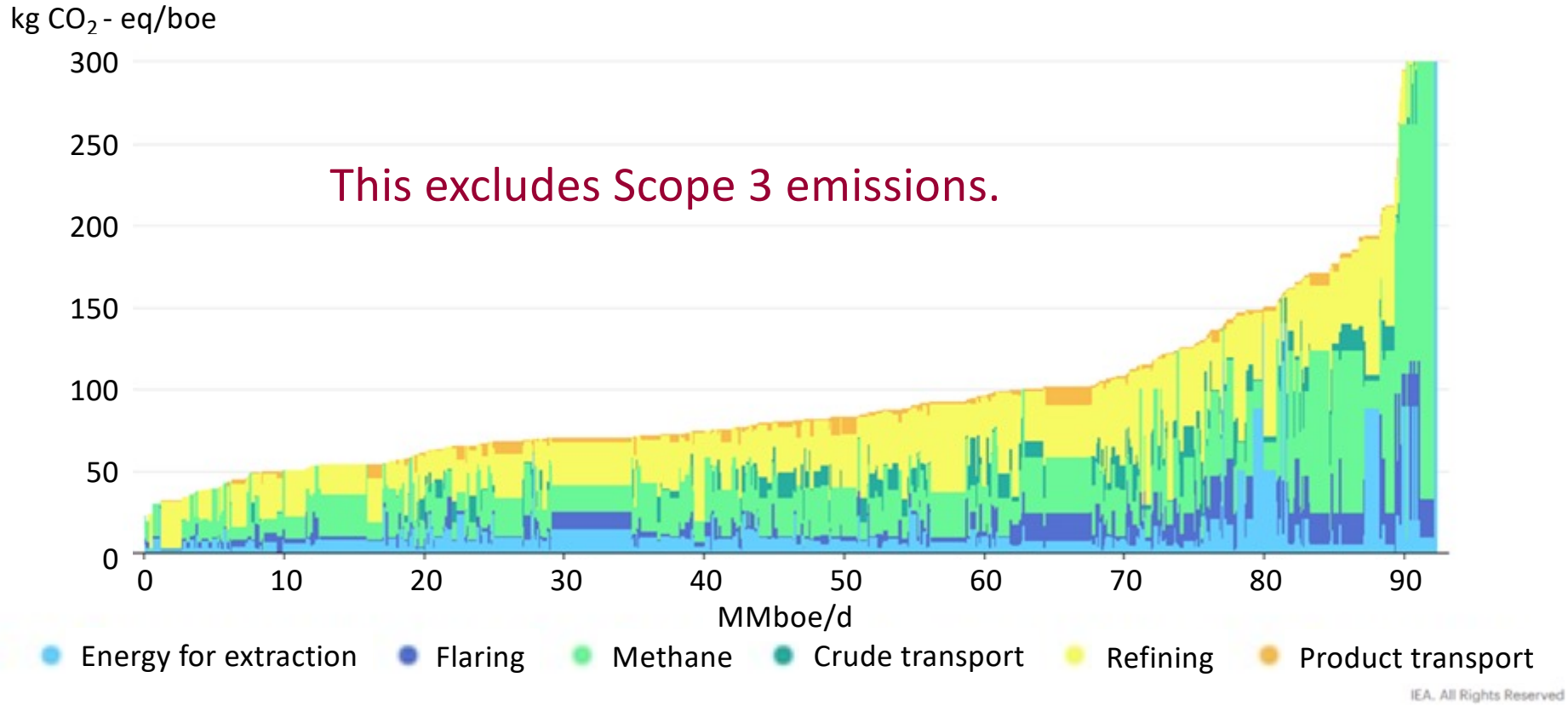
Life Cycle GHG Emissions from Crude Oil



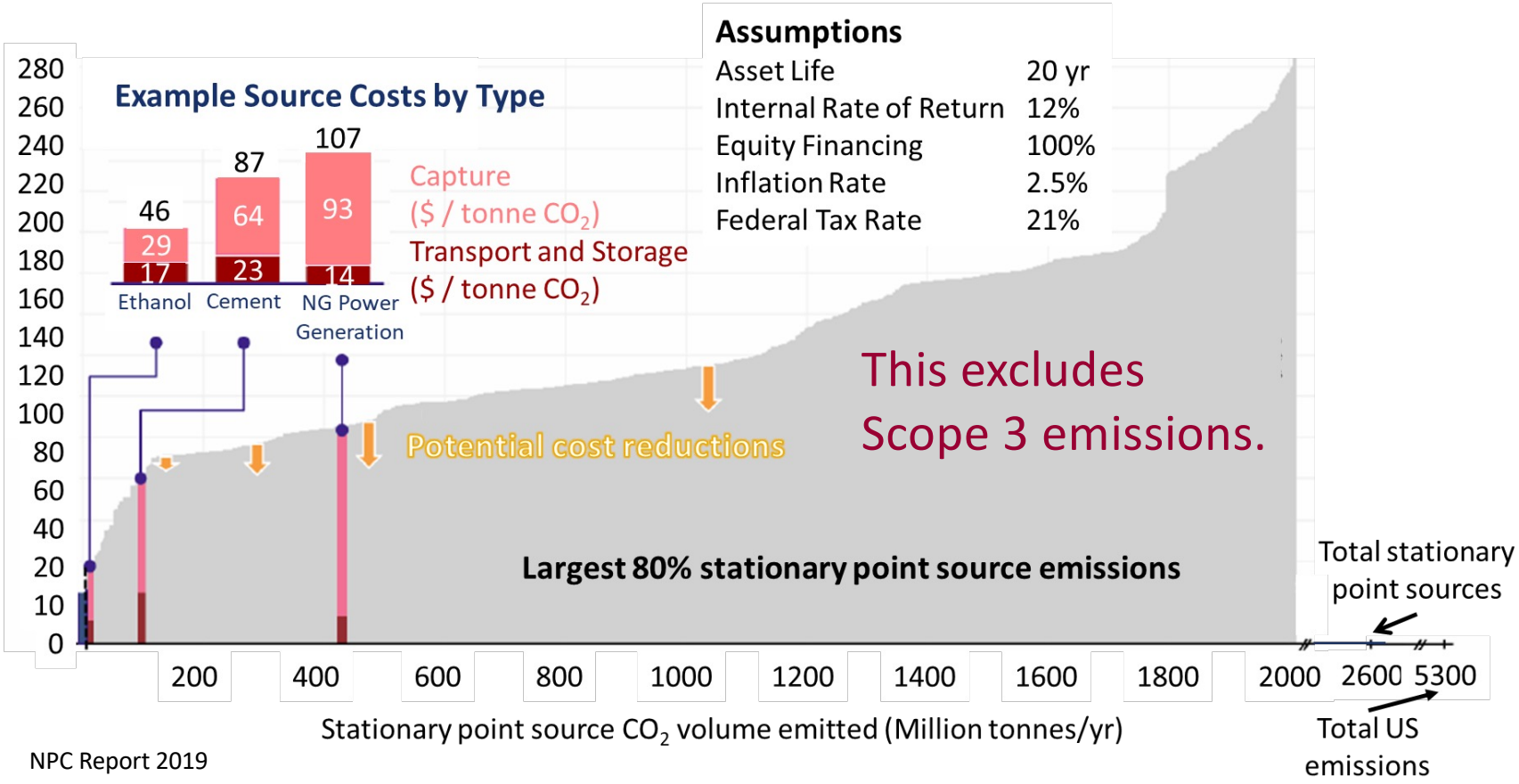
Forrest 2016

ARC Financial Corp.

