BUREAU OF ENERGY AND
TECHNOLOGY POLICY

Slides for the morning and afternoon sessions are in separate decks. This is the **afternoon** deck.

November 4, 2022

# Alternative Fuels

Technical Session 6
CT 2022 Comprehensive Energy Strategy

**Session is being recorded**

# Today's Agenda – Morning

Slides for the morning session are in a separate deck

| | |
|---|---|
| General Introduction | 9:00-9:05 am |
| Topic Introduction | 9:05-9:30 am |
| Public Comments | 9:30-9:45 am |
| Overview of Alternative Fuels | 9:45-10:15 am |
| Q&A | 10:15-10:30 am |
| Benefits of Alternative Fuels | 10:30-11:45 am |
| Q&A | 11:45 am-12:00 pm |
| ---------------------------------LUNCH---------------------------------- | 12:00-1:00 pm |

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# Today's Agenda – Afternoon

Click on an agenda section heading to jump to the relevant slides

| | |
|---|---|
| Challenges with Alternative Fuels | 1:00-2:35 pm |
| Q&A | 2:35-2:50 pm |
| Alternative Fuels – Strategies for Optimal Use | 2:50-3:50 pm |
| Q&A | 3:50-4:05 pm |
| Public Comment | 4:05-4:20 pm |
| Wrap Up | 4:20-4:30 pm |

# Challenges of Alternative Fuels

Jeff Howard – Bureau of Energy & Technology Policy – CT DEEP

Dr. Tim Searchinger – Princeton University

Jaimeson Sinclair – Air Bureau – CT DEEP

Mike Henchen – RMI

Cara Bottorff – Sierra Club

Keegan Plaskon – American Bureau of Shipping (ABS)

Chase Whiting – Conservation Law Foundation (CFL)

(speaker order may vary)

BUREAU OF ENERGY AND
TECHNOLOGY POLICY

# Bureau of Energy & Technology Policy – CT DEEP

# Challenges of GHG accounting for biofuels

- Under international GHG accounting norms and EPA's GHG protocol, carbon emissions from combustion of biofuels are counted in jurisdiction where *feedstocks are grown*, rather than jurisdiction where *combustion occurs*
- These "biogenic emissions" are *noted* in inventory of jurisdiction where combustion occurs – but *do not materially influence inventory's carbon accounting*

# Challenges of GHG accounting for biofuels (continued)

This convention:

- Is being contested by prominent climate scientists as ill-founded, detrimental to integrity of GHG accounting, and harmful to global climate system
- In state inventories, puts biofuels accounting on “lifecycle” basis, in contrast with accounting for most other sources, which are counted at “point of emission”
- Encourages states to sanction use of biofuels whose carbon emissions are “externalized” onto accounts of other states
- Requires a leap of faith – Provides no assurance that any “upstream” state is actually accounting for these emissions
- Threatens to distort energy policies by encouraging importation of biofuels whose combustion does not affect the importing state’s GHG inventory

Connecticut’s inventory now follows this international convention; but DEEP intends to grapple with this issue in CES

# Another relevant challenge: Leaking fuel tanks

Majority (77%) of fuel oil releases are from homes rather than fuel terminals or commercial oil tanks

Over 80% of U.S. households heating with oil are in Northeast, and CT is $4^{th}$ highest consumer of residential heating oil -- About half of CT residences rely on fuel oil for heat

DEEP receives releases of heating oil per month

Many residences rely on private water supply wells, which can be contaminated by releases of oil

Average cost of responding to and remediating a residential release of heating oil is ~$7,400 per incident

- Releases with significant environmental impacts can have costs as high as $198,000
- DEEP has over $600,000 in expenditures this year alone in oil spill remediation

# Princeton University

# Bioenergy

**Tim Searchinger, Princeton University,**

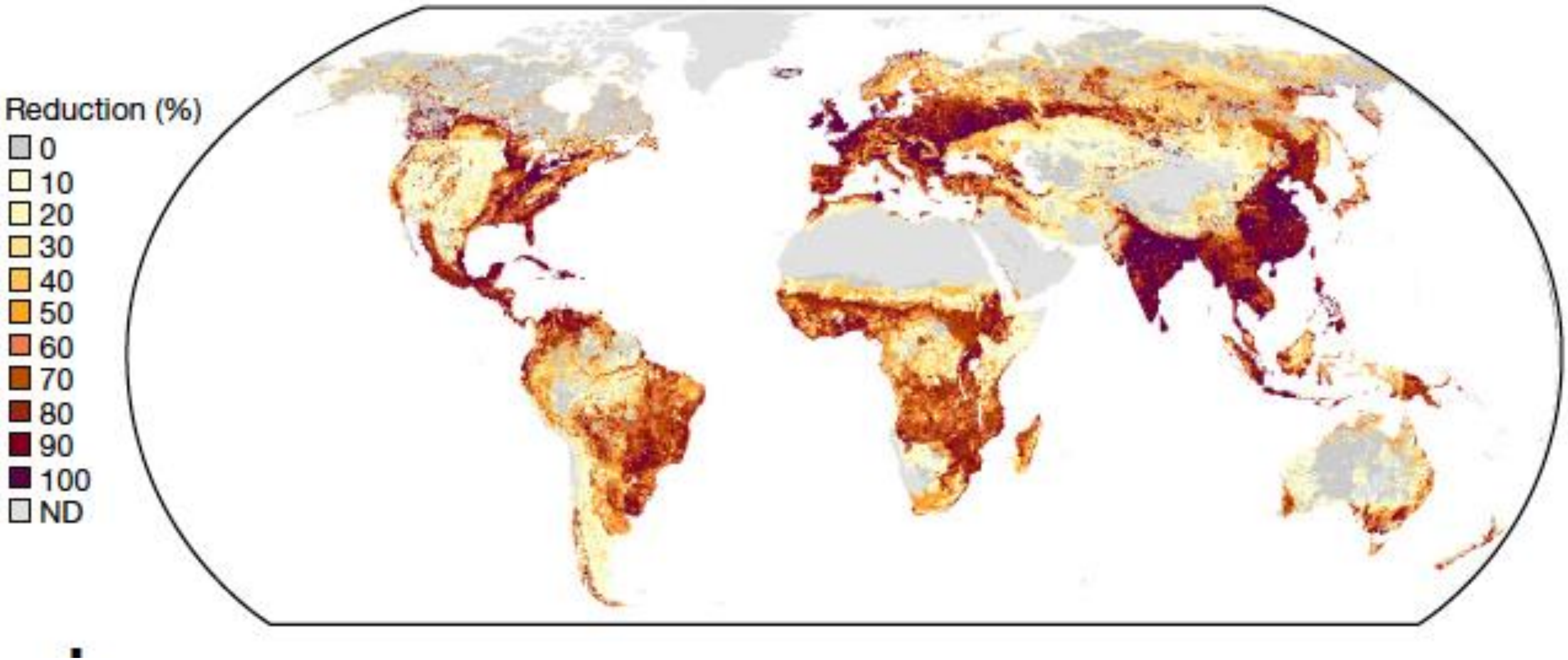
**Senior Fellow & Technical Director Food Program, World Resources Institute**

**2022**

**(tsearchi@princeton.edu)**

**(202) 465-2074**

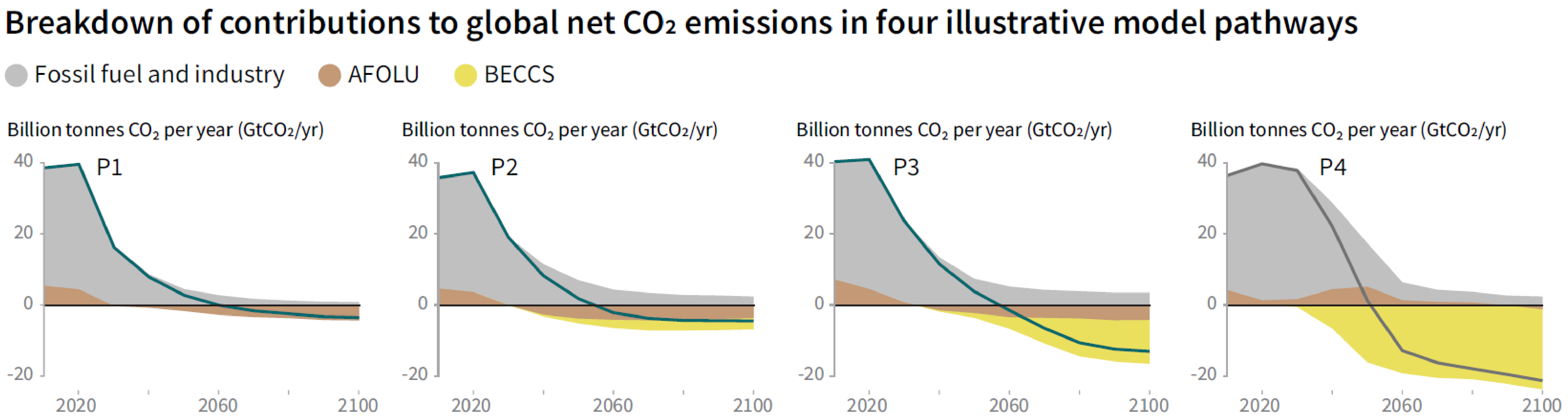
# Land Use Change ~20-25% Carbon in Atmosphere




K-H Erb *et al.* *Nature* **553,** 73–76 (2018) doi:10.1038/nature25138

# Ongoing Land Use Change ~10% of Emissions

# Climate Strategies Require No Additional Land Use Change

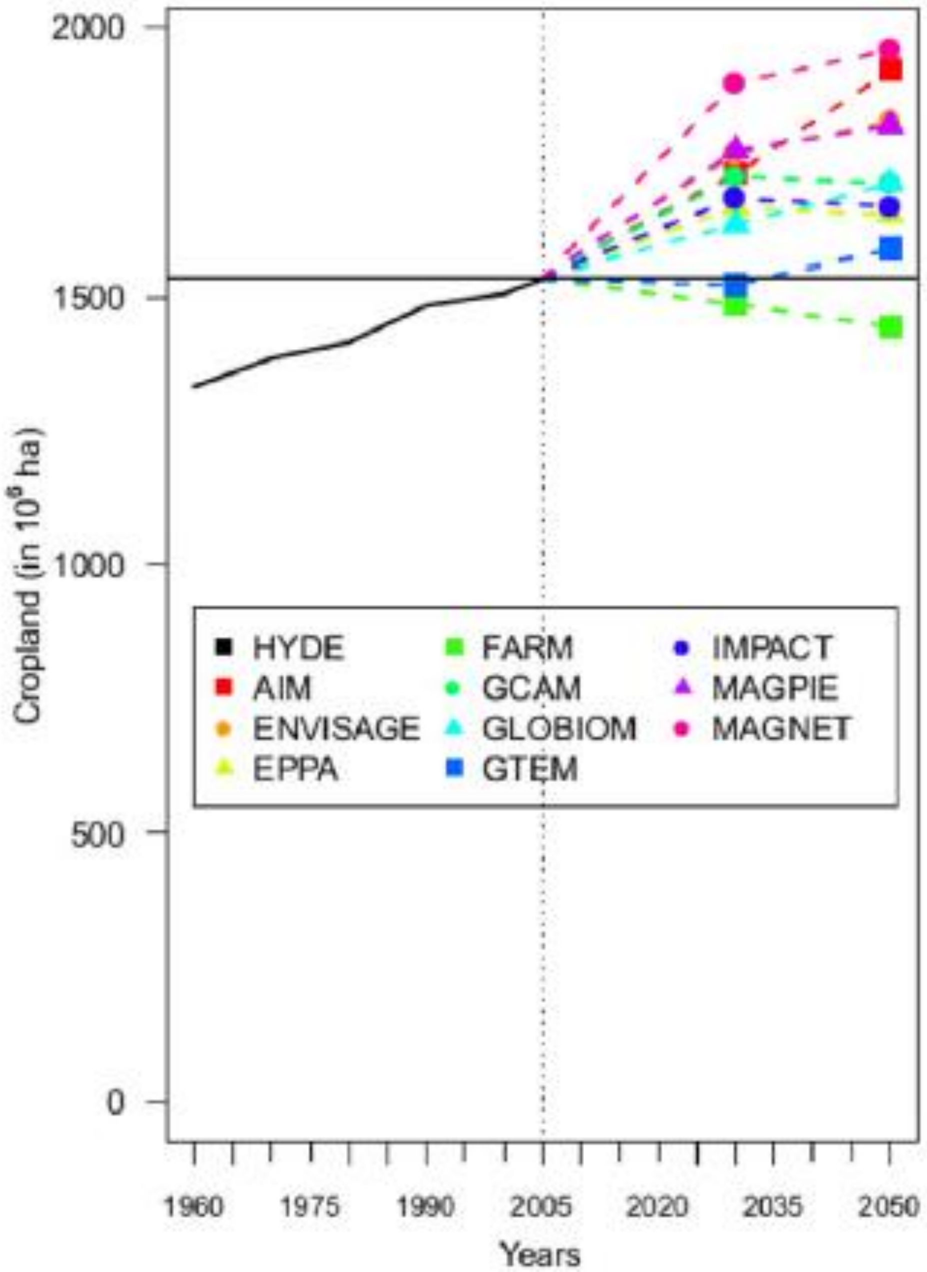



IPCC, 2018

# Global land use demands by 2050 relative to 2010 (without more bioenergy)

- >50 more crops
- ~70% more livestock products
- ~50% more wood
- ~100 million hectares of urban land

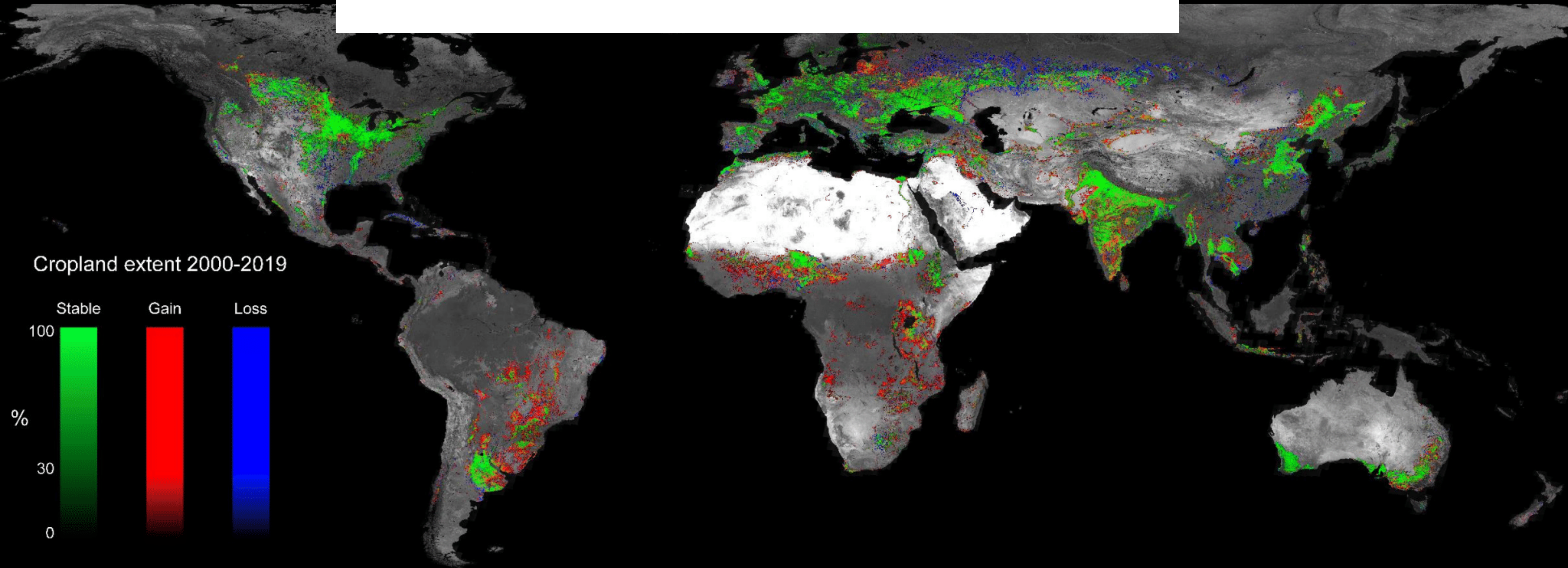
# Nearly all studies project more cropland for food by 2050