Well to Tank Emissions Intensity



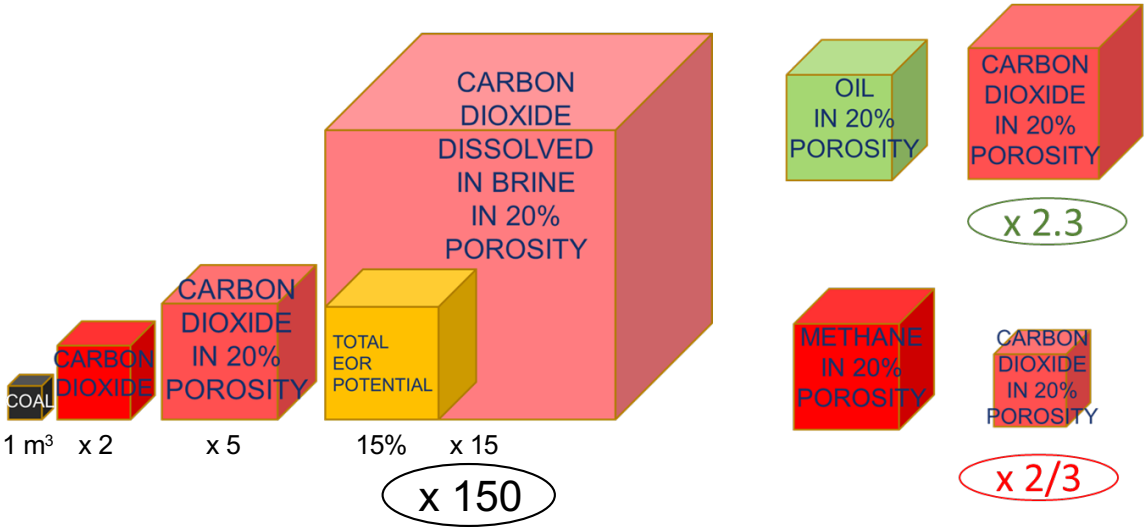
U.S. CCUS Costs in $/tonne CO_2



NPC Report 2019

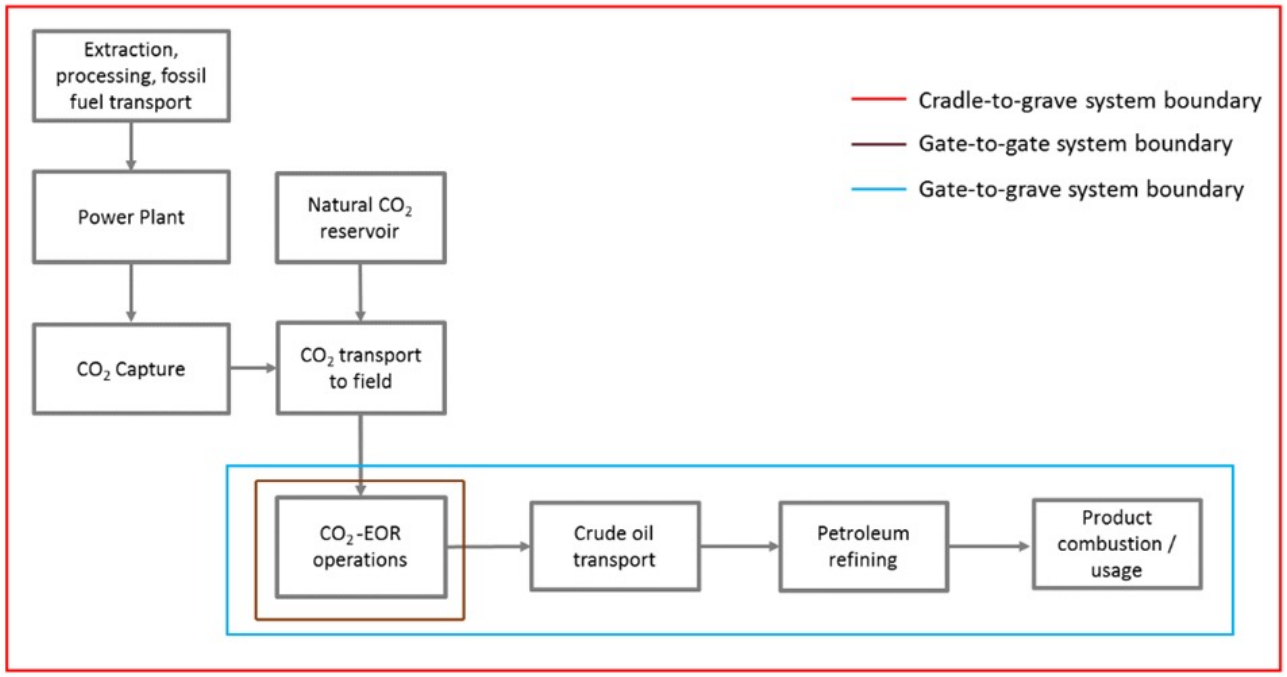
Carbon Capture Utilization and Storage (CCUS)

A Sobering Pore Space Reality



Confined Saline Aquifer Storage Capacity ($t\ CO_2/Ac\text{-}ft$)		
Storage Mode	Not pressurized	Pressurized
Primary	**~0**	**0.0014**
Secondary	**0.35**	

EOR+ LCA System Boundaries



Nuñez-López et al. 2019

EOR+ carbon neutrality depends on

- CO_2 source
- External impact

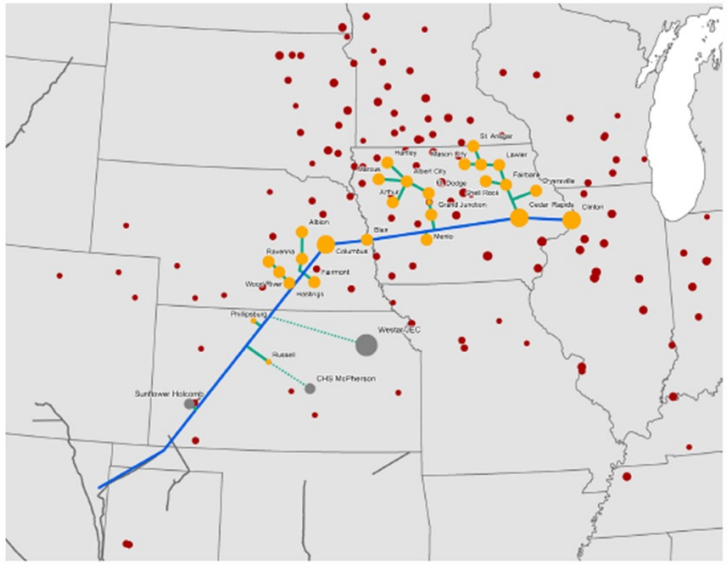
Difficult to achieve

Life Cycle Analysis (LCA)

Potential CNCO EOR+ Opportunity

CO_2 Capture from Ethanol Refineries

- ~ 40% carbon neutral CO_2
- May be cost competitive through incentives
  - 45 Q
  - California Low Carbon Fuel Standard



Ethanol Plants with Capture

Ethanol Plants without Capture

Ethanol plant production capacity by size of orange circle from 40 to 350 million gal/yr

CO_2 Trunk Pipeline

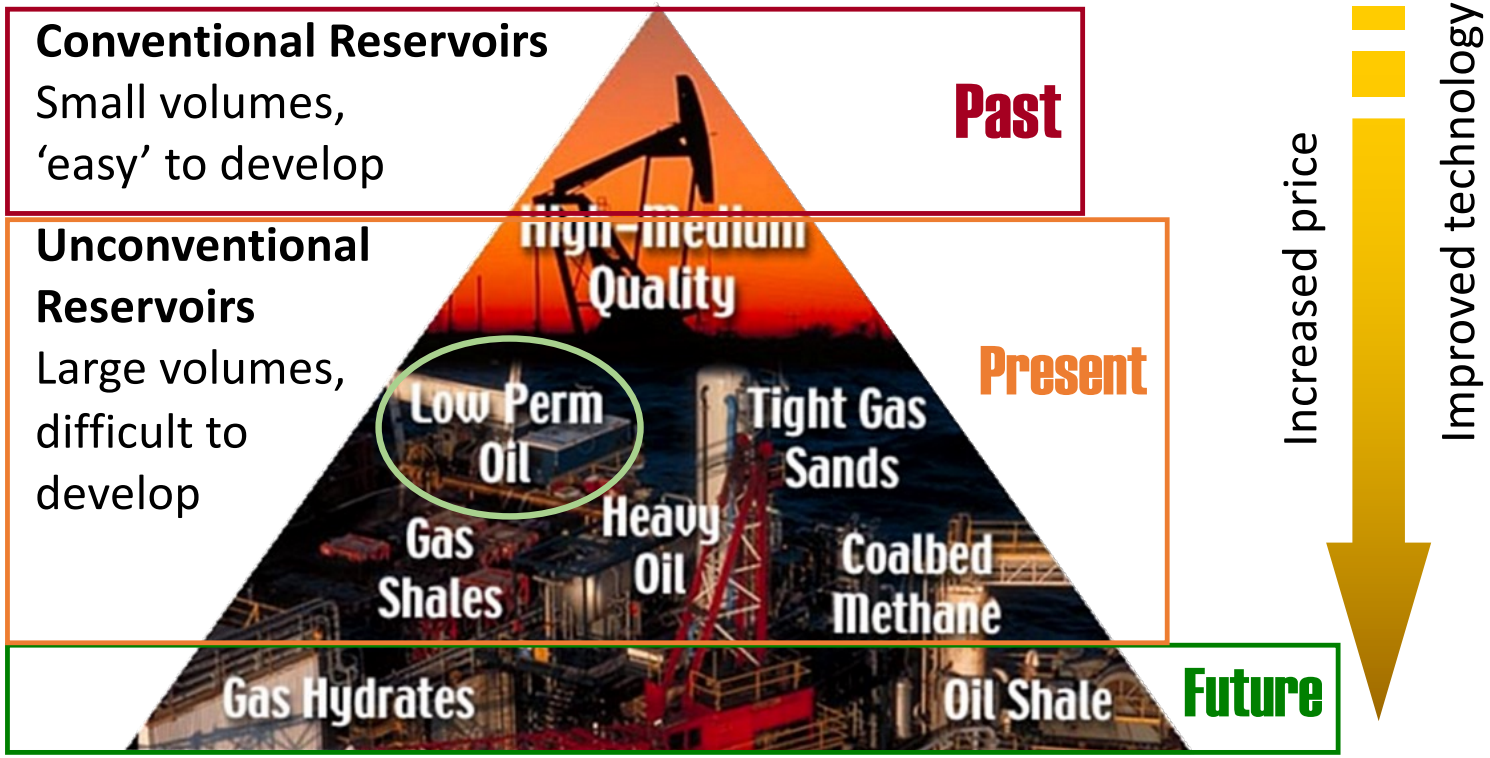
CO_2 Feeder Pipelines

Existing CO_2 Pipelines

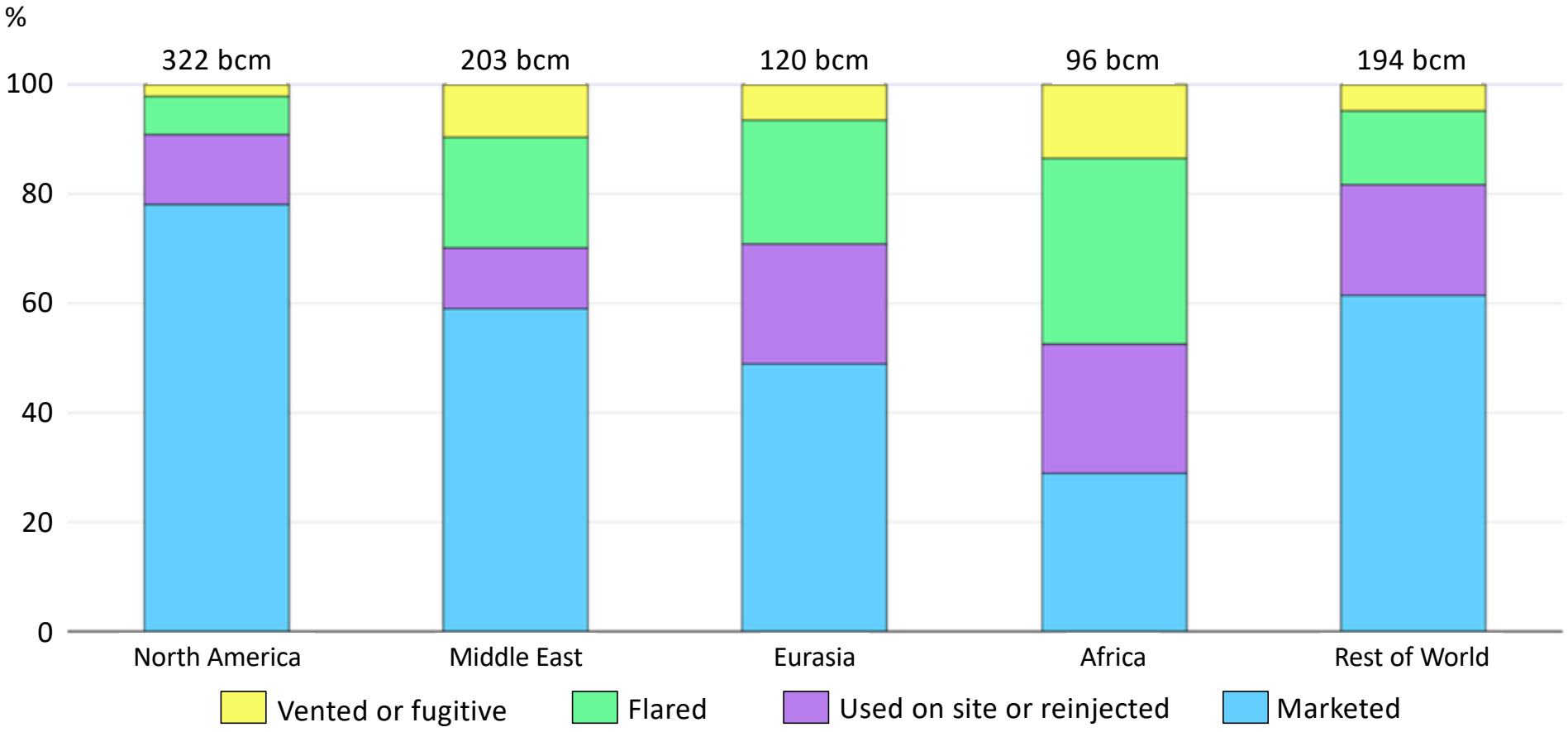
State CO2 – EOR Deployment Work Group

Carbon Neutral Crude Oil (CNCO)

Hydrocarbon Resource Triangle



Uses for Associated Gas



Source: IEA

Carbon Neutral Crude Oil (CNCO) Using Natural Gas-Powered Direct Air Capture (NG-DAC)

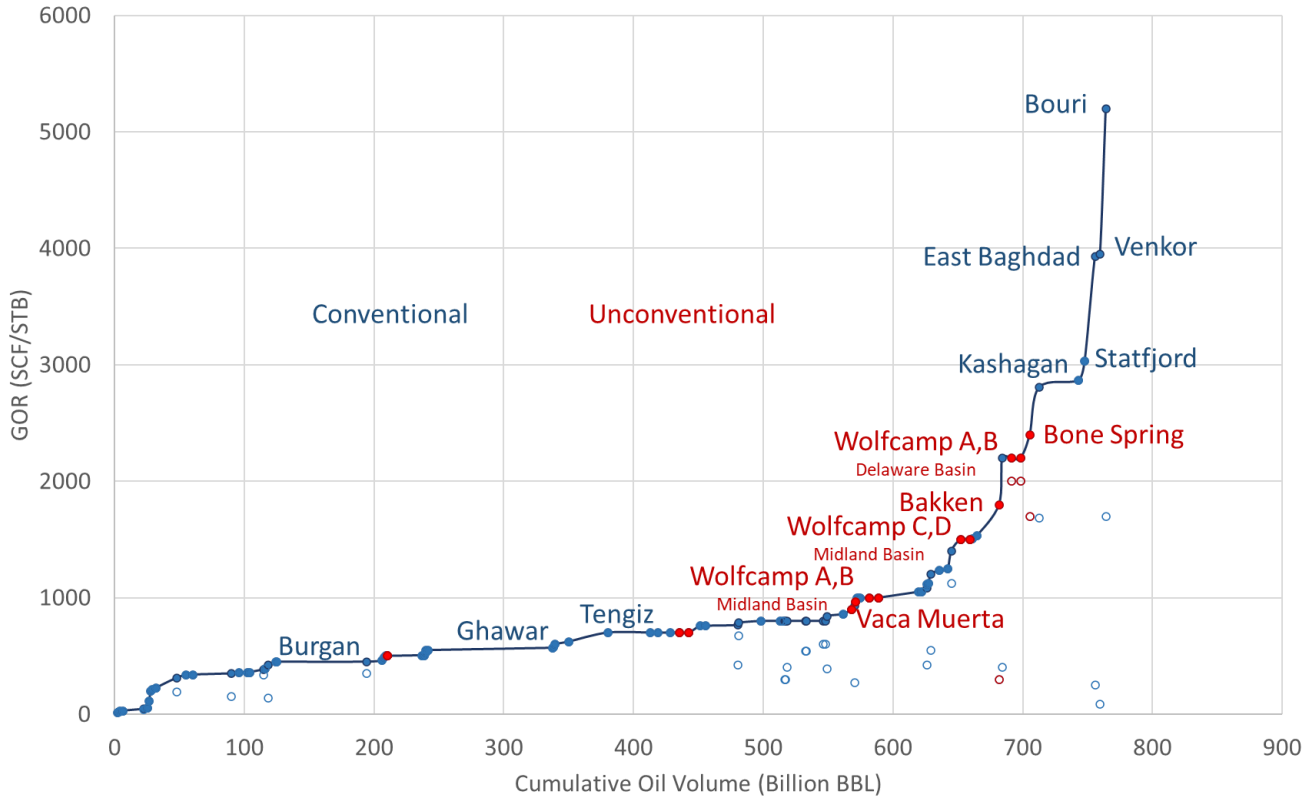
- Offsets Scope 3 CO_2 emissions from crude oil products using otherwise flared stranded associated gas
- Costs as low as \$58/ t CO_2 when using flared gas
- Costs less than many of the point source captures reported by the NPC
- More expensive than nature-based negative emission technologies, but
  - Much smaller land footprint
  - More verifiable
- Near breakeven cost through
  - 45 Q tax credit
  - Sale of captured CO_2 for EOR

Direct Air Capture (DAC) Unit

Keith et al. 2018

URTeC 5437

Solution Gas-Oil-Ratios for Large Fields and Plays



Tight oil has the advantage over big oil!

URTeC 5437

Carbon Neutral Crude Oil

- ↑ No change in downstream crude oil refining and products use
- ↑ New jobs requiring petroleum engineering expertise
- ↑ Avoids petrochemical products dilemma
- ↓ Does not avoid urban pollution from NO_x, SO_x, VOCs

Uses stranded associated gas from **light** crude oil

Carbon Neutral Fuel is

NOW

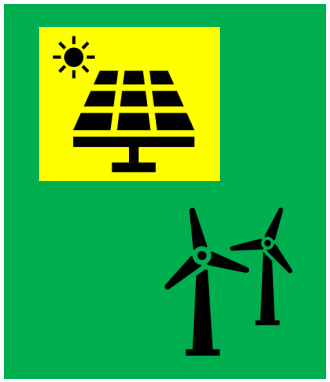
Highlights

- **Carbon Neutral Crude Oil (CNCO)**
- **Carbon Neutral Natural Gas**
  - **better known as Blue Hydrogen**