C. Schmitz et al. Agricultural Economics 45 (2014) 69–84

# Cropland now expanding ~11 Mha/year 2011-2019

*Rate would convert 1.5x India 2010-2050*

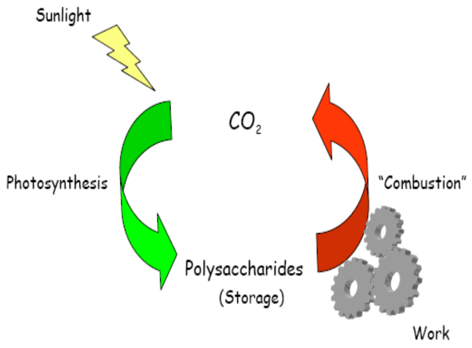


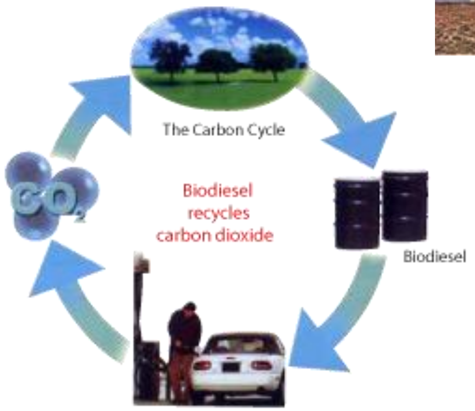

Potapov et al., *Nature Food* (2022)– 10 MHA net arable expansion
+ FAO – probably 2 Mha permanent cropland

(Slide courtesy of Matt Hanson, GLAD, UMD)

# Both biomass and fossil fuel combustion emit carbon dioxide, Potential Savings Come from Plant Uptake

Combustion of biomass provides carbon neutral energy




Source: Biodiesel Association of Australia

# Carbon neutral means land is “free”

| Source of fuel* | Producing Feedstock (crude oil or crop) | Refining | Tailpipe Emis-sions | Ferment-ation emissions | Total GHGs & % Increase for Biofuel *Without Plant Credit* | Credit for Plant Growth | Total GHGs & % Savings for Biofuel |
|---|---|---|---|---|---|---|---|
| **Gasoline** | +4.5 | +8 | +73.3 | - | 85.8 | - | **85.8** |
| ***EU Ethanol*** | *+40* | *+21.2* | ~~*+71.4*~~ | ~~*+35.7*~~ | *168.3 (+96%)* | ~~*107.1*~~ | ***+61.2 (-29%)*** |

Lifecycle Analysis Grain-Based Ethanol - $CO_2$ eqv. per mega joule of fuel

Source: European Joint Research Center – Grain Ethanol

**Benefit: Use land to produce plants to displace fossil emissions**

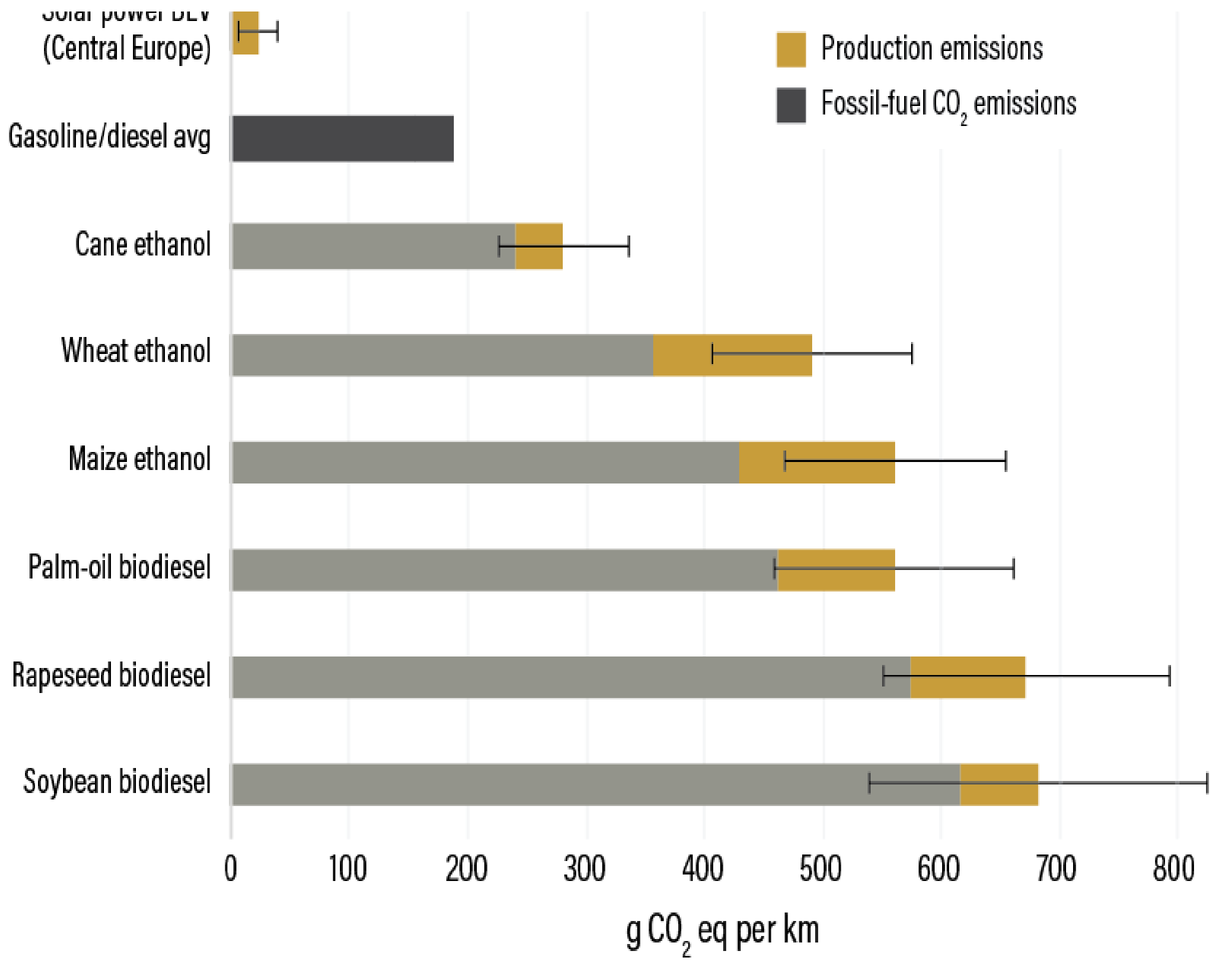
but

**Cost: Not using land for some other purpose**

# Land Costs v. Benefits of (Optimistic) Biofuels

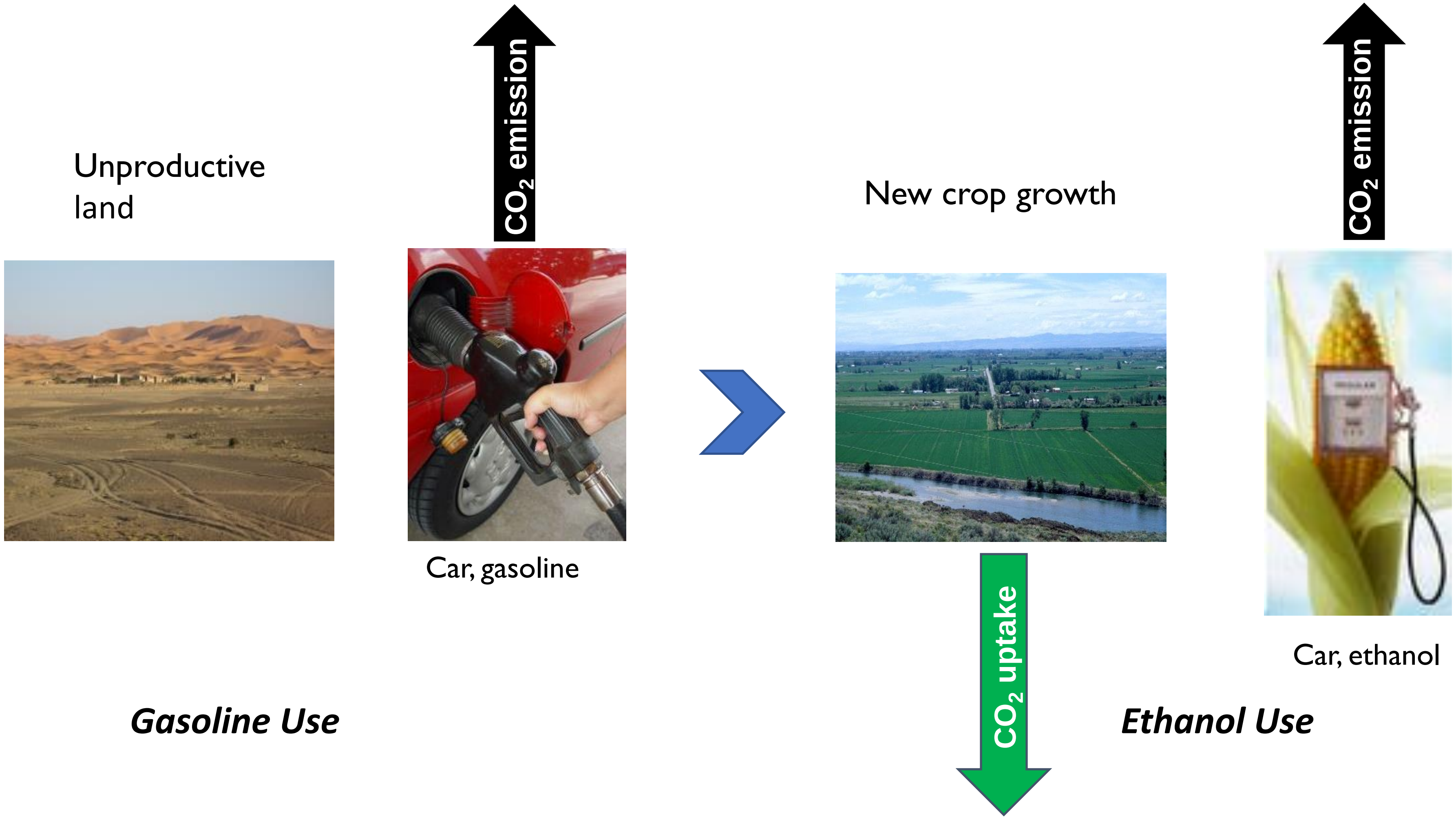
| Alternative Use of Land | Land cost of biofuels (tC/ha/y) | Benefit of biofuels (tC/h/y) (very high cellulosic ethanol yield & replaces fossil fuels) |
|---|---|---|
| Tropical seasonal forest (Gibbs et al. 2008) | ~6.6 | ~3 |
| Humid tropical savanna (Gibbs et al. 2008) | ~3.5 | ~3 |
| Existing temperate forests (conservative) | ~6-~8 tons | ~3 |
| "Surplus" land | ~3 | ~3 |

# Counting average carbon lost to produce the crops, ethanol & biodiesel have 2-3 times higher emissions than gasoline/diesel




Searchinger et al. *Nature* (2018)

## **Effect of switching from gasoline to biofuels grown on otherwise unproductive land –** Reduced atmospheric $CO_2$ through increased plant growth