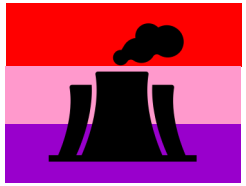
Many Colors of Hydrogen

Electrolysis

Renewable Energy

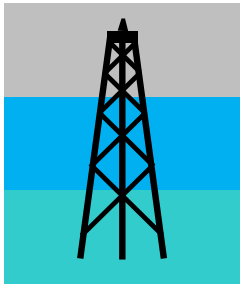


Nuclear Energy



Methane Reforming

Natural Gas



Without CCS

With CCS

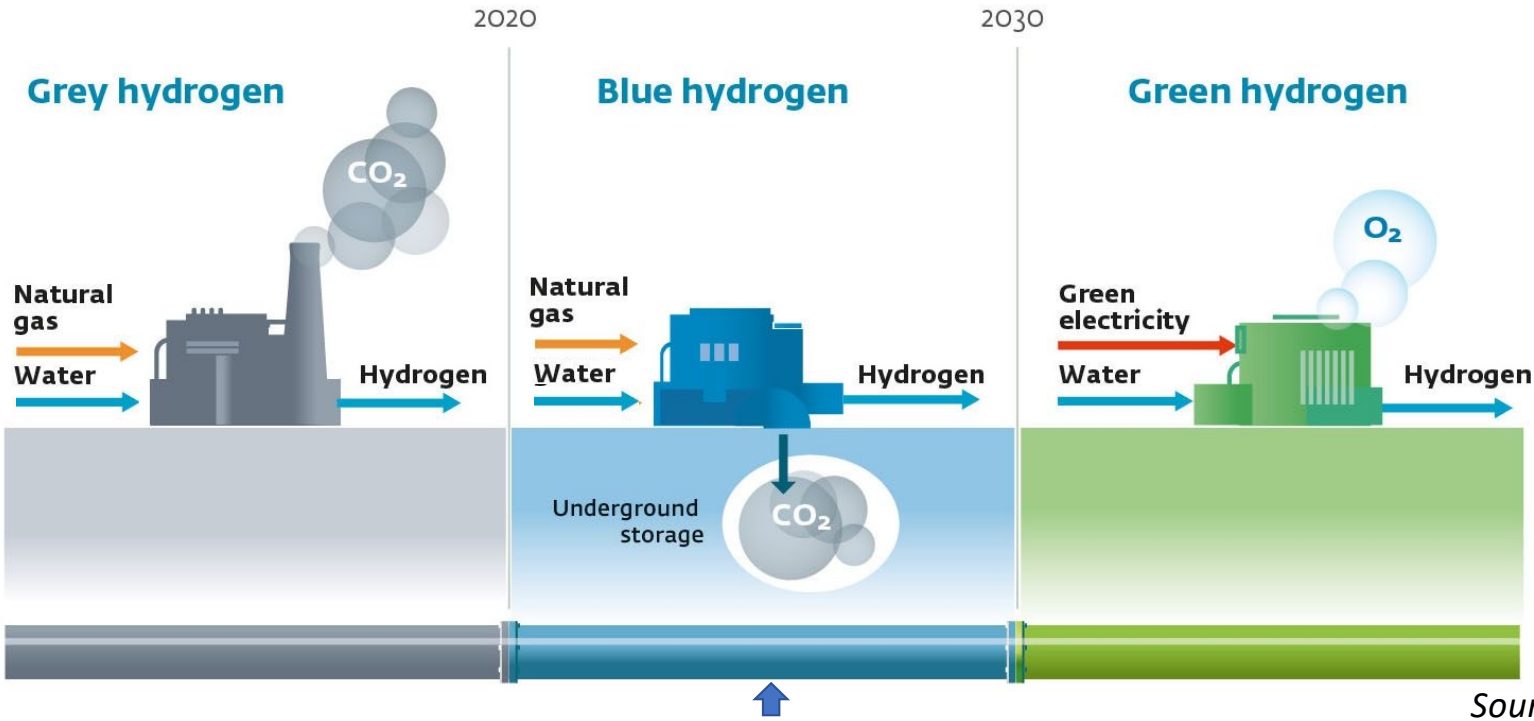
Produces Solid Carbon

Coal Gasification

Black Coal

Lignite Coal

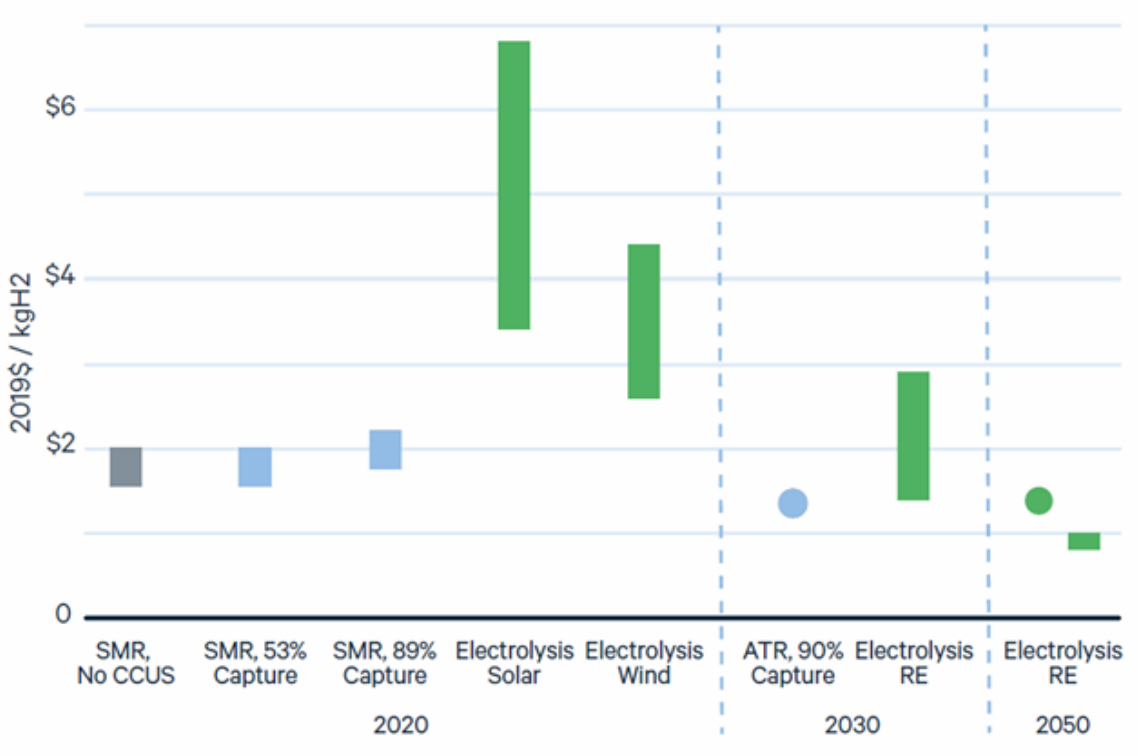
Carbon Neutral Blue Hydrogen



Source Gasunie

- Powers upstream production and reforming with produced blue hydrogen
- Requires half water needed for green hydrogen