**Using otherwise burned or decomposed crop residues for biofuels -** Reduced emissions through reduced land sources

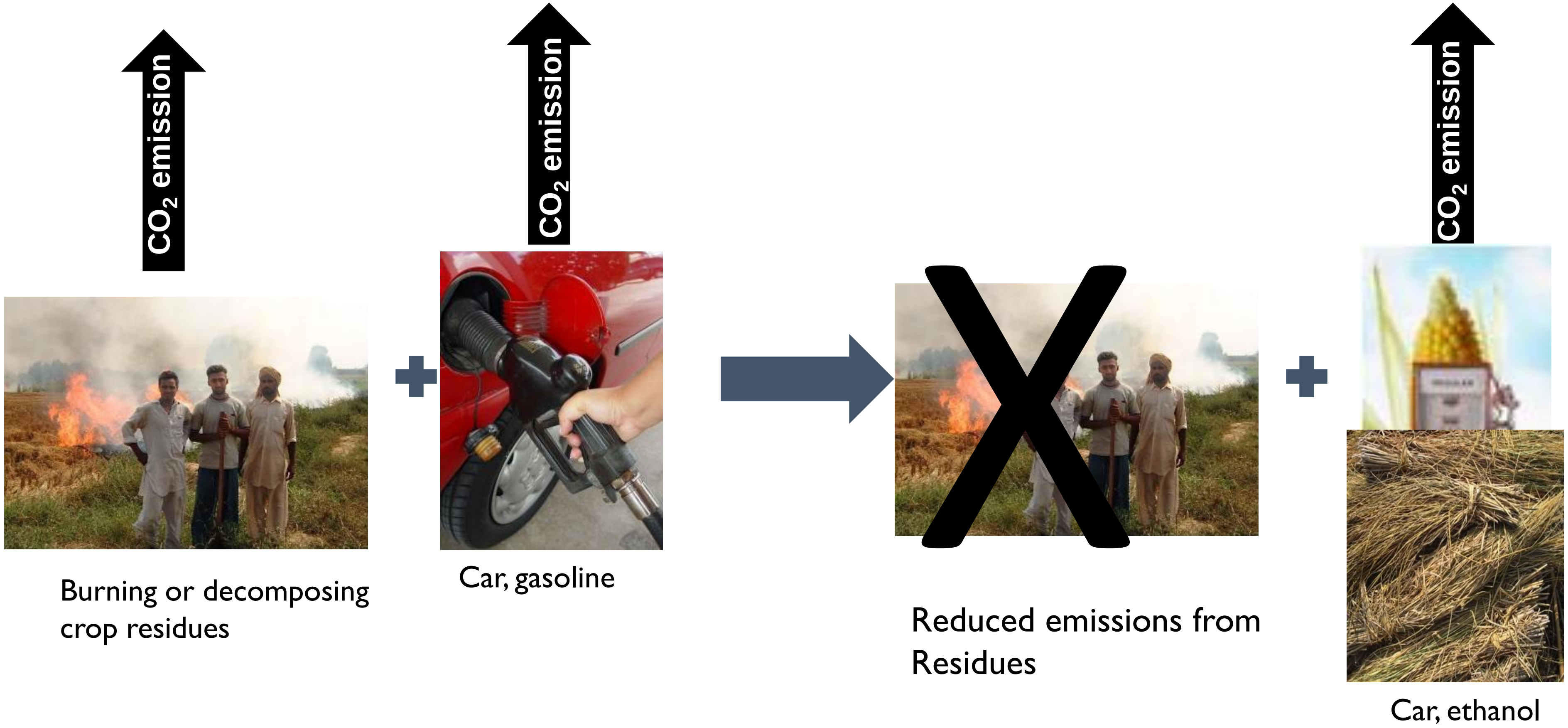


**Figure 2 - Direct effect of switching from gasoline to biofuels that use existing crops –** No change in emissions

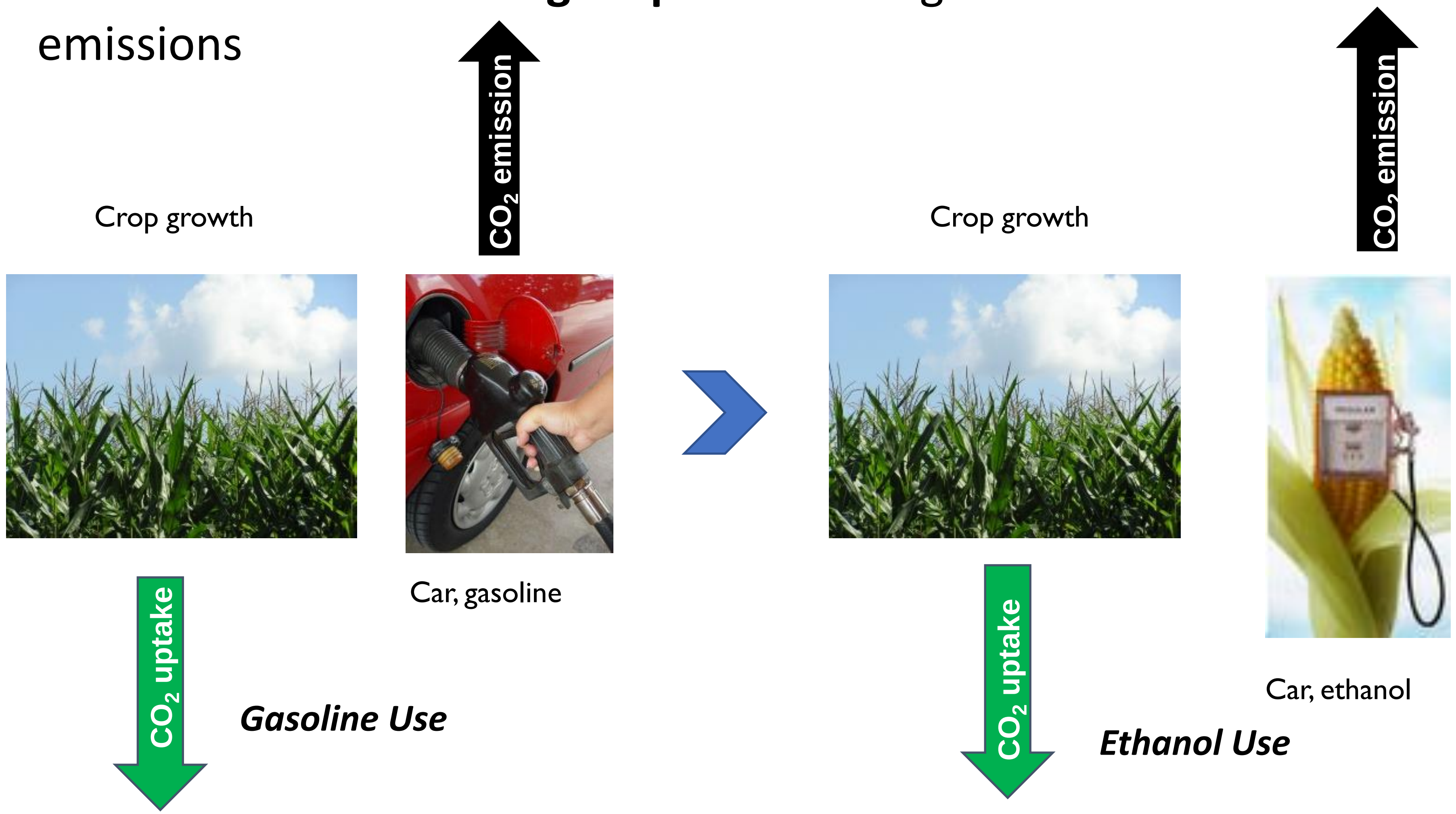
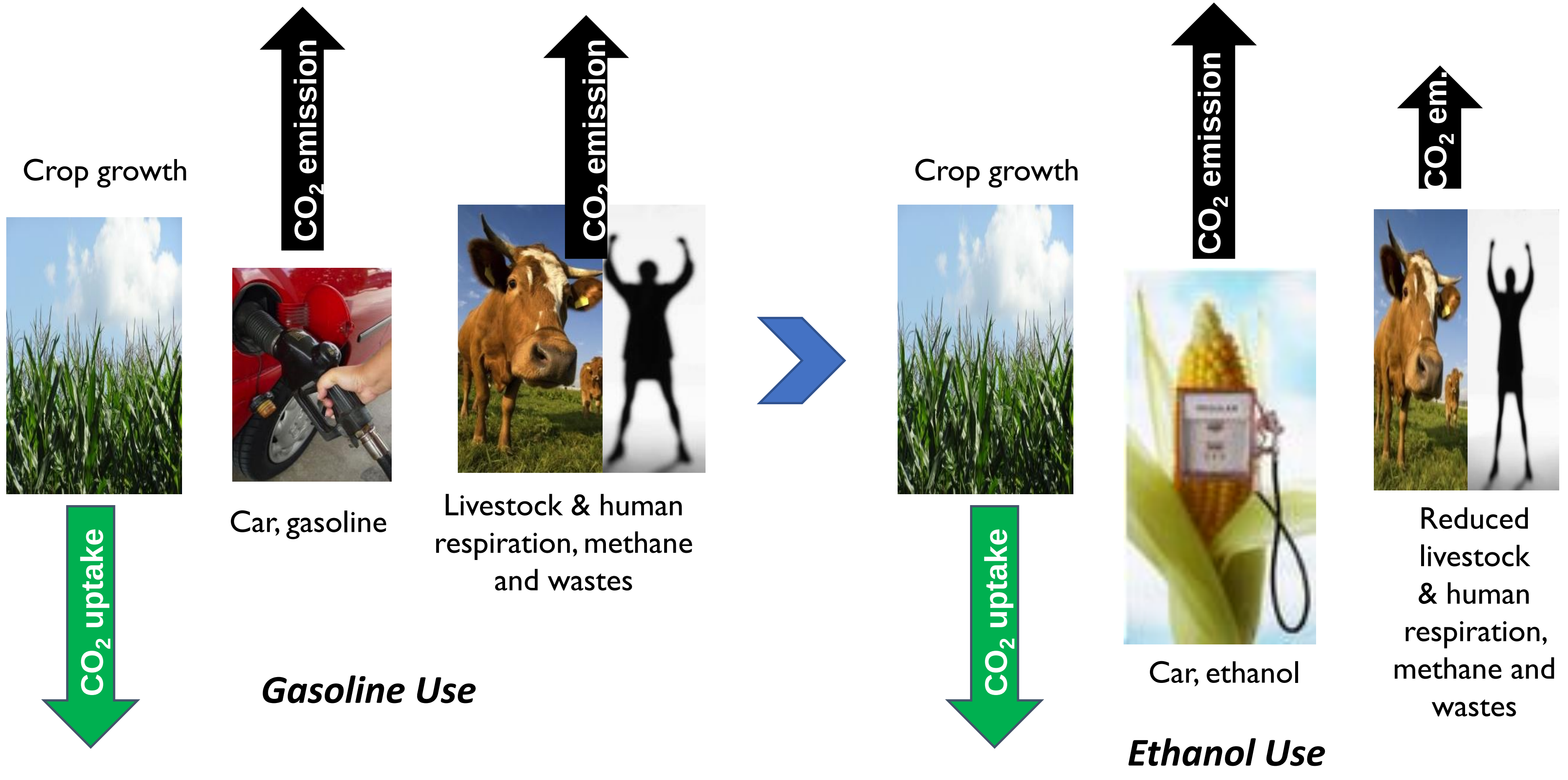
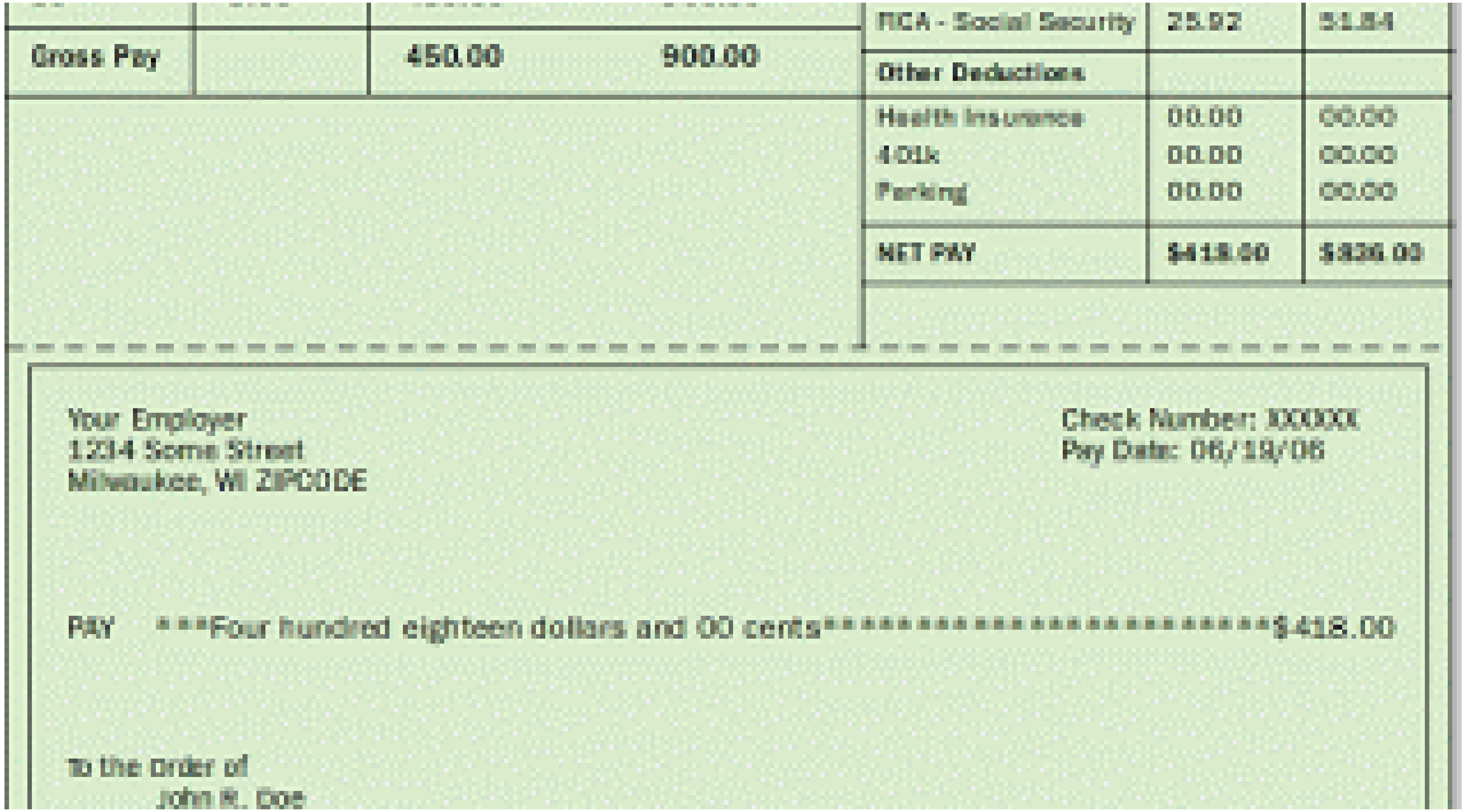


**Figure 3 - Indirect effect I of adopting ethanol** – Ethanol leads to less crop consumption for feed and food, which reduces $CO_2$




*(vertical arrows indicate carbon uptake and emissions)*

# Renewable Does Not Equal Free



| | | | | FICA - Social Security | 25.92 | 51.84 |
|---|---|---|---|---|---|---|
| Gross Pay | | 450.00 | 900.00 | Other Deductions | | |
| | | | | Health Insurance | 00.00 | 00.00 |
| | | | | 401k | 00.00 | 00.00 |
| | | | | Parking | 00.00 | 00.00 |
| | | | | NET PAY | $418.00 | $826.00 |

Your Employer
1234 Some Street
Milwaukee, WI ZIPCODE

Check Number: XXXXXX
Pay Date: 06/19/06

PAY ***Four hundred eighteen dollars and 00 cents****************************$418.00

To the Order of
John R. Doe

# Solar conversion efficiencies

Iowa corn

Ethanol **0.15%**

**Most optimistic location future US switchgrass (DOE)**

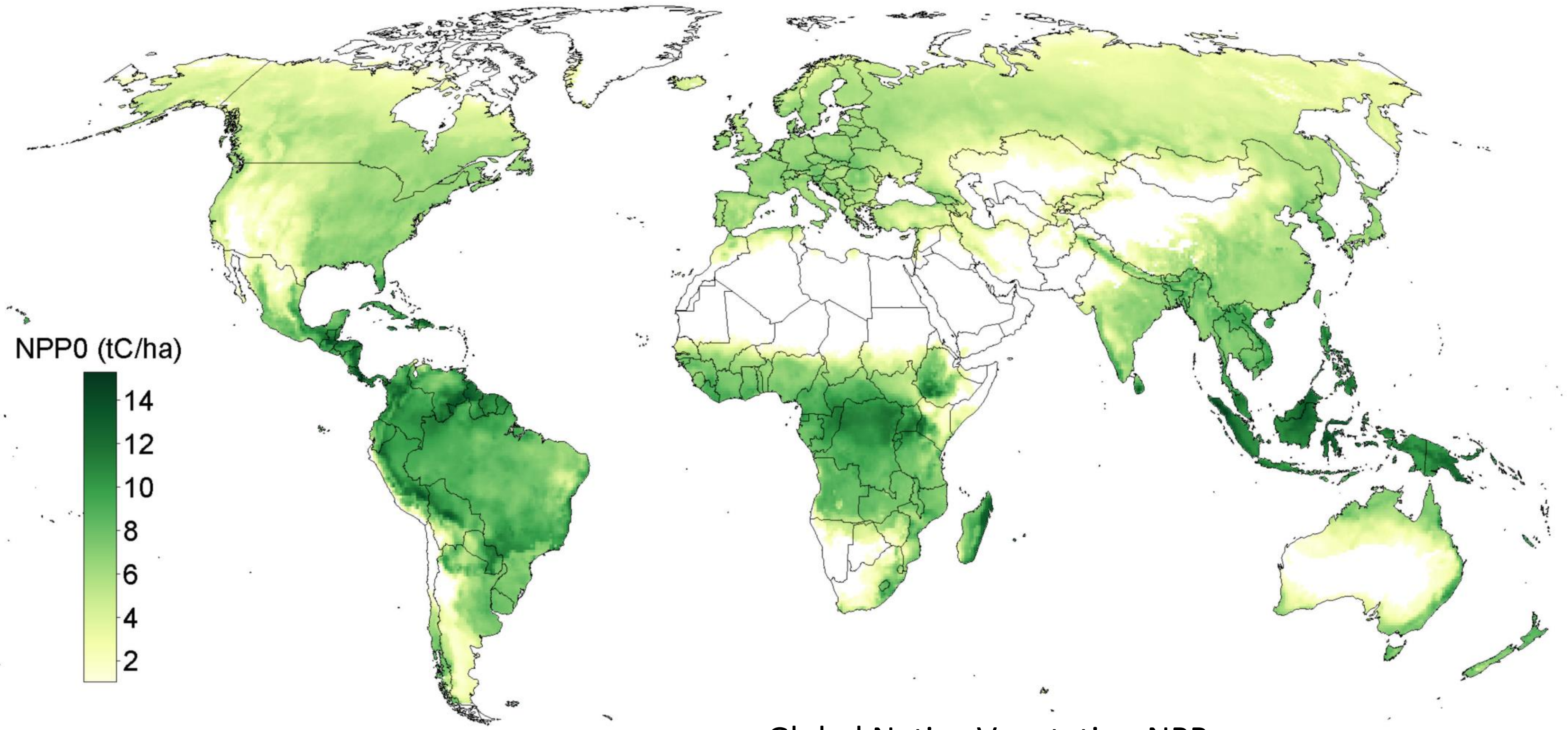
**(24 tDM/ha and 100 gallons/tonne)**

**0.35%**

**Brazilian sugarcane ethanol 0.2%**

**PV today – 20% gross; ~15% net**

# Land is Not Free!




Global Native Vegetation NPP

Searchinger et al., Nature (2018)

# Air Bureau – CT DEEP

# Connecticut Department of Energy and Environmental Protection

Connecticut Department of
ENERGY &
ENVIRONMENTAL
PROTECTION

# Air Pollution in CT for Technical Session on Alternative Fuels

11/4/2020
Jaimeson Sinclair
Enter Event / Location

# What we'll cover

- Brief overview of Clean Act Requirements and CT's current air quality
- Combustion basics and how burning fuel creates air pollution
- Considerations when advancing alternative fuels

# Takeaways:

- The situationally appropriate use of alternative fuels and technologies to burn them can improve air quality and reduce GHG emissions
- The benefits and consequences of alternative fuels need to be weighed and balanced in a thoughtful way

# Clean Air Act Overview

In depth overview of Clean Air Act Can be found at Overview of the Clean Air Act and Air Pollution | US EPA

- Clean Air Act Amendments of 1990
  - Sets lower National Ambient Air Quality Standards (NAAQS) for Criteria Air Pollutants, and process for periodically reviewing and amending the standards
  - Establishes Air Toxics Program
    - Creates a list of 188 Hazardous Air Pollutants to be regulated to reduce near term health effects
  - Clean Air Act and Amendments deal with GHG emissions in a very limited way relative to Criteria Air Pollutants and Hazardous Air Pollutants.
    - Some GHGs are regulated under other CAA programs because they are hazardous air pollutants or ozone depleting substances
    - The majority of GHG emission regulation is the result of legal precedent where the case was made that GHG are a threat to human health and the environment by virtue of the affects of Climate Change over the long term.

# The State of CT’s Air

- CT’s air quality complies with all NAAQS except for Ozone.
- CT’s ozone non-attainment has persisted for nearly 50 years
- CT’s ozone non-attainment results in significant adverse public health, economic, and environmental impacts.
- Ozone non-attainment is the most significant air quality challenge in CT in terms of effort to comply and near-term adverse impacts (health, environment, economic)

# The State of CT’s Air

- Additional challenges
  - Reducing Hazardous Air Pollutant emissions, especially in dense population centers
  - Reducing GHG emissions to satisfy CT’s Global Warming Solutions Act and mitigates the future impacts of climate change.

# Fuel Combustion and Air Pollution

- Theory: Fuel + $O_2$ → $CO_2$ + $H_20$ + HEAT

- Real World

$$C_xH_yO_zN_a(\text{Trace Minerals})_b + (N_2 + O_2)$$

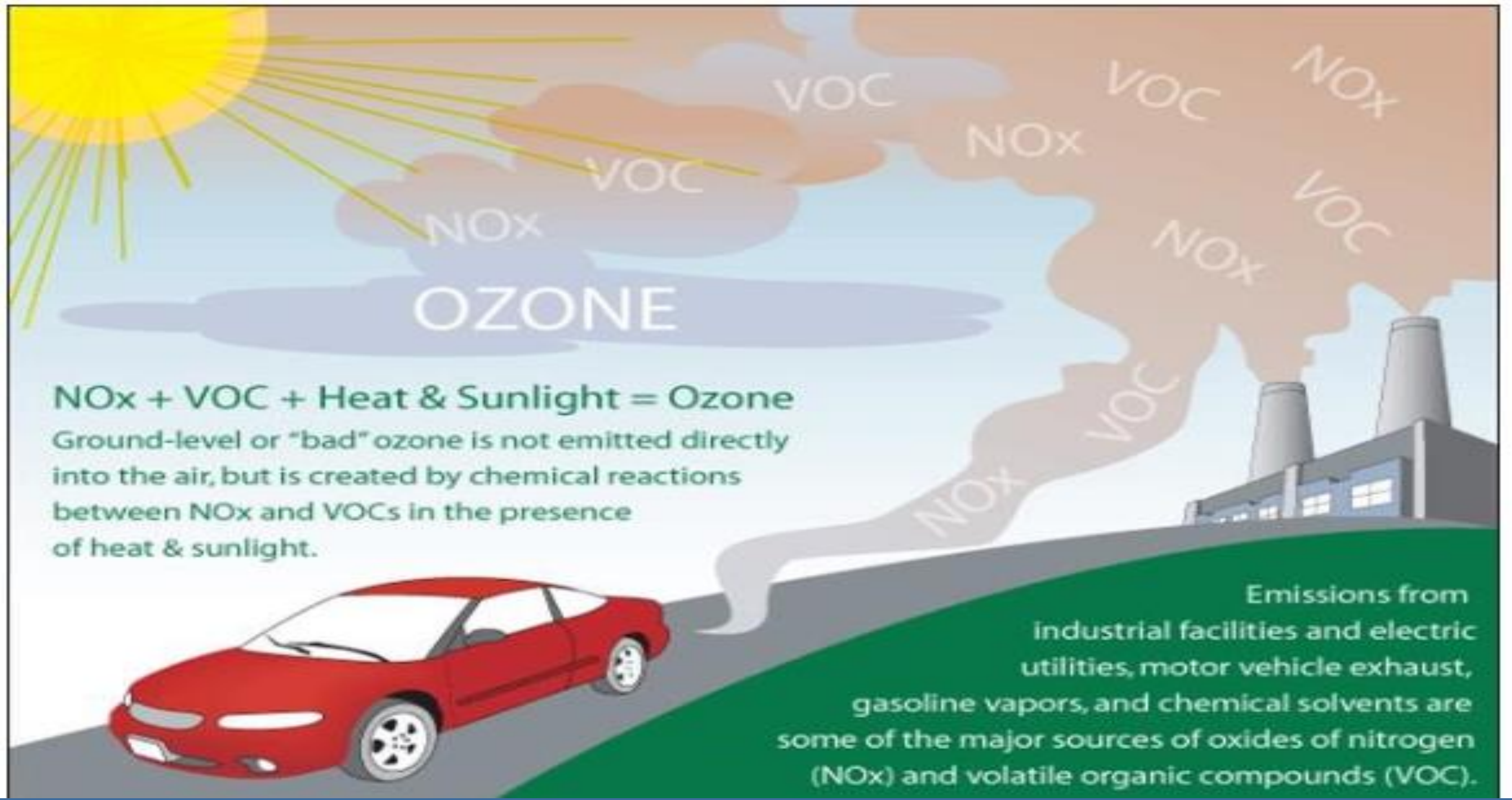
$$\longrightarrow$$

$$CO_2 + H_20 + \text{HEAT} + NO_2 + SO_2 + CO + \text{PICs}$$

where PICS = Pb, VOC, hazardous air pollutants & PM

# Fuel Combustion and Air Pollution

## What about the Ozone?



# How can Alt fuels and Fuel Switching reduce air pollution

- Electricity generated by non-emitting renewable sources of electricity is the least air polluting way to fuel anything
- Gaseous fuels tend to be cleaner burning and less polluting than liquid and solid fuels
- More refined liquid fuels tend to be cleaner burning and less polluting than heavier liquid fuels and solid fuels

# Important Considerations: Carbon Intensity

**Carbon Dioxide Emissions Coefficients by Fuel**

| Carbon Dioxide ($CO_2$) Factors: | Pounds $CO_2$ Per Unit of Volume or Mass | Kilograms $CO_2$ Per Unit of Volume or Mass | Pounds $CO_2$ Per Million Btu | Kilograms $CO_2$ Per Million Btu |
|---|---|---|---|---|
| **For homes and businesses** | | | | |
| Propane | 12.68 gallon | 5.75 gallon | 138.63 | 62.88 |
| Diesel and Home Heating Fuel (Distillate Fuel Oil) | 22.45 gallon | 10.19 gallon | 163.45 | 74.14 |
| Kerosene | 21.78 gallon | 9.88 gallon | 161.35 | 73.19 |
| Coal (All types) | 3,876.61 short ton | 1,758.40 short ton | 211.87 | 96.10 |
| Natural Gas | 120.96 thousand cubic feet | 54.87 thousand cubic feet | 116.65 | 52.91 |
| Finished Motor Gasoline[a] | 17.86 gallon | 8.10 gallon | 148.47 | 67.34 |
| Motor Gasoline | 19.37 gallon | 8.78 gallon | 155.77 | 70.66 |
| Residual Heating Fuel (Businesses only) | 24.78 gallon | 11.24 gallon | 165.55 | 75.09 |
| **Other transportation fuels** | | | | |
| Jet Fuel | 21.50 gallon | 9.75 gallon | 159.25 | 72.23 |
| Aviation Gas | 18.33 gallon | 8.32 gallon | 152.54 | 69.19 |
| **Industrial fuels and others not listed above** | | | | |
| Petroleum coke | 32.86 gallon | 14.90 gallon | 225.13 | 102.12 |

U.S. Energy Information Administration - EIA - Independent Statistics and Analysis

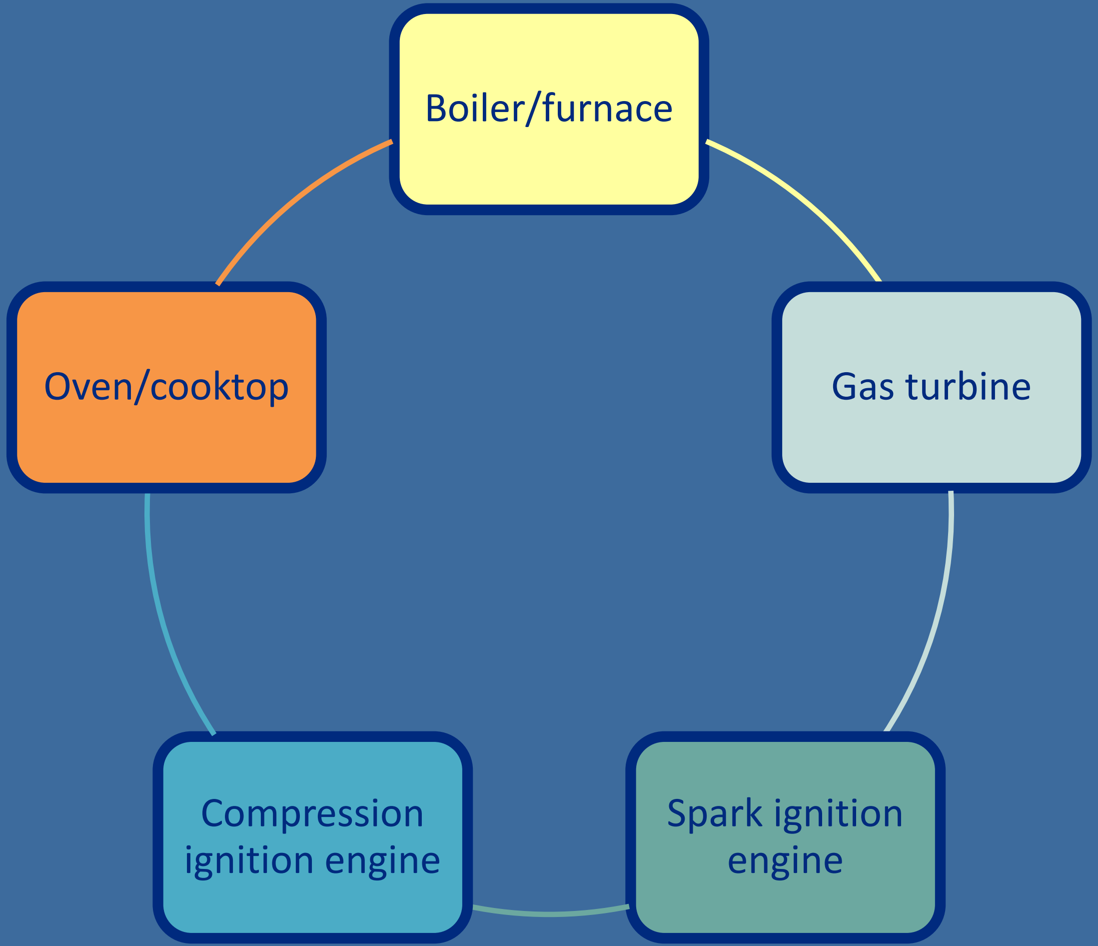
# Important Considerations: Heat Content