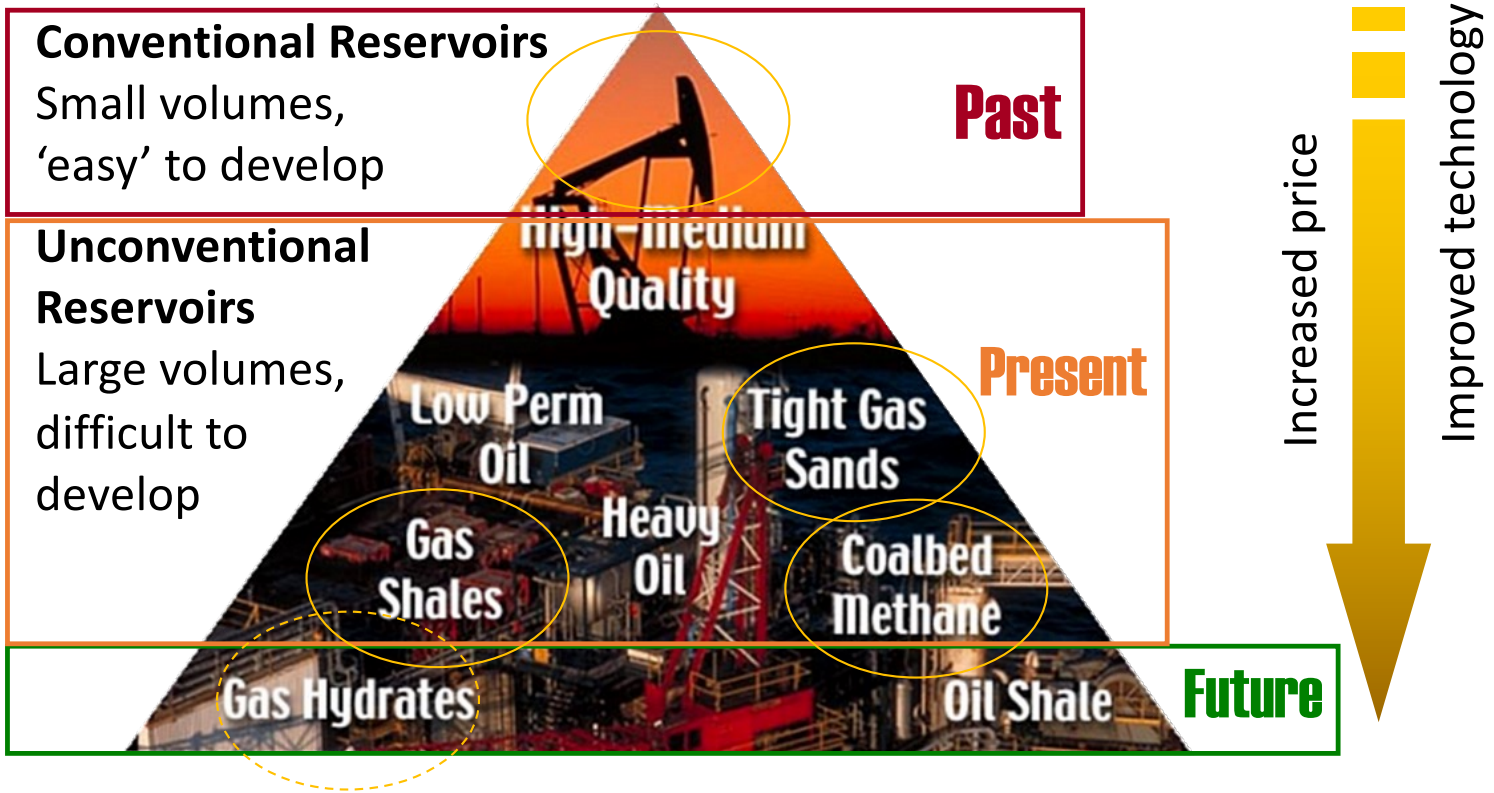
Hydrogen Generation Costs, 2019



$$ Blue H_2 << Green H_2 $$

Bartlett and Krupnick 2020

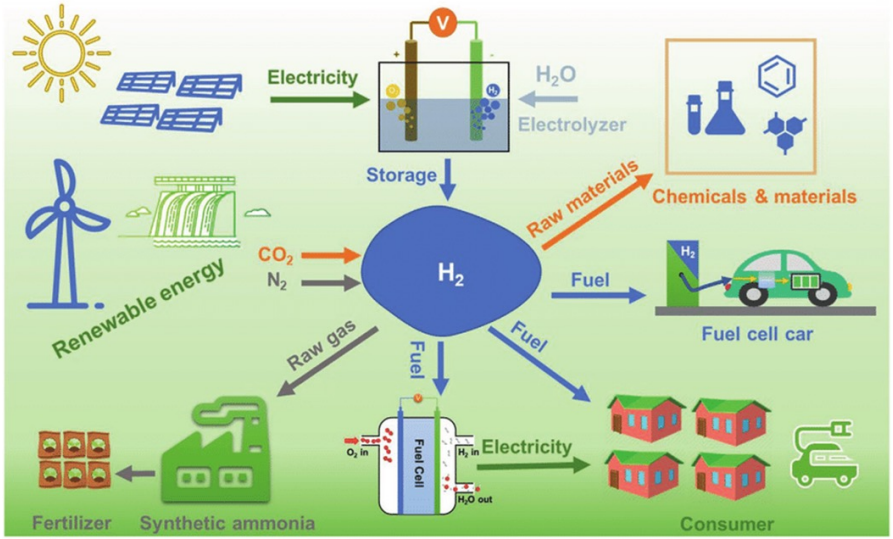
Hydrocarbon Resource Triangle



Hydrogen Economy without Fossil Energy

2003 Whitehouse press release

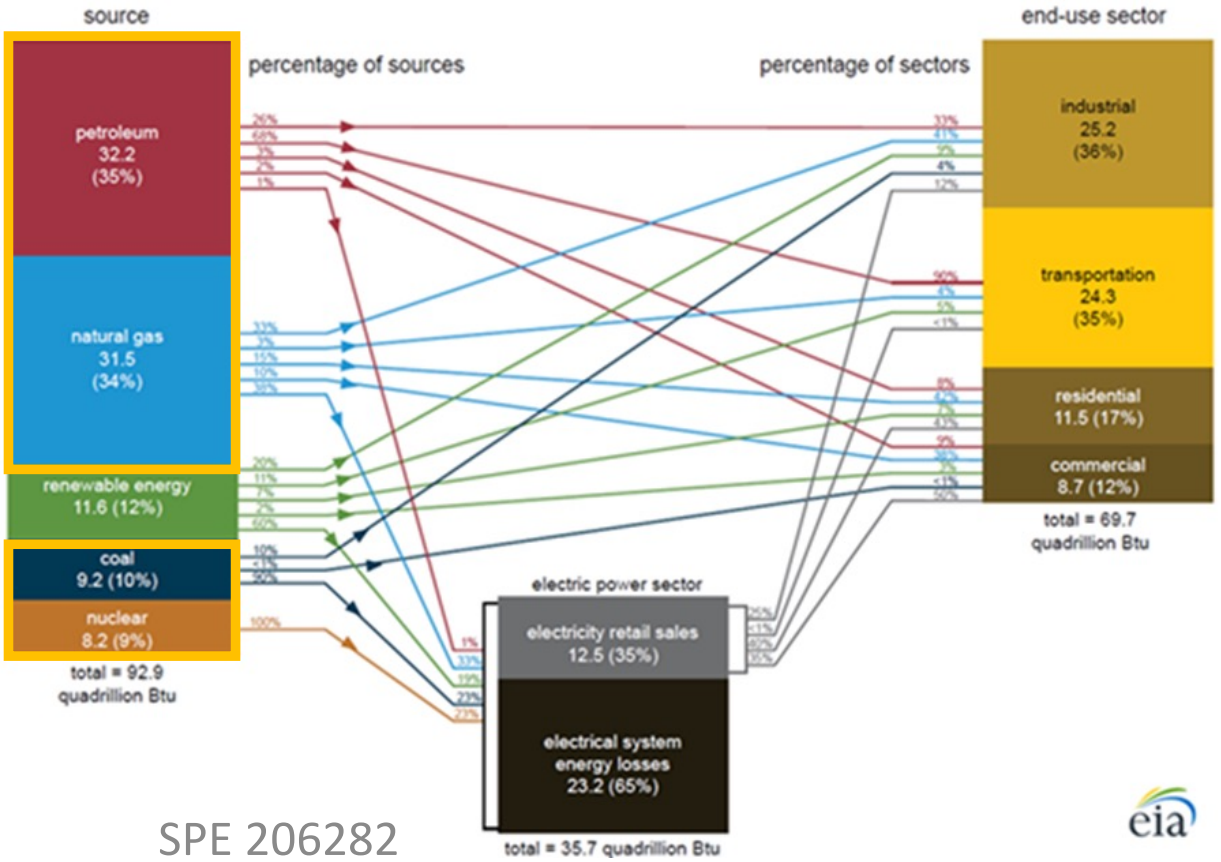
President Bush's $1.2 billion hydrogen fuel initiative aims to reverse America's growing dependence on foreign oil by accelerating the commercialization of hydrogen-powered fuel cells to power cars, trucks, homes and businesses with no pollution or greenhouse gases.



Through partnerships with the private sector, the hydrogen fuel initiative and FreedomCAR will make it practical and cost-effective for large numbers of Americans to choose to use clean, hydrogen fuel cell vehicles by 2020.

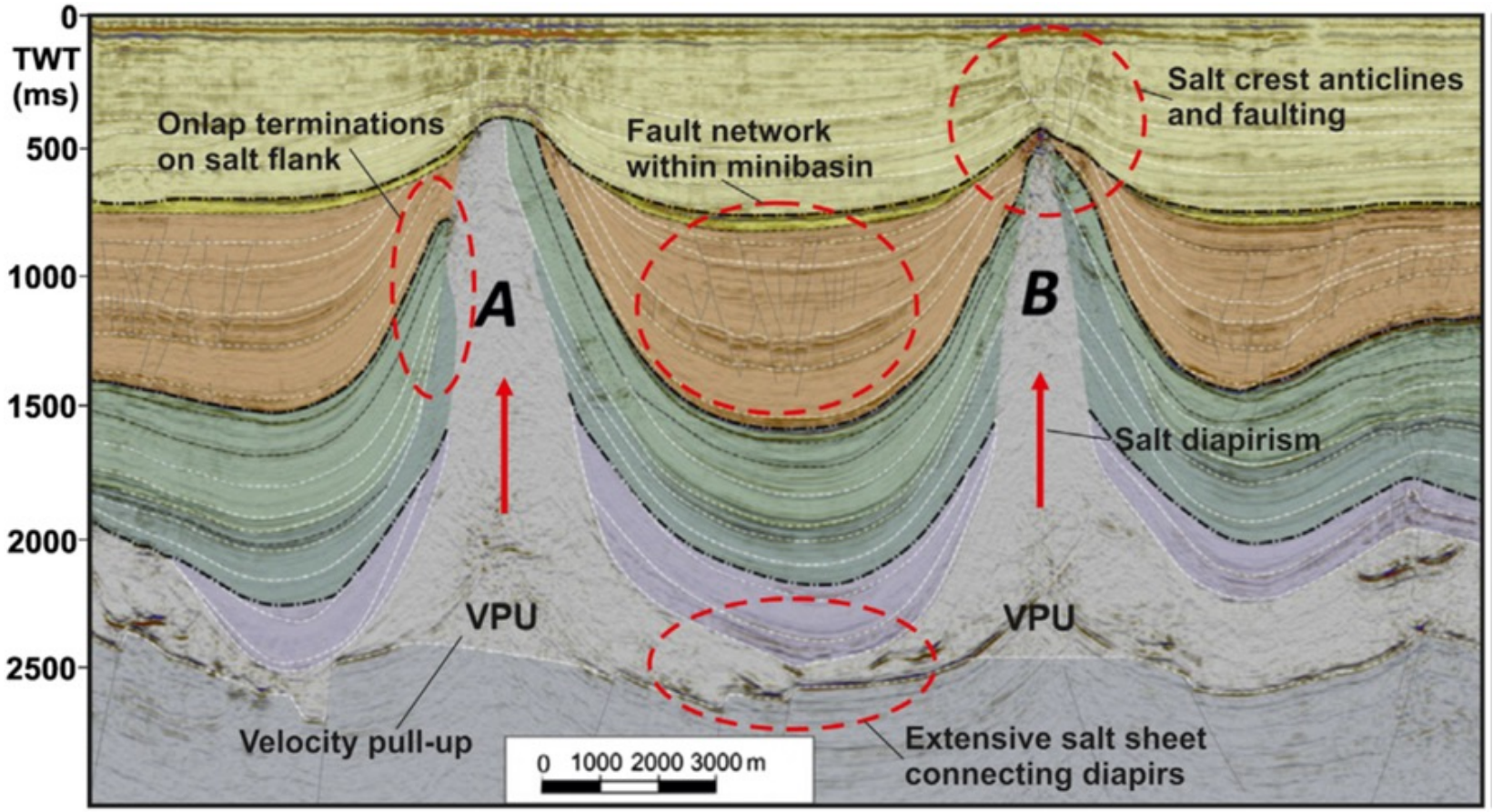
U.S. Energy Consumption by Source and Sector (Quads), 2020

2020 energy mix is still 88% nonrenewable.



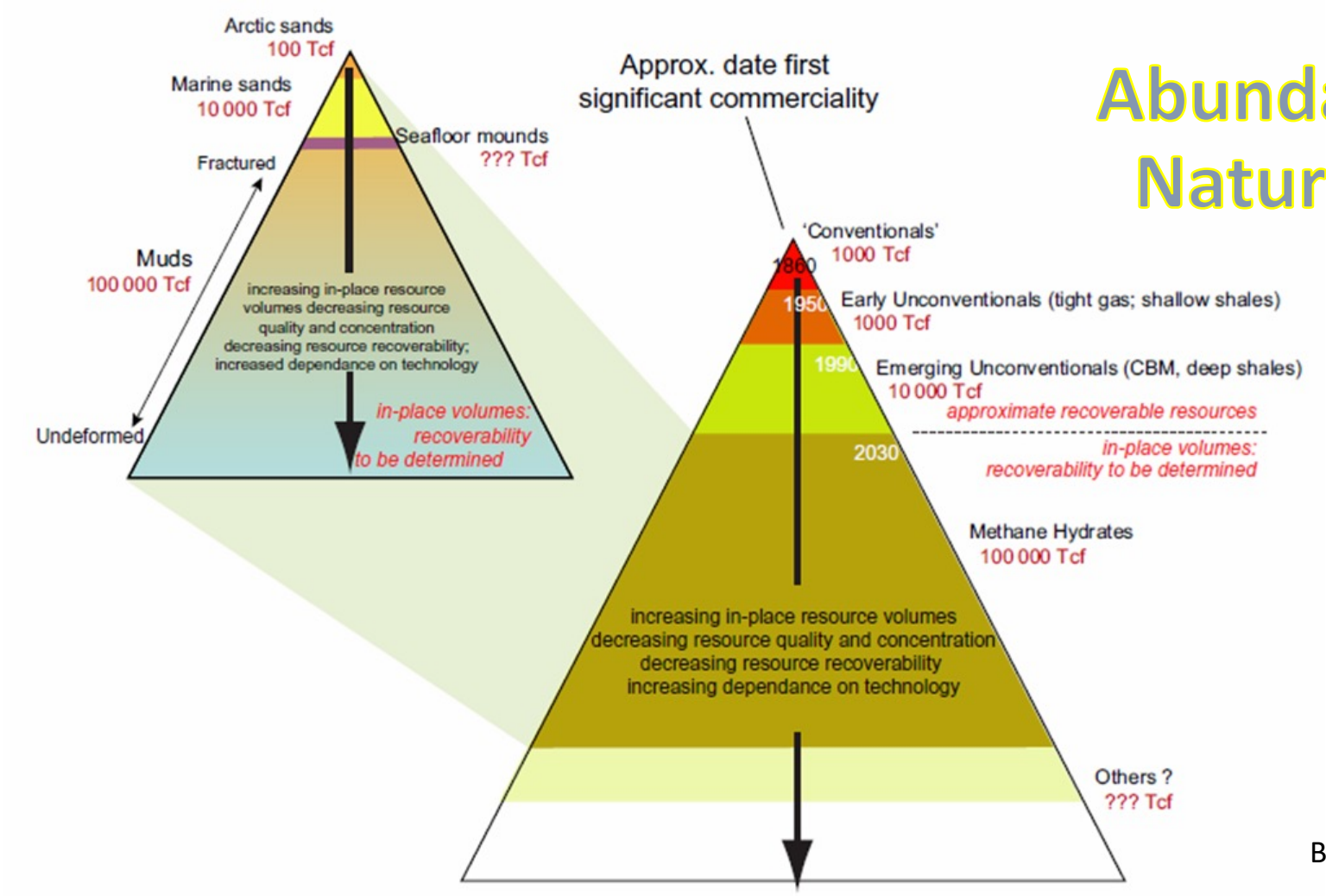
SPE 206282

Methane Production and CO_2 and H_2 Storage



Cox et al. 2020

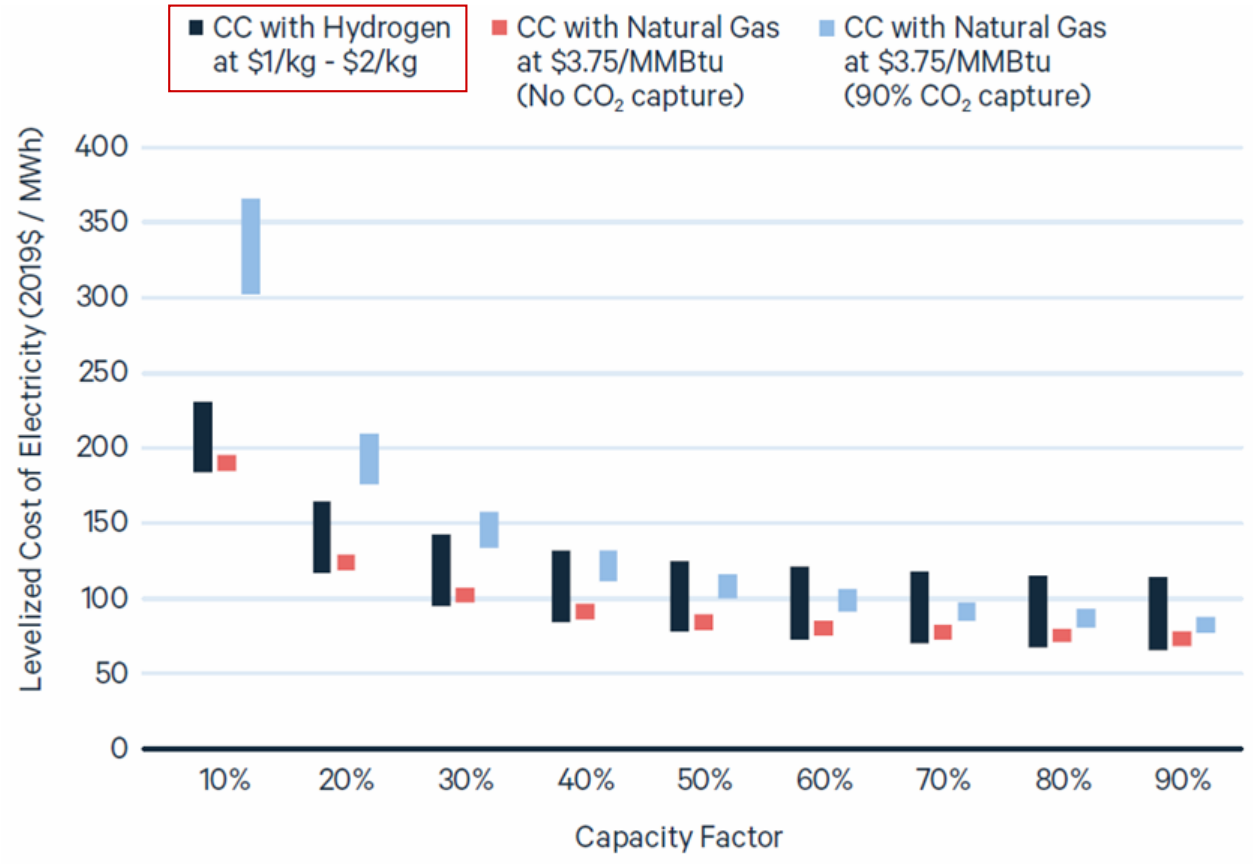
Abundance of Natural Gas



Boswell et al. 2013

Decarbonized Electricity from Natural Gas

Combined Cycle (CC) Electric Power Generation

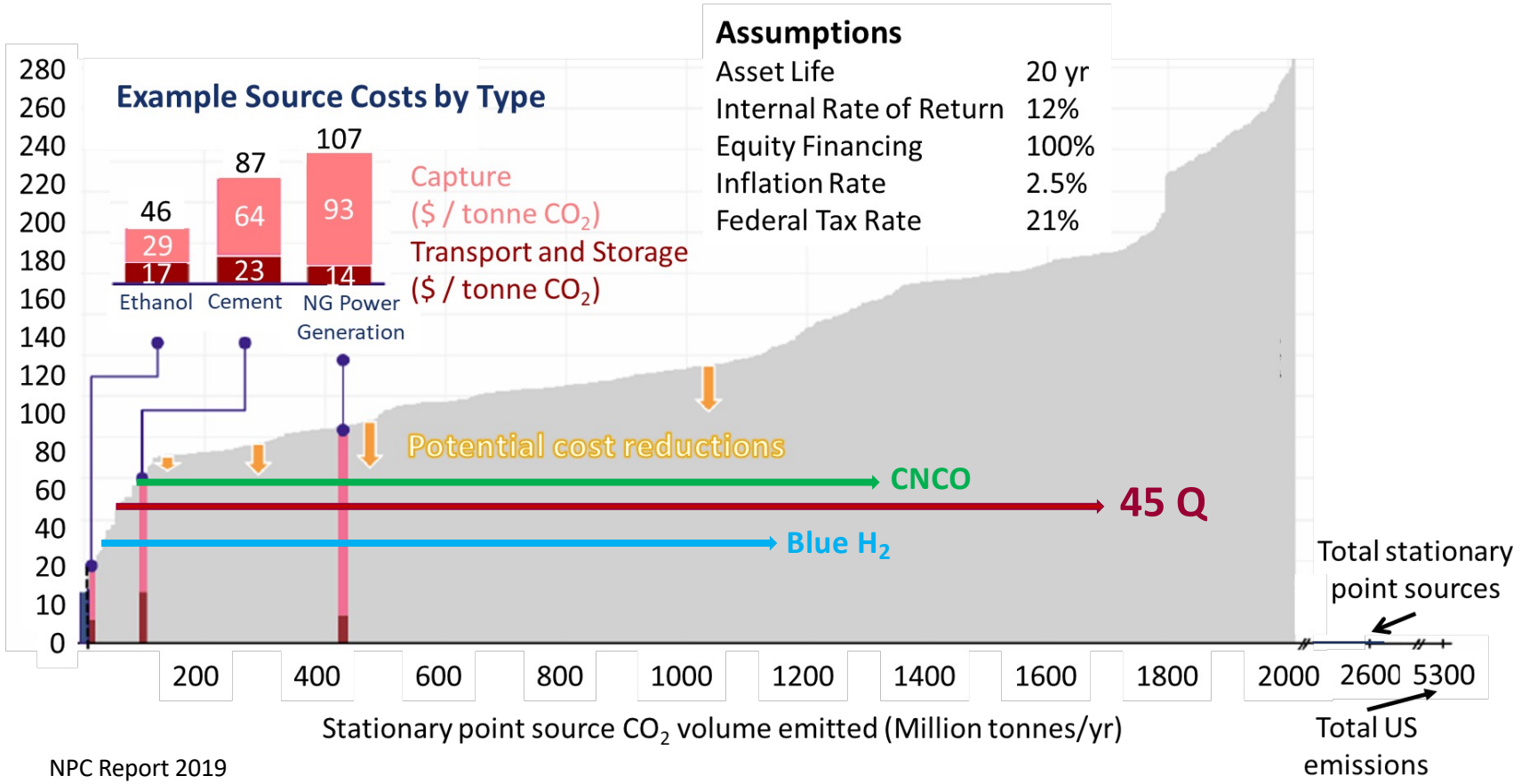


Blue H_2 is nearly competitive

NOW

Bartlett and Krupnick 2020

U.S. CCUS Costs by Point Source in $/tonne CO_2



NPC Report 2019

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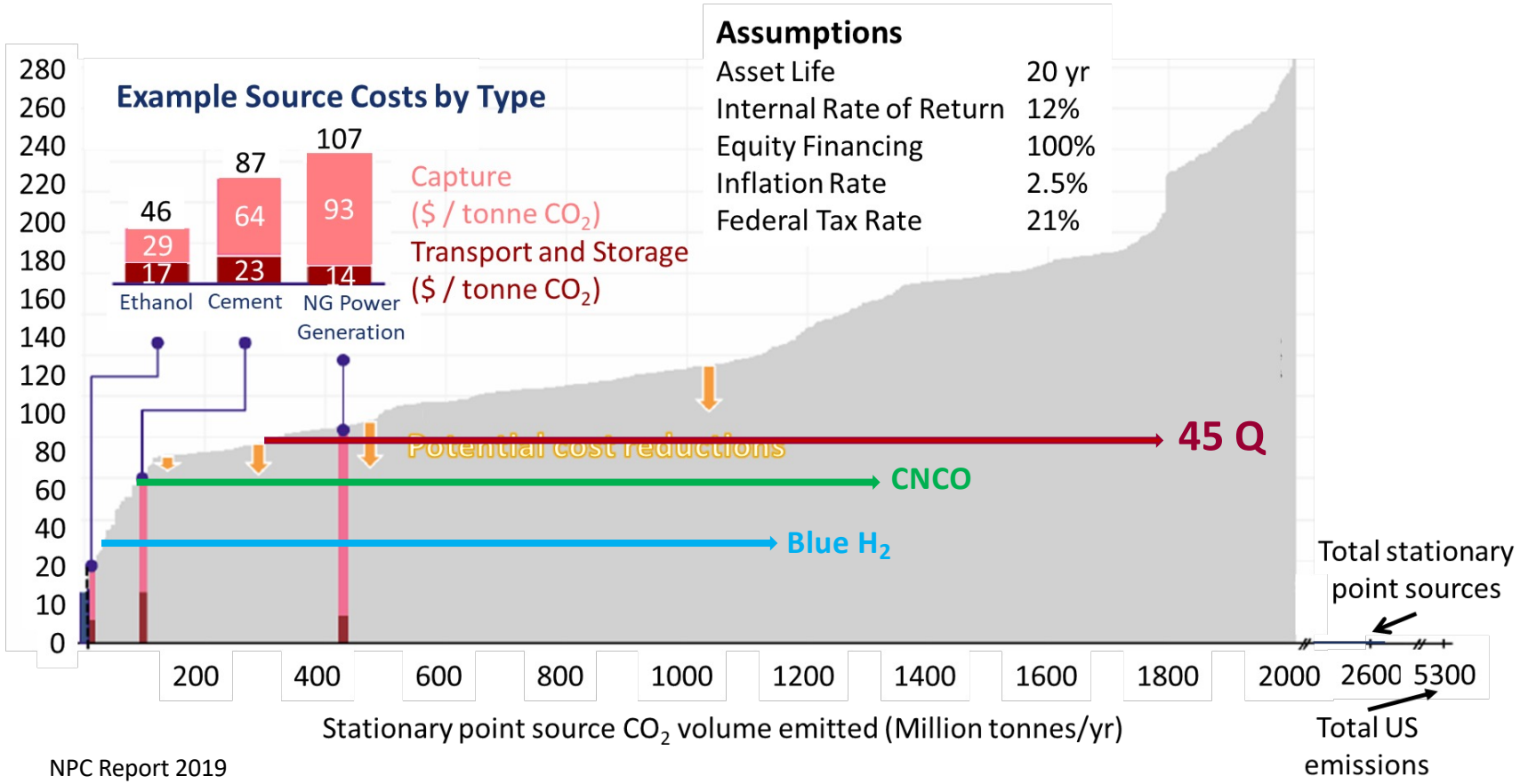


NPC Report 2019

Carbon Neutral Fuel – Blue H_2 is

NOW

Electric Vehicles (EVs)

Battery electric vehicle (BEV) charging

- 300 miles in ~20 minutes only with V3 supercharger
- 25 miles in 60 minutes with common Level 2 charger

Fuel cell electric vehicle (FCEV) refueling 300 miles in 5 minutes