**HEATING VALUES OF HYDROGEN AND FUELS**

| Fuels | Lower Heating Value (LHV) [1] | | | Higher Heating Value (HHV) [1] | | | Density |
|---|---|---|---|---|---|---|---|
| **Gaseous Fuels @ 32 F and 1 atm** | **Btu/ft3 [2]** | **Btu/lb [3]** | **MJ/kg [4]** | **Btu/ft3 [2]** | **Btu/lb [3]** | **MJ/kg [4]** | **grams/ft3** |
| Natural gas | 983 | 20,267 | 47.141 | 1089 | 22,453 | 52.225 | 22.0 |
| Hydrogen | 290 | 51,682 | 120.21 | 343 | 61,127 | 142.18 | 2.55 |
| Still gas (in refineries) | 1458 | 20,163 | 46.898 | 1,584 | 21,905 | 50.951 | 32.8 |
| **Liquid Fuels** | **Btu/gal [2]** | **Btu/lb [3]** | **MJ/kg [4]** | **Btu/gal [2]** | **Btu/lb [3]** | **MJ/kg [4]** | **grams/gal** |
| Crude oil | 129,670 | 18,352 | 42.686 | 138,350 | 19,580 | 45.543 | 3,205 |
| Conventional gasoline | 116,090 | 18,679 | 43.448 | 124,340 | 20,007 | 46.536 | 2,819 |
| Reformulated or low-sulfur gasoline | 113,602 | 18,211 | 42.358 | 121,848 | 19,533 | 45.433 | 2,830 |
| CA reformulated gasoline | 113,927 | 18,272 | 42.500 | 122,174 | 19,595 | 45.577 | 2,828 |
| U.S. conventional diesel | 128,450 | 18,397 | 42.791 | 137,380 | 19,676 | 45.766 | 3,167 |
| Low-sulfur diesel | 129,488 | 18,320 | 42.612 | 138,490 | 19,594 | 45.575 | 3,206 |
| Petroleum naphtha | 116,920 | 19,320 | 44.938 | 125,080 | 20,669 | 48.075 | 2,745 |
| NG-based FT naphtha | 111,520 | 19,081 | 44.383 | 119,740 | 20,488 | 47.654 | 2,651 |
| Residual oil | 140,353 | 16,968 | 39.466 | 150,110 | 18,147 | 42.210 | 3,752 |
| Methanol | 57,250 | 8,639 | 20.094 | 65,200 | 9,838 | 22.884 | 3,006 |
| Ethanol | 76,330 | 11,587 | 26.952 | 84,530 | 12,832 | 29.847 | 2,988 |
| E-Diesel Additives | 116,090 | 18,679 | 43.448 | 124,340 | 20,007 | 46.536 | 2,819 |
| Liquefied petroleum gas (LPG) | 84,950 | 20,038 | 46.607 | 91,410 | 21,561 | 50.152 | 1,923 |
| Liquefied natural gas (LNG) | 74,720 | 20,908 | 48.632 | 84,820 | 23,734 | 55.206 | 1,621 |
| Dimethyl ether (DME) | 68,930 | 12,417 | 28.882 | 75,610 | 13,620 | 31.681 | 2,518 |
| Dimethoxy methane (DMM) | 72,200 | 10,061 | 23.402 | 79,197 | 11,036 | 25.670 | 3,255 |
| Methyl ester (biodiesel, BD) | 119,550 | 16,134 | 37.528 | 127,960 | 17,269 | 40.168 | 3,361 |
| Fischer-Tropsch diesel (FTD) | 123,670 | 18,593 | 43.247 | 130,030 | 19,549 | 45.471 | 3,017 |
| Liquid Hydrogen | 30,500 | 51,621 | 120.07 | 36,020 | 60,964 | 141.80 | 268 |
| Methyl tertiary butyl ether (MTBE) | 93,540 | 15,094 | 35.108 | 101,130 | 16,319 | 37.957 | 2,811 |
| Ethyl tertiary butyl ether (ETBE) | 96,720 | 15,613 | 36.315 | 104,530 | 16,873 | 39.247 | 2,810 |
| Tertiary amyl methyl ether (TAME) | 100,480 | 15,646 | 36.392 | 108,570 | 16,906 | 39.322 | 2,913 |
| Butane | 94,970 | 19,466 | 45.277 | 103,220 | 21,157 | 49.210 | 2,213 |
| Isobutane | 90,060 | 19,287 | 44.862 | 98,560 | 21,108 | 49.096 | 2,118 |
| Isobutylene | 95,720 | 19,271 | 44.824 | 103,010 | 20,739 | 48.238 | 2,253 |
| Propane | 84,250 | 19,904 | 46.296 | 91,420 | 21,597 | 50.235 | 1,920 |
| **Solid Fuels** | **Btu/ton [2]** | **Btu/lb [5]** | **MJ/kg [4]** | **Btu/ton [2]** | **Btu/lb [5]** | **MJ/kg [4]** | |
| Coal (wet basis) [6] | 19,546,300 | 9,773 | 22.732 | 20,608,570 | 10,304 | 23.968 | |
| Bituminous coal (wet basis) [7] | 22,460,600 | 11,230 | 26.122 | 23,445,900 | 11,723 | 27.267 | |
| Coking coal (wet basis) | 24,600,497 | 12,300 | 28.610 | 25,679,670 | 12,840 | 29.865 | |
| Farmed trees (dry basis) | 16,811,000 | 8,406 | 19.551 | 17,703,170 | 8,852 | 20.589 | |
| Herbaceous biomass (dry basis) | 14,797,555 | 7,399 | 17.209 | 15,582,870 | 7,791 | 18.123 | |
| Corn stover (dry basis) | 14,075,990 | 7,038 | 16.370 | 14,974,460 | 7,487 | 17.415 | |
| Forest residue (dry basis) | 13,243,490 | 6,622 | 15.402 | 14,164,160 | 7,082 | 16.473 | |

https://chemeng.queensu.ca/courses/CHEE332/files/ethanol_heating-values.pdf

# Important Considerations: Technology



# Important Considerations: Energy/Pollution Intensity to Produce Fuel

Using an alternative fuel or fuel switching that requires more energy and generates more pollution to produce the fuel to reduce emissions at the point of combustion may not be wise.

# Important Considerations: Biofuels

Some have a lower heating value than their petroleum-based counterparts so quantity needed to do the job, emissions resulting from doing the job and life cycle emissions need to be evaluated

At the point of combustion, many biofuels result in less PM, VOC, and Hazardous Air Pollutants than their petroleum-based counterparts

# Important Considerations:  Hydrogen

Best use is in a fuel cell

High flame temps could result in increased NOx emissions

In a combustion application, it takes a lot of cubic feet of hydrogen to do the same amount of work as lessor amounts of other fuels

# RMI

# Low Carbon Fuels' Limited Role in Building Decarbonization

Mike Henchen

November 4, 2022

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- **Low carbon fuels will have an important role to play in decarbonizing hard to electrify sectors.**
- **Early priorities in CT might include: industrial thermal processes, aviation, maritime, long-distance trucking.**

- **Low carbon fuels are *not* a practical solution for heating buildings at scale:**
  - Inefficient use of carbon-free electricity
  - Impractical infrastructure requirements and high costs
  - Limited RNG potential and high-risk feedstocks
  - High RNG heating costs

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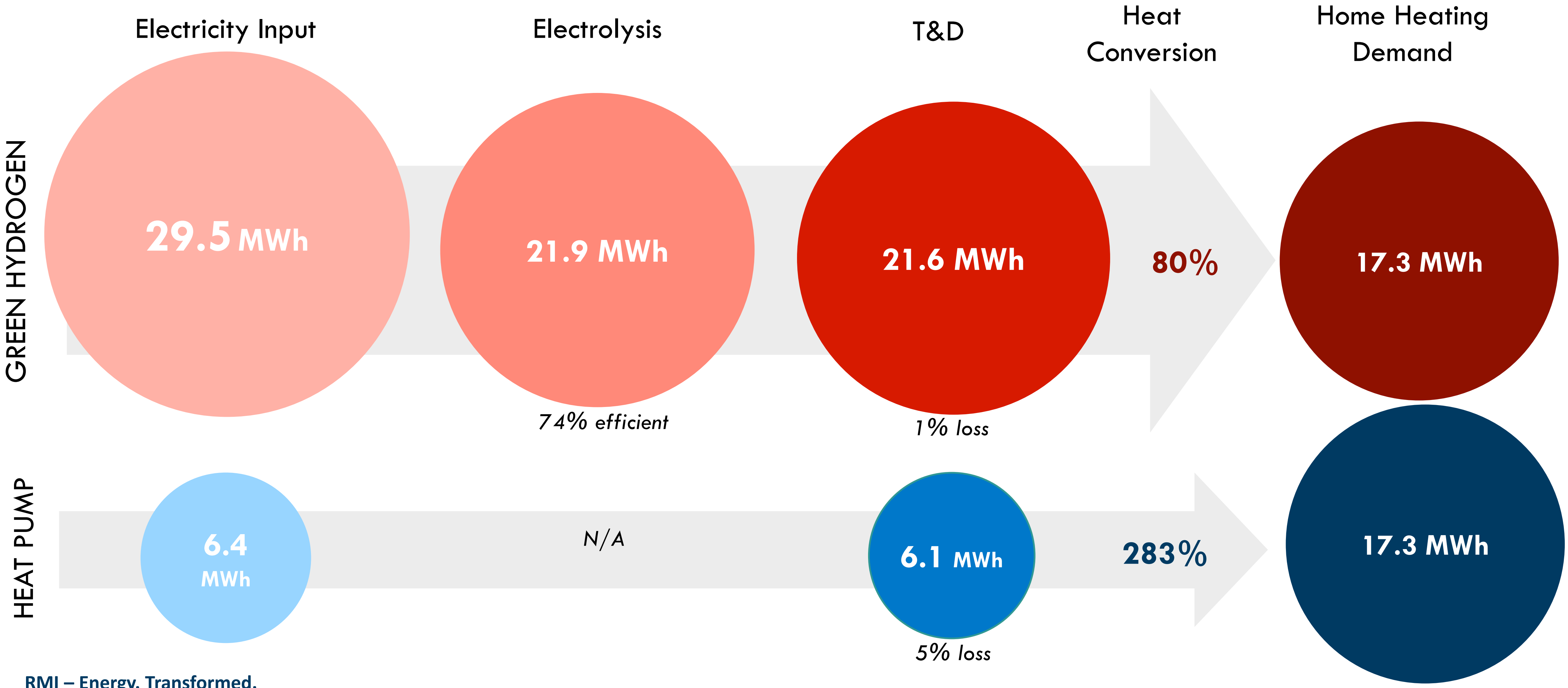
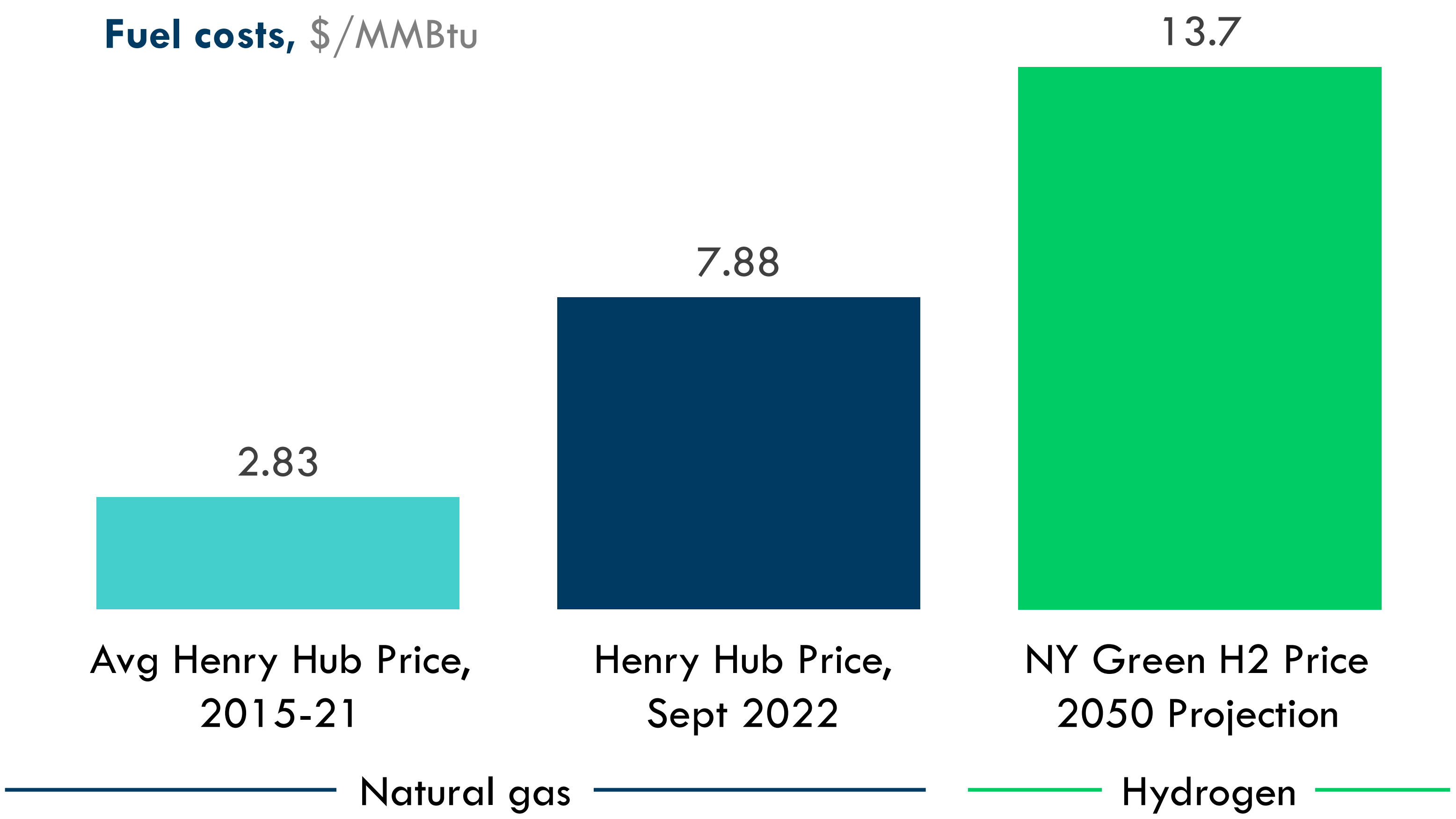
# Heating a Connecticut home with hydrogen would require significantly more energy input than heating with an electric heat pump.




**RMI – Energy. Transformed.**

*Source: RMI Analysis*

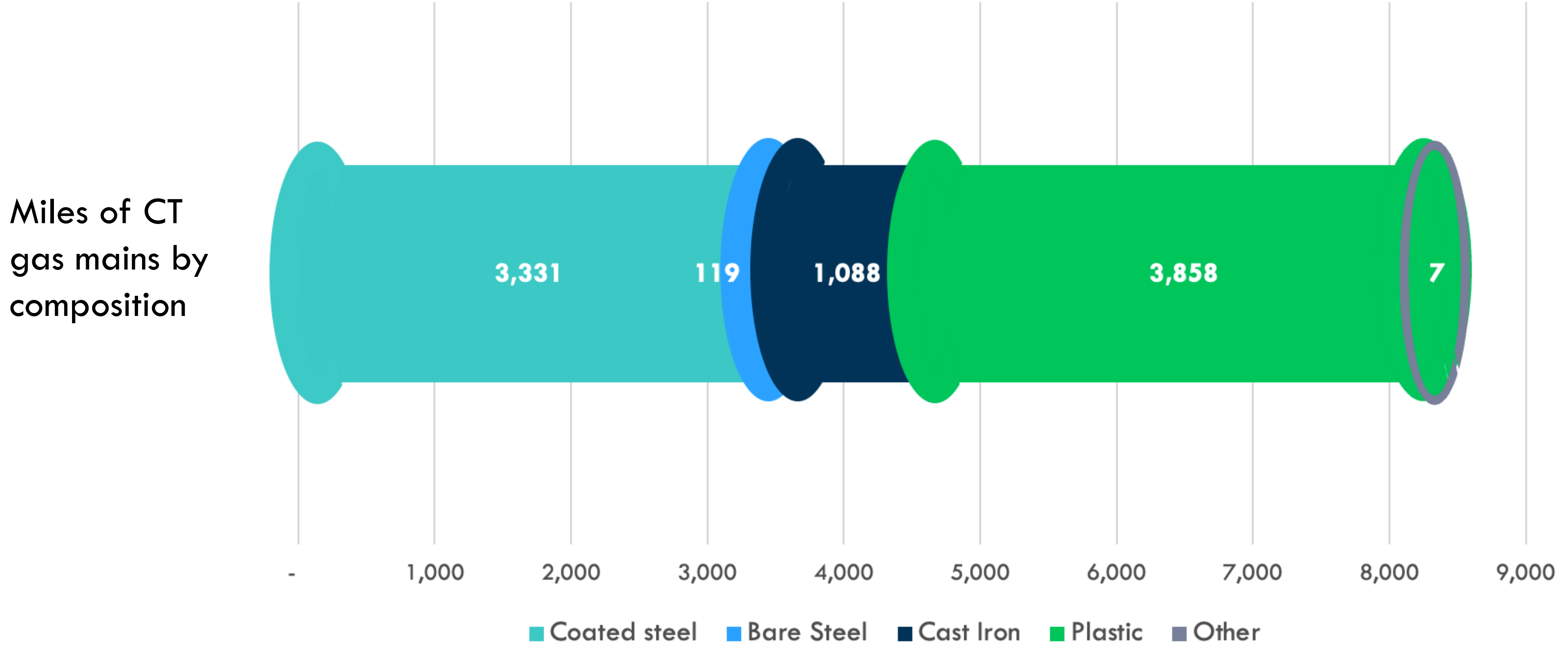
# Future hydrogen heating projects suggest significantly higher heating costs over gas today