No pollution from an EV

Cost Comparison (2/20/2023)

Hydrogen (per GGE)		Gasoline (per gallon)*			
Blue	Grid	Regular	Mid	Premium	Diesel
$2.77	$3.92	$2.895	$3.329	$3.701	$3.916

AAA 2022

GGE is gallon of gasoline equivalent

*Based on Retailers profit of $0.07/gal

Carbon Neutral (Blue) Hydrogen

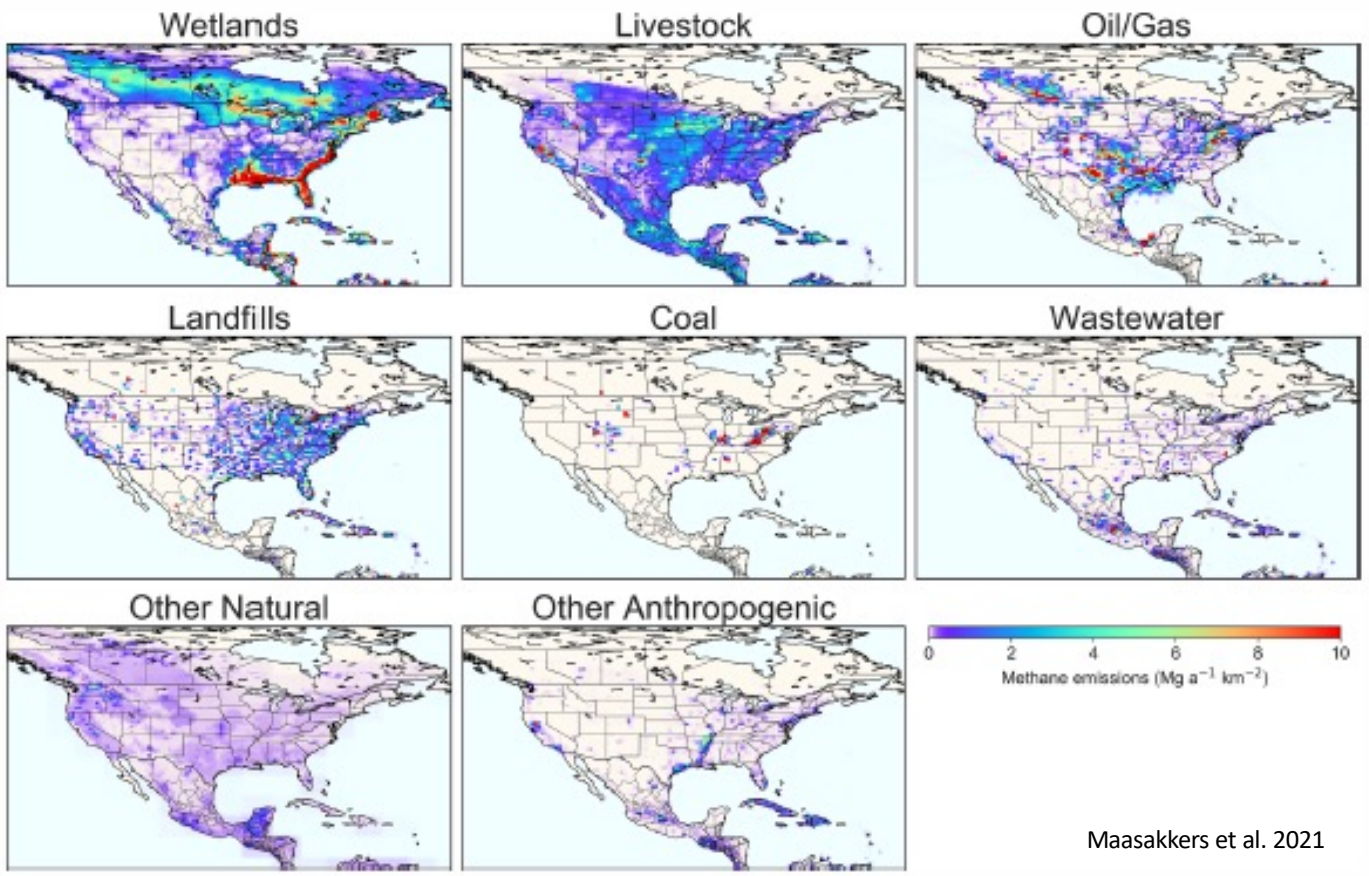
For transportation fuel

- ↑ Cost competitive with gasoline and diesel
- ↓ Requires new infrastructure
- ↑ Quick refueling
- ↑ No pollution
- ↑ Potential candidate for air and sea transportation

Cost competitive with decarbonized natural gas power generation for decarbonized power generation

- ↑ Less expensive than BAU for peaking power
- ↑ Avoids NO_x pollution

GOSAT Methane Emissions for 2010–2015



Maasakkers et al. 2021

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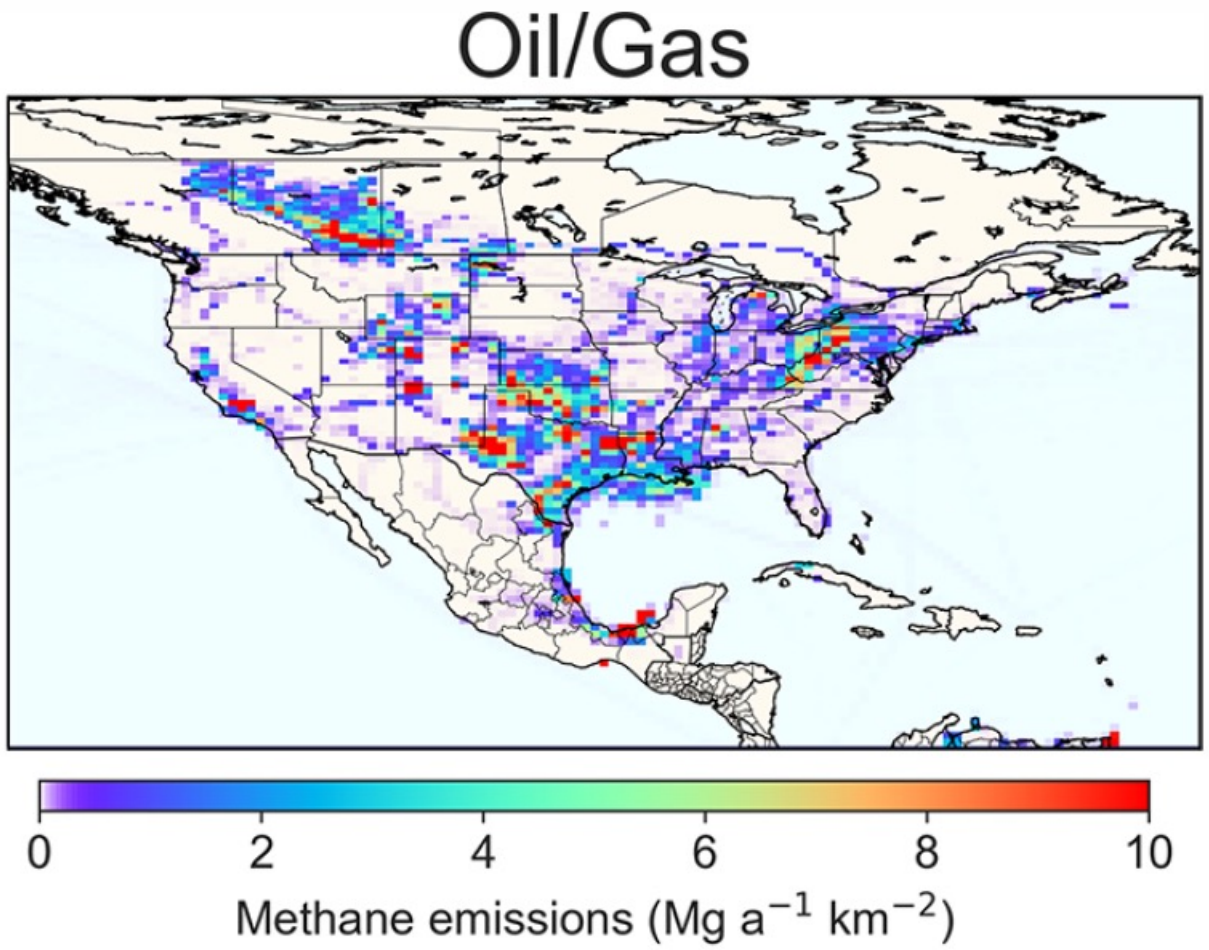