*Source: EIA Henry Hub Natural Gas spot Price; New York CAC Green Hydrogen Cost Estimate*

# Over 50% of all Connecticut gas mains are made of steel or cast-iron, which would require expensive upgrades or replacements to deliver a high blend of hydrogen



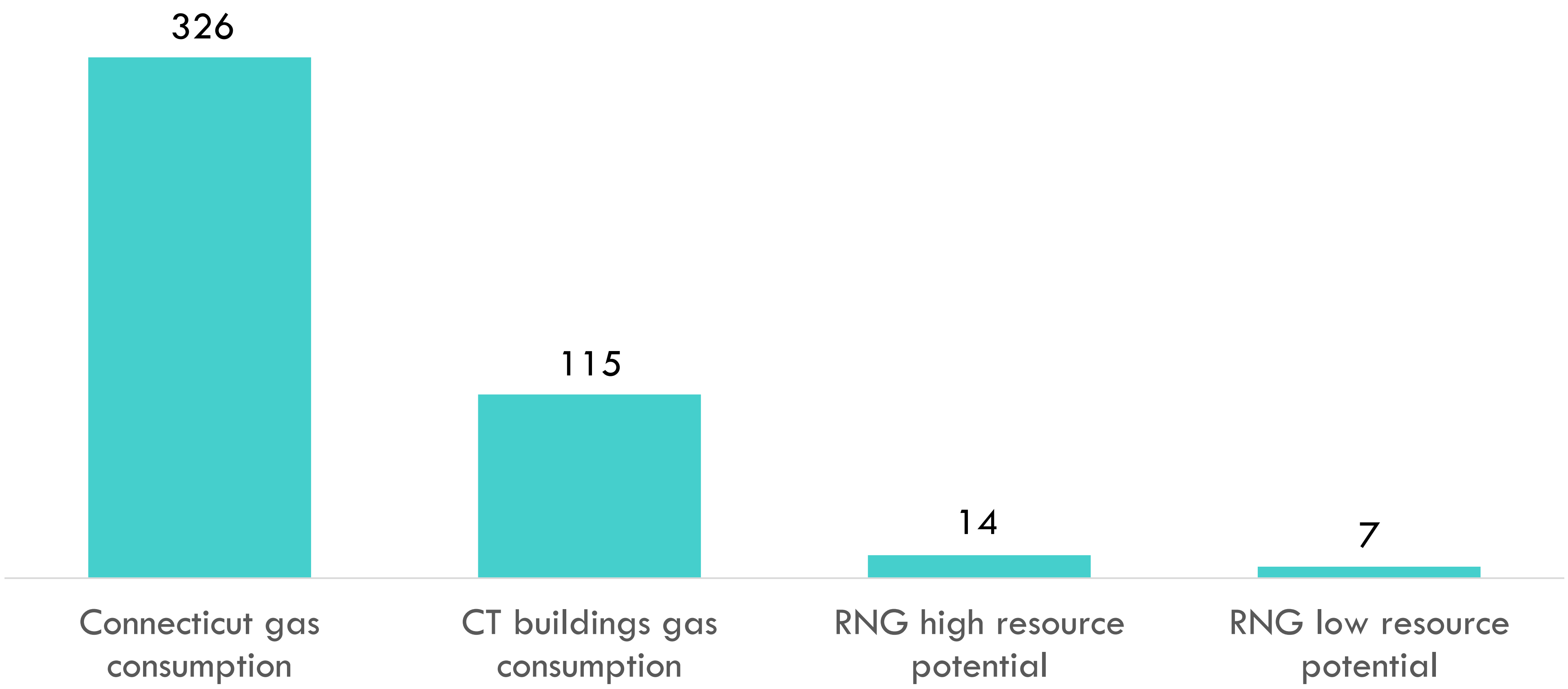



Source: PHMSA

# Contents

# RNG potential estimates in Connecticut are just 2-4% of statewide gas demand and 6-12% of buildings demand

**2021 fuel demand and 2040 ICF resource potential estimates,** TBtu

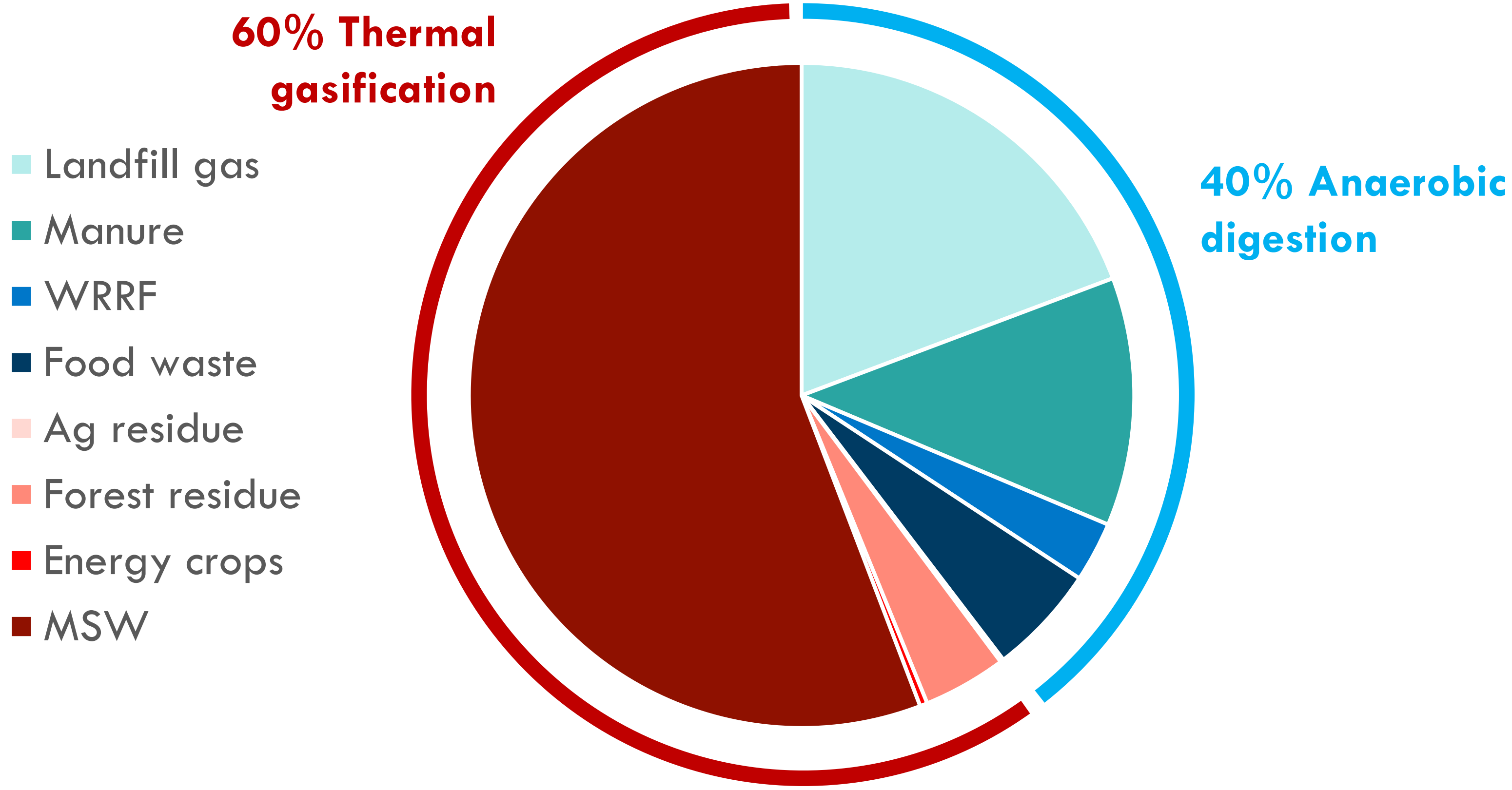





Sources: EIA consumption data; AGF/ICF Renewable Sources of Natural Gas

# Thermal gasification comprises the majority of CT's RNG resource potential.

**2040 High resource potential by feedstock**

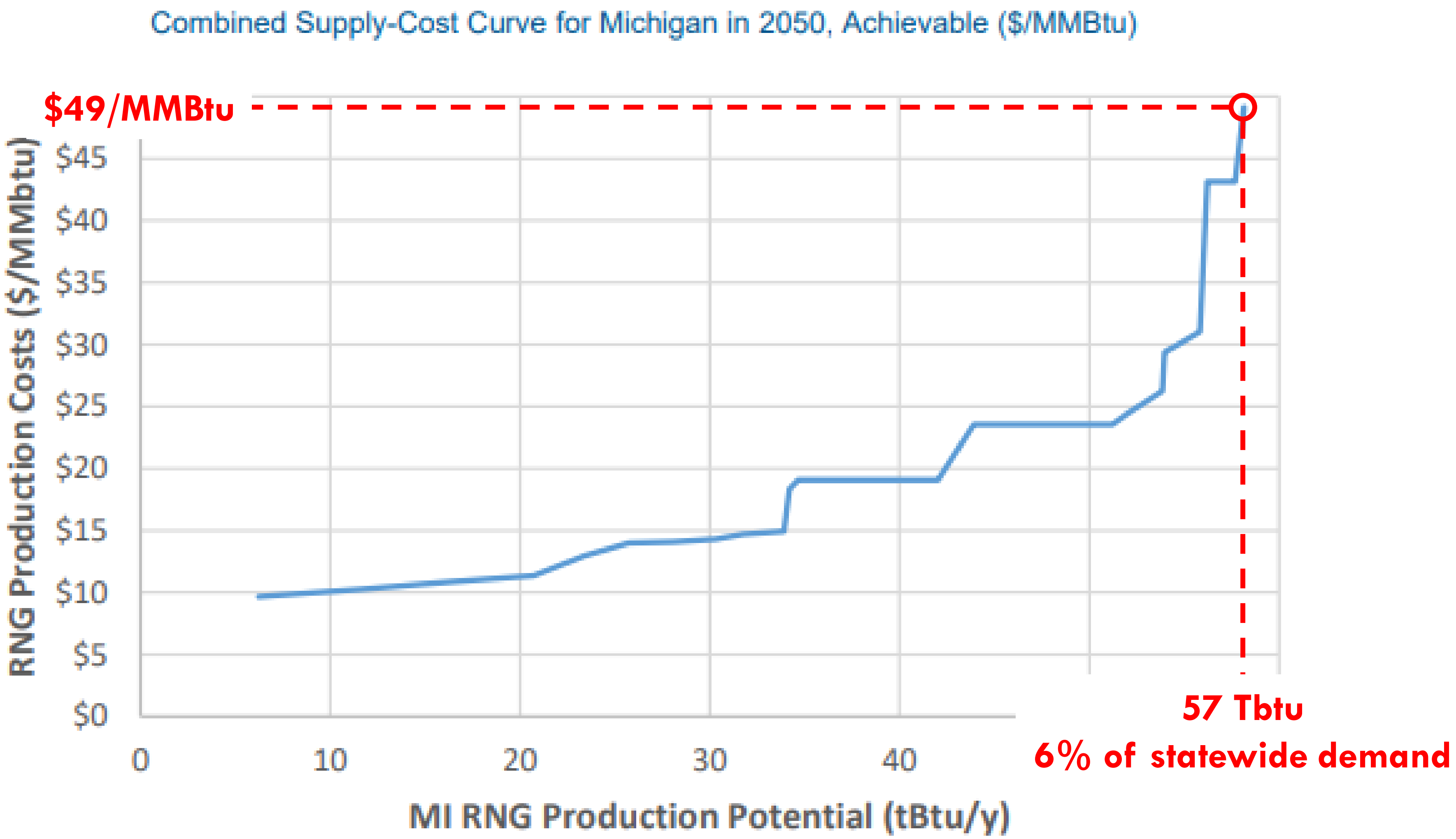



- New methane creation = leakage risk
- Lifecycle emissions approach / exceed fossil gas



Source: AGF/ICF Renewable Sources of Natural Gas

# Cost curves from outside Connecticut illustrate expense of seeking high RNG volumes






Source: Michigan Renewable Natural Gas Study, Sept 2022

# Conclusion

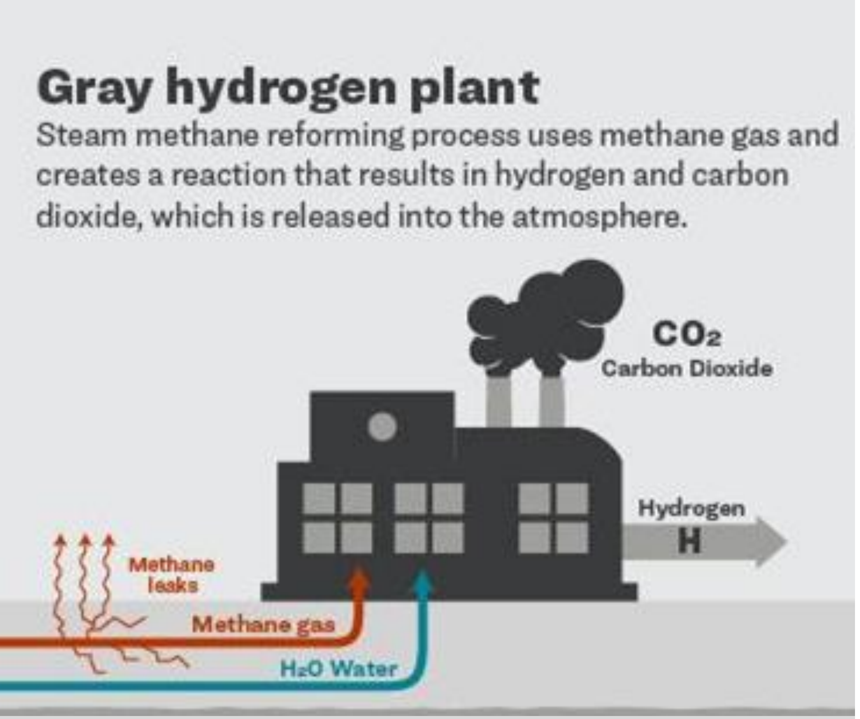
- Climate strategies that rely on hydrogen or RNG for heating buildings would impose impractical infrastructure challenges, costs, and health risks.
- These fuels should be targeted to the hardest to decarbonize sectors
- Even if there is limited use of RNG, the dominant strategy must be eliminating gas demand

# Sierra Club

# Challenges with Alternative Fuels and Strategies for Optimal Use

Comprehensive Energy Strategy
Technical Meeting 6: November 2022

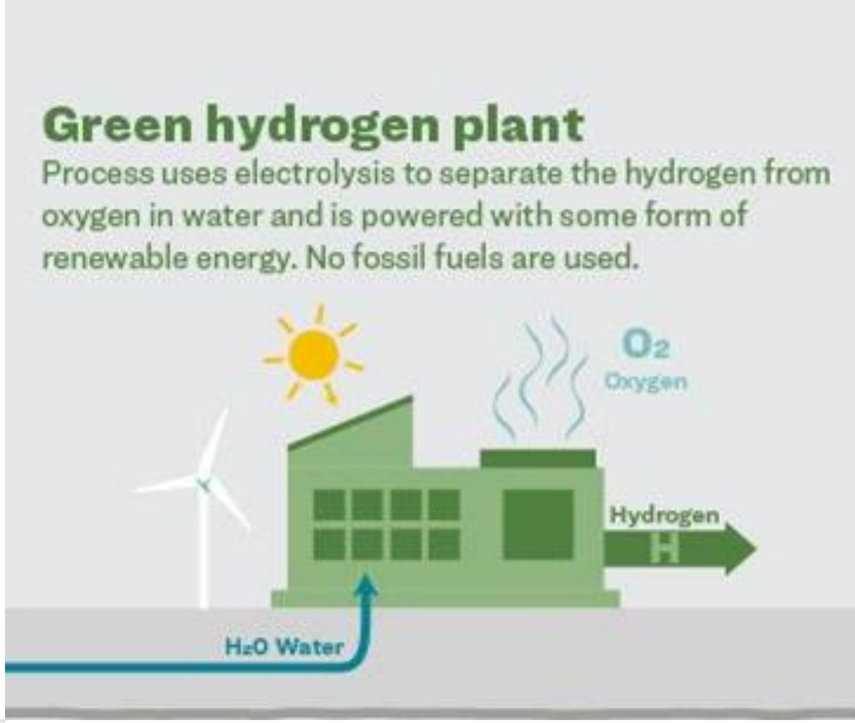
SIERRA CLUB




# Blue Hydrogen

Same issues as gray hydrogen.