Maasakkers et al. 2021

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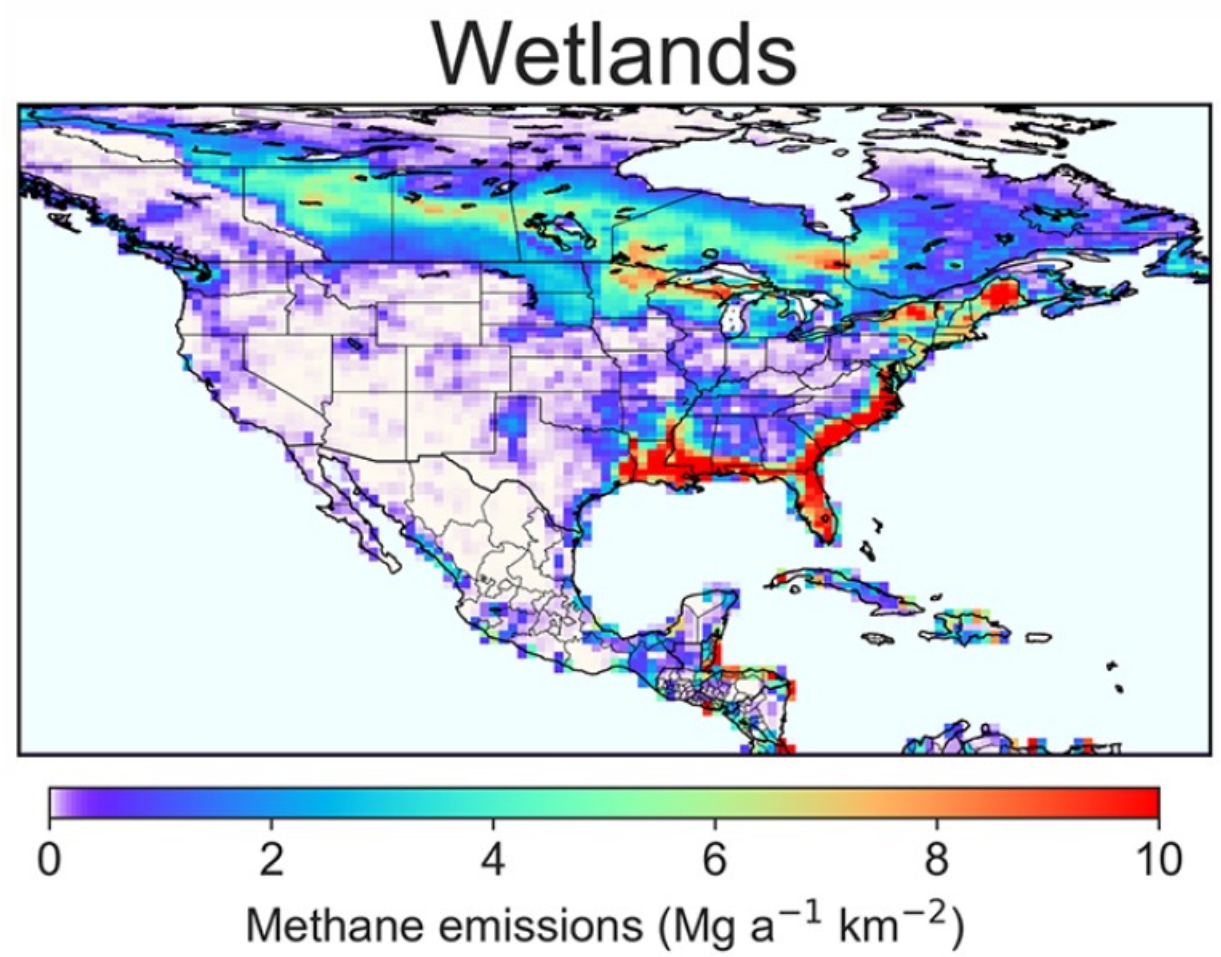
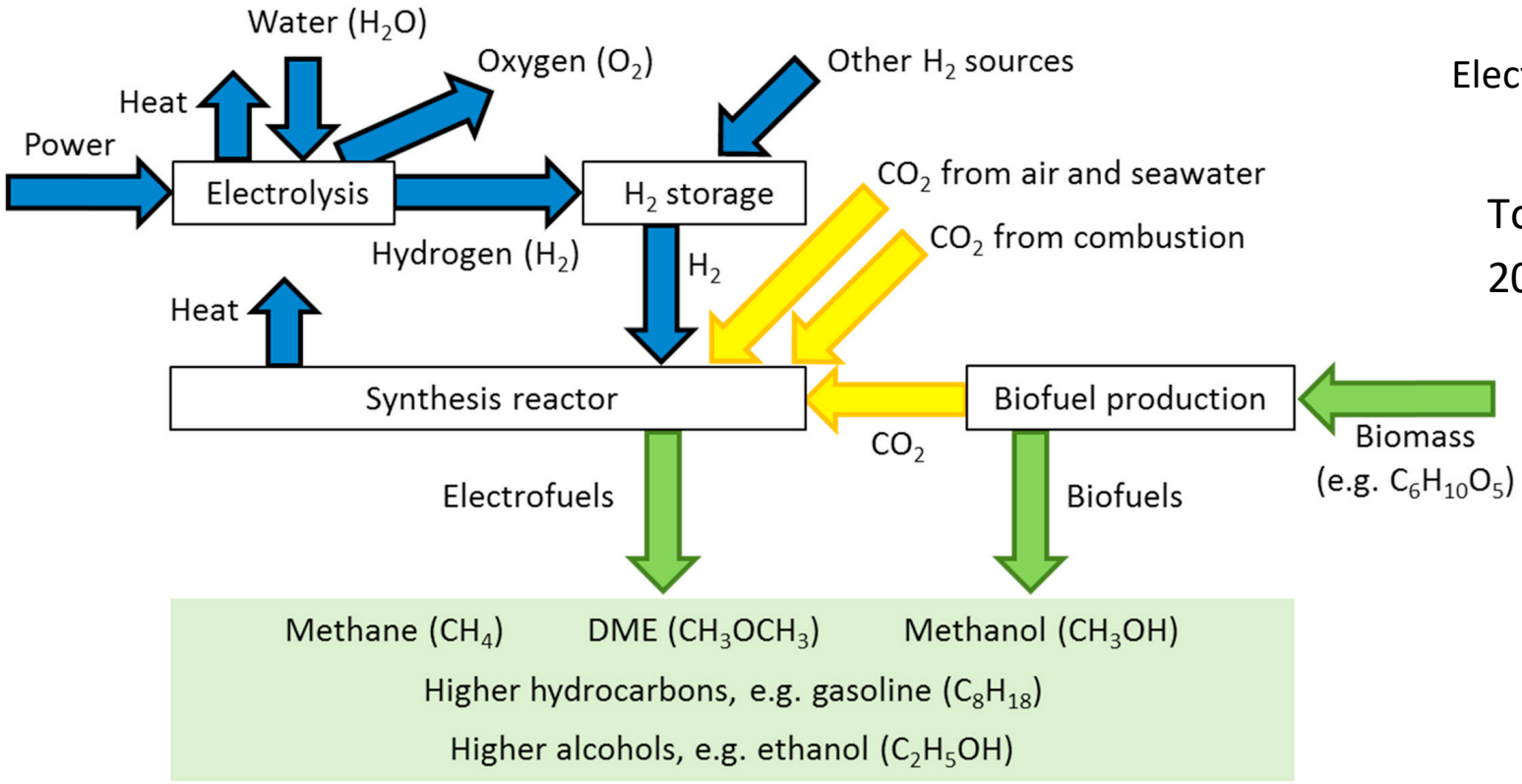


Maasakkers et al. 2021

Electrofuel (E-fuel)



Electrofuel Gasoline (MTG)

Cost range ($/gal)

Today 7.52 - 18.71

2030 5.29 - 17.49

Brynolf et al. 2017

Methanol to gasoline (MTG)

Electrofuel

- ⬆ Electrofuel process replaces crude oil refining
- ⬆ Minor changes in fuel distribution infrastructure
- ⬆ New jobs requiring petroleum engineering expertise
- ⬆ Avoids urban pollution from SO_x, VOCs
- ⬇ Does not avoid urban pollution from NO_x

Conclusions

- Using associated gas for CO_2 DAC turns flaring into a CNCO opportunity.
- The petroleum industry has technological leadership in all aspects related to blue hydrogen generation, supply, and use, and could lead the energy transition with a blue hydrogen economy.
- Electrofuel may also be cost competitive, but with different incentives.

SUBSURFACE CONSULTANTS

Training Course through Subsurface Consultants & Associates, LLC:

Carbon Capture Utilization and Storage – An Engineering Perspective

Upcoming Offering: November 06-08, 2023 in Houston, TX

https://scacompanies.com/training/course-listing/carbon-capture-utilization-and-storage-an-engineering-perspective/

Presentation References

Slide #	Reference
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Thank you – questions?

Thanks for your attention.

Christine Ehlig-Economides
University of Houston
ceconomides@uh.edu