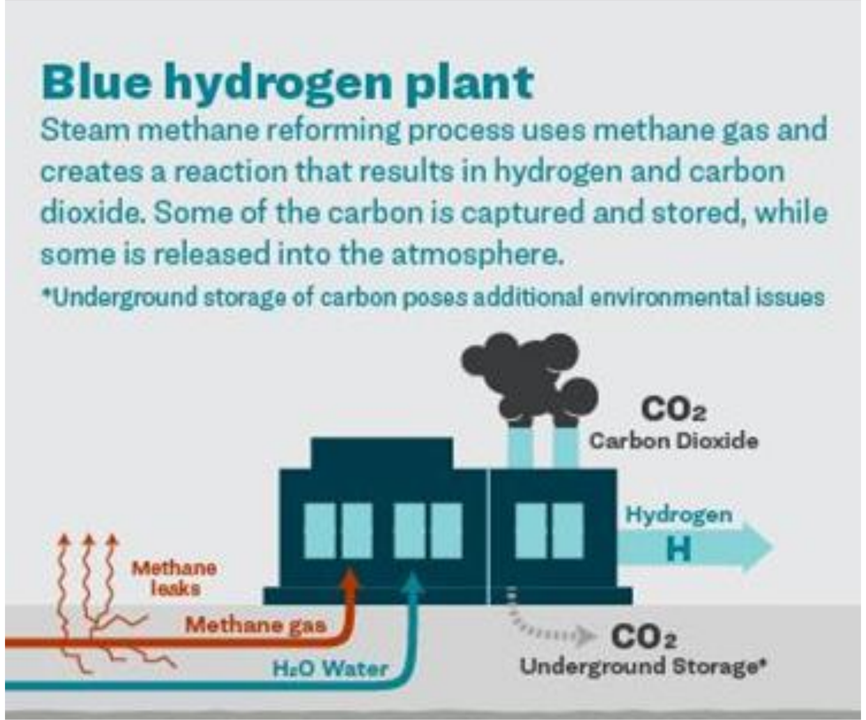
False Solution: Studies show emissions impact is worse than using gas directly.




# Gray Hydrogen

Locks us into continued fossil fuel use and additional investments in fossil fuel infrastructure.

This is how 99% of the US's hydrogen is currently produced.




# Green Hydrogen

This is the only kind Sierra Club might support.

Other conditions still need to be met.

# Should Hydrogen Be Used In...?

Hydrogen should only be used for end uses where electrification is not an option.

## Buildings

**NO**: Electrification is a better option. It is more readily available, more efficient, more cost-effective, and provides cleaner indoor air.

## Electric Sector

**NO**: Renewables offer a cleaner, more efficient, and more cost effective option in most cases.

**Maybe**: Potential for use as a long-term energy storage option.

## Transportation

**NO**: Electric vehicle options are available, more efficient, and cheaper.

**Maybe**: Long-haul freight trucking, aviation, maritime shipping.

## Industry

**NO**: Where electrification is possible; where transition is possible.

**Yes**: High heat processes that can not be electrified; feedstock.

# Green Hydrogen Considerations

## Green Hydrogen is not a Solution Everywhere

- ✓ Only for uses that cannot otherwise directly rely on clean electricity, which is much more efficient.
  - Green hydrogen is 20-40% less efficient than using renewables directly.
- ✓ Should not be used to justify a buildout of facilities that otherwise increase pollution or fossil fuel use.
- ✓ Must plan for 100 percent green hydrogen.
- ✓ Must not increase NOx pollution.

# Hydrogen's Limited Climate Benefits

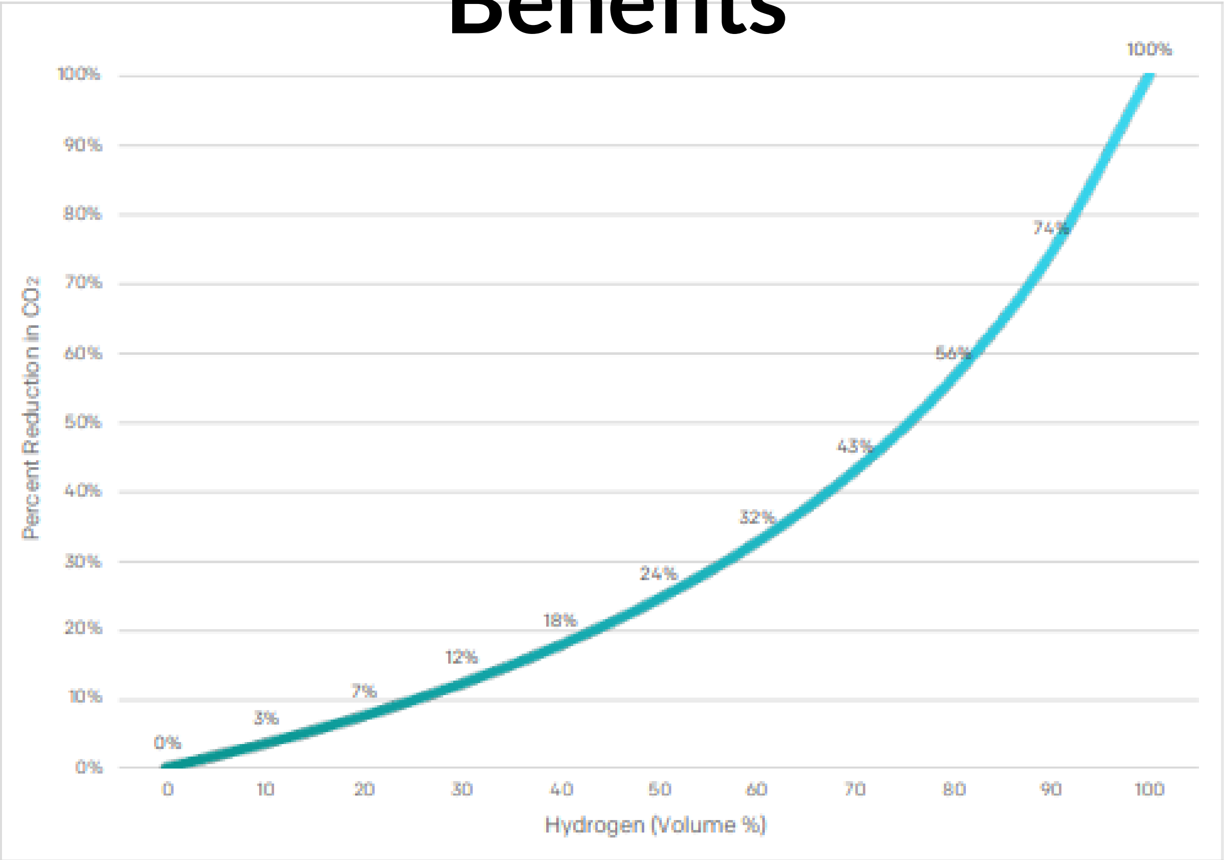



Figure: Relationship between CO2 emissions from combustion and hydrogen/methane fuel blends

Source: EarthJustice, Reclaiming Hydrogen for a Renewable Future (2021)

**Key takeaways:**

- Hydrogen does not produce carbon emissions when burned at end use.
- Lower energy density of hydrogen means you need more of it (by volume) to create the same amount of energy.
- Green hydrogen must be considered against reasonable alternatives (i.e., electrification).
- Blue hydrogen can produce more emissions than burning gas.
- Hydrogen leakage: Hydrogen is an indirect greenhouse gas 5x more potent than CO2 over 100 years.

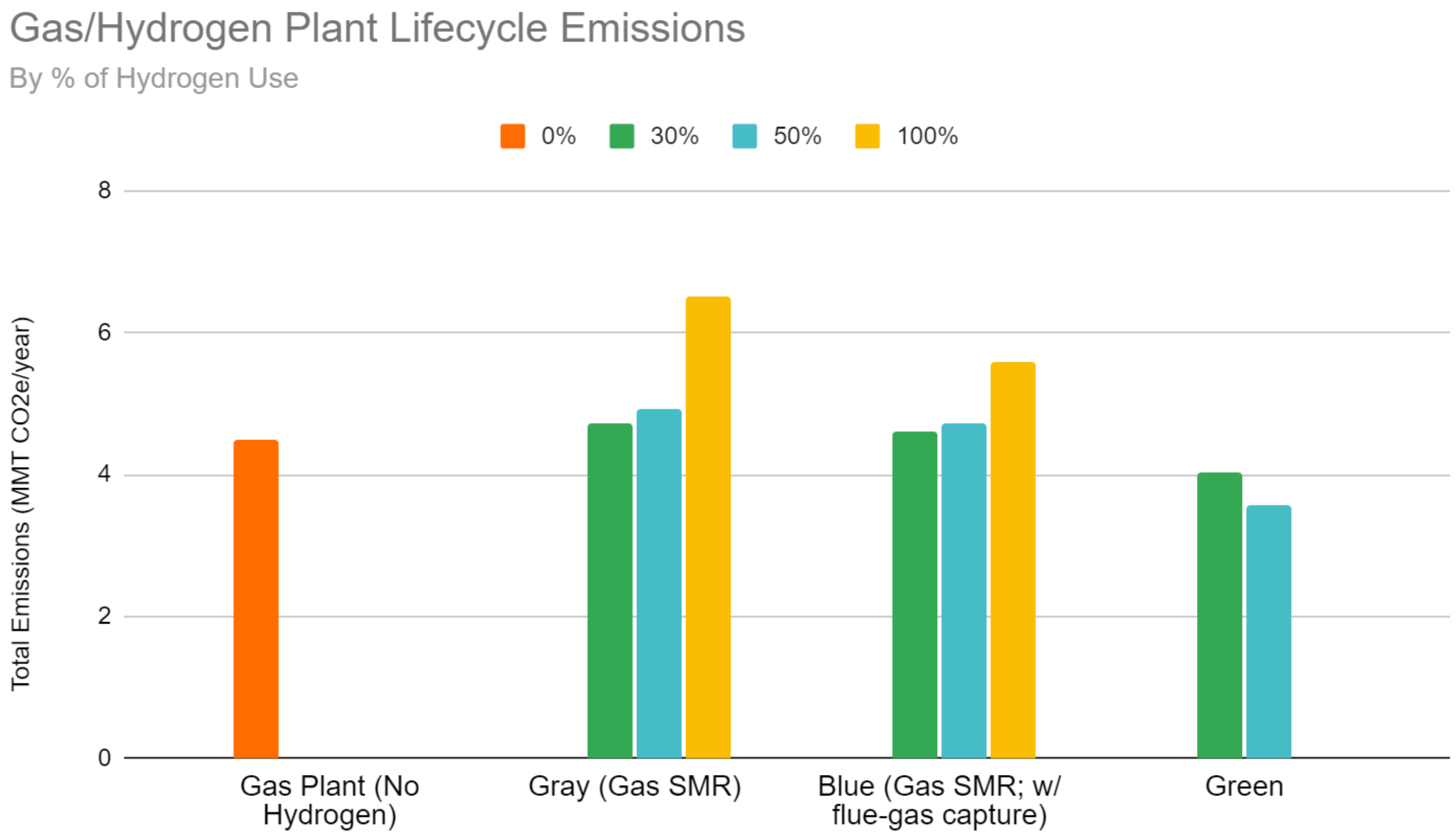
# Issues: Moving and Storing Hydrogen

System is not prepared or safe

- Pipelines
  - 96% of existing gas transmission pipelines (steel) are susceptible to hydrogen embrittlement.
  - Safe transportation of hydrogen requires:
    - Plastic pipelines with a coating to prevent hydrogen leakage.
      - Over half of distribution pipelines are plastic.
    - Substantial modification of steel pipes.
  - 1,600 miles of hydrogen pipelines (mainly in Gulf Coast) compared to 3 million miles of gas pipelines.
  - Leak detection systems not designed for hydrogen.
- Storage
  - Low energy density of hydrogen makes it hard to store.
  - Salt caverns - limited locations.
  - Conversion to a liquid for long-term storage - cryogenic temps, very expensive.
  - Globally, it would require 3 to 4 times more storage infrastructure, at a cost of $637 billion by 2050, to provide the same level of energy security as the world would have with gas.
- Compressor Stations
- Metering Systems

# GHG Comparison

## Ex: Entergy TX Plant (1,215 MW, CC)




**Key takeaways:**

- Lower energy density of hydrogen means you need more of it (by volume) to create the same amount of energy.
- Gray or blue hydrogen production for use in a gas plant creates more GHG than simply burning gas in that plant.
  - GHG increase, not decrease as you use more hydrogen in the plant.
- Methane Assumptions
  - 20-year GWP = 82.5
  - Leakage rate = 2.9%
  - Blue hydrogen still produces more emissions than using gas if leakage is reduced to 1.5%.
- Blue hydrogen is NOT a climate solution.

# Sources of RNG

## Potentially Climate Beneficial:

**LANDFILL GAS** is generated from residential, industrial, and commercial organic waste—like leftover food, yard clippings, or paper—breaking down in landfills.

**WASTEWATER TREATMENT** plants break down biosolids from wastewater using anaerobic digestion.

## Unlikely To Be Climate Beneficial:

**ORGANIC COMPONENTS OF MUNICIPAL SOLID WASTE** like leftover food, used paper, and yard waste are generated daily in homes, businesses, and other institutions and can be a source for anaerobic digestion.

**AGRICULTURAL RESIDUE**—including crop residues from orchards and vineyards, field and seed crops, food processing, and vegetable crops—can be a source for thermal gasification.

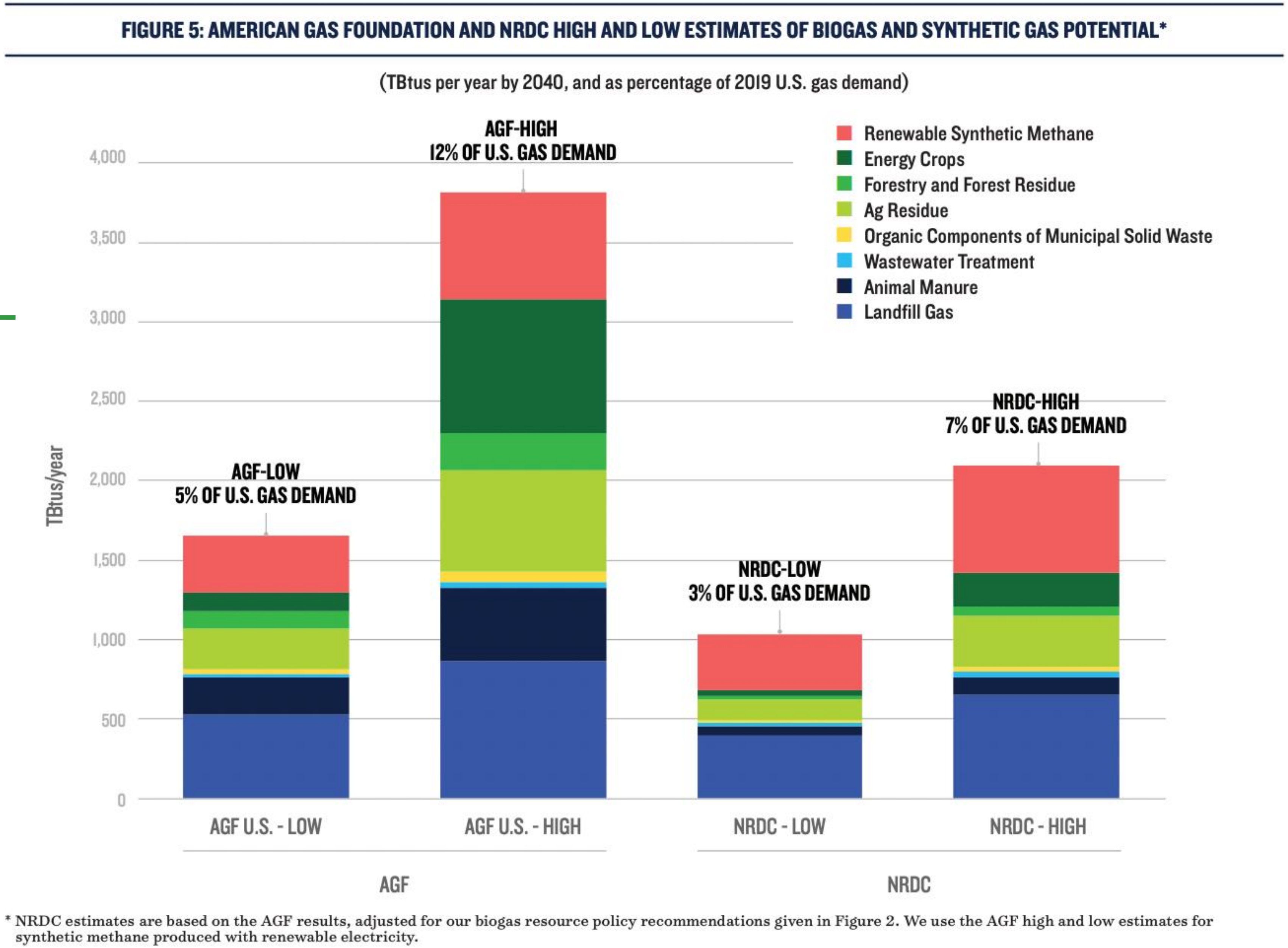
**ANIMAL MANURE** can generate methane when digesters process it in anaerobic conditions.

**ENERGY CROPS** are grown specifically to produce energy.

**FORESTRY AND FOREST PRODUCT RESIDUE**, including tree branches, brush, sawmill wastes, and non-merchantable trees from logging and thinning, can be a source for thermal gasification.

Adapted from NRDC, A Pipe Dream or Climate Solution? https://www.nrdc.org/sites/default/files/pipe-dream-climate-solution-bio-synthetic-gas-ib.pdf

# RNG Availability




Source: NRDC, A Pipe Dream or Climate Solution? https://www.nrdc.org/sites/default/files/pipe-dream-climate-solution-bio-synthetic-gas-ib.pdf

# Where should RNG be used?

- Given limited quantities and high cost, RNG should be prioritized to address the hardest to decarbonize sectors of the economy—should be dedicated to its "highest and best" uses.

- Hard to decarbonize sectors include: aviation, high-heat industrial end-uses, shipping, chemical feedstocks.

- Not appropriate for end uses that are easily and more efficiently decarbonized through electrification (i.e. building heating).

# RNG inappropriate for buildings

- No viable pathway to decarbonize the buildings sector using RNG:
  - Limited quantity of RNG available.
  - High cost:
    - American Gas Foundation study showed RNG costs of $7–$20 per MMBtu, compared with $2–$4 for fossil gas in 2020 and $5–$6 during the late 2021 gas price spike.
  - Dubious climate benefits—will leak from gas distribution system as methane, a highly potent greenhouse gas.
- Building heating is an excellent candidate for electrification through air source heat pumps and networked geothermal.

# Biodiesel: Challenges

- Cannot provide significant greenhouse gas emissions reductions over conventional heating oil.
    - According to EPA, depending on production process, feedstock, and timeframe of analysis, biodiesel may be responsible for even more GHGs than fossil fuels on an energy-equivalent basis.
- Heating infrastructure cannot readily accommodate biodiesel blends above 20 percent.
    - American Society for Testing and Materials D396 heating oil specification limits biodiesel blends to 20 percent in most situations.

# American Bureau of Shipping (ABS)

# Alternative Marine Fuels: Understanding Challenges

Keegan P. Plaskon | November 4, 2022

Connecticut Comprehensive Energy Strategy
Technical Session 6

Keegan Plaskon
Director – Eastern Americas
American Bureau of Shipping
kplaskon@eagle.org

- Introduction
- Current State of Affairs
- Decarbonization Strategies
- Fuel Options and Limitations
- Conclusions

ABS

# IMO Emissions – Greenhouse Gas Reduction Strategy

- By 2030, reduce $CO_2$ emissions per cargo transport work by 40%, aiming at 70% in 2050, compared to 2008
- By 2050, reduce total greenhouse gas (GHG) emissions by at least 50% compared to 2008


## Key activities prior to 2023 adoption of revised IMO strategy

- Data collection from ships (January 2019)
- Fourth IMO GHG study using data from 2012-2018
- Review energy efficiency requirements (EEDI) for new ships

# Driver– GHG Emission reductions

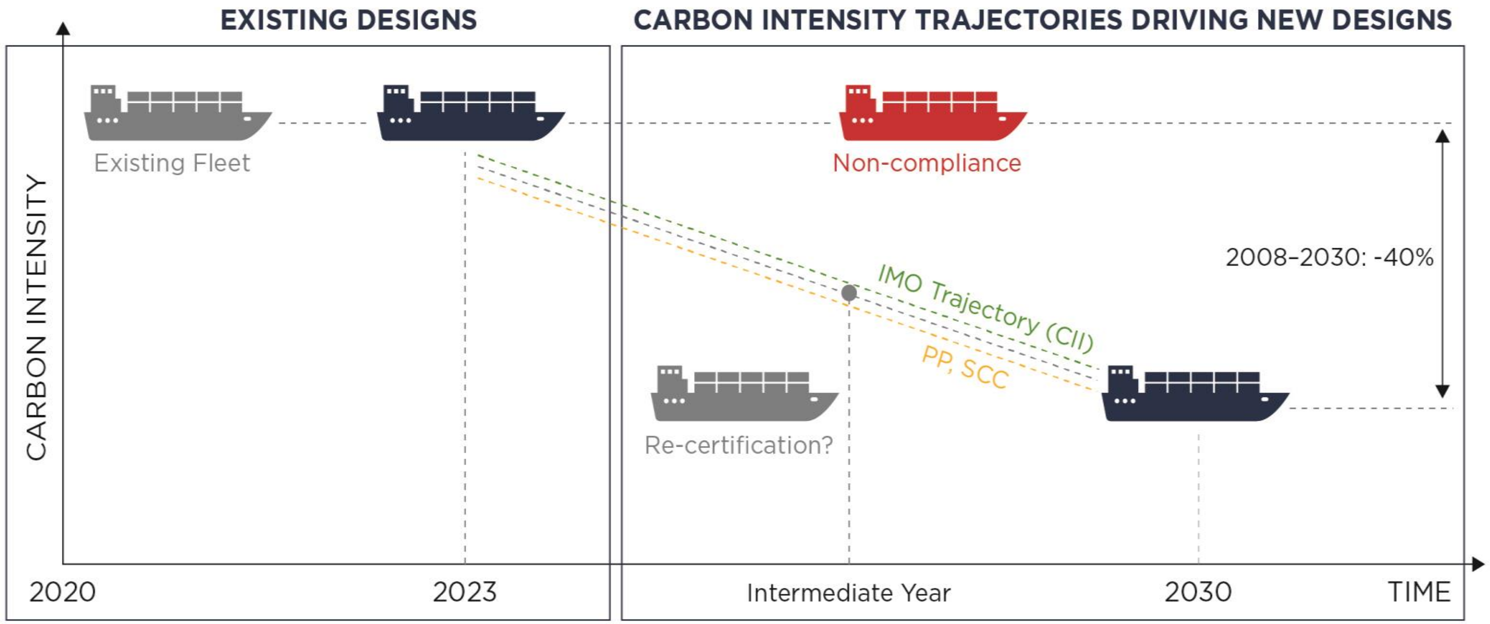
Emissions Regulations

International Maritime Organization (IMO)

European Union

Banks and Charter Parties

- By 2030, reduce $CO_2$ emissions per cargo transport work by 40%, aiming for 70% in 2050 compared to 2008
- By 2050, reduce total GHG emissions by at least 50% compared to 2008



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# Potential Impacts on World Fleet ( >60k vessels)

Number of vessels requiring improvement to become Energy Efficiency Index (EEXI) compliant

| | |
|---|---|
| Bulk Carriers | 87% Sample 11,179 vessels |
| Container Ships | 88% Sample 5,080 vessels |
| Tankers | 85% Sample 9,546 vessels |
| Gas Carriers | 95% Sample 1,705 vessels |

Percent of vessels requiring an operational change or **improvement by 2030 to stay within A, B or C** for Carbon Intensity Index (CII) compliance

| | 2020 |
|---|---|
| Bulk Carriers | 82% Sample 1,377 Vessels |
| Container Ships | 78% Sample 731 Vessels |
| Tankers | 70% Sample of 1,110 Vessels |
| Gas Carriers | 80% Sample 128 Vessels |
| LNG Carriers | 54% Sample 98 Vessels |



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# Decarbonization Solutions

**Alternative Fuels and Energy Sources**

- LNG
- Hydrogen
- LPG/Ethane
- Ammonia
- Methanol (Regional)
- Biofuels (Regional)
- Biofuels (Global)

**Technology Improvements**

- Air Lubrication
- Improved Hull and ESD Options
- Wind/Solar
- Hybrid
- Fuel Cells
- Electric Propulsion
- Cold Ironing
- Carbon Capture (Shore/Ship)

**Operational Efficiency**

- Weather Routing
- New Charter Arrangements
- Speed Optimization
- Just in Time Shipping
- Vessel Performance Reporting
- Smart Vessel/ Improved Reliability
- Fleet Interactive Performance/ Optimization

**Pathway to 2050**

**2050**



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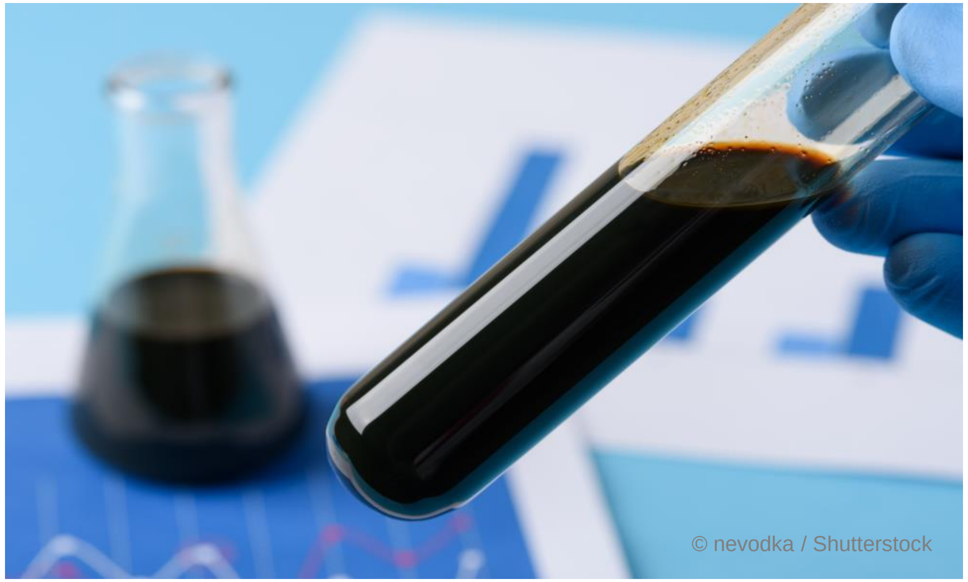
# Compliance Options

**MGO – Marine Gas Oil**
**MDO – Marine Diesel Oil**
**VLSFO – Very Low Sulfur Fuel Oil**
**ULSFO – Ultra Low Sulfur Fuel Oil**
**GTL – Gas To Liquid**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## DISTILLATE OR BLENDED FUELS

- MGO 0.1%
- MDO 0.5%S
- New marine fuels, 'Hybrid' - residual or distillate source
- VLSFO 0.5%
- ULSFO 0.1%

## HIGH SULPHUR FUELS

- With Exhaust Gas Cleaning Systems (EGCS)

## ALTERNATIVE FUELS

- LNG
- **Methanol**
- Ethane
- LPG
- Ammonia
- Hydrogen

## NEW FUELS

- Bio-fuels
- GTL
- Synthetic fuels
- e-fuels

# Alternative Fuels Comparison

| Fuel | Boiling point (ºC) | Safety Risk | Storage volume compared to MGO | Infrastructure | Tank-to-wake $CO_2$ emissions | Impact on newbuilding ship cost |
|---|---|---|---|---|---|---|
| Hydrogen ($H_2$, liquid) | -253 | High | 4.1 | Nothing available<br>Costly to establish and transport | None | High |
| Ammonia ($NH_3$) | -33 | Medium | 3.4 | Existing LPG network could be used<br>> 700 LPG carrier | None | **Medium** |
| Methanol ($CH_3OH$) | 65 | Low | 2.3 | Infrastructure in place available in many ports | Similar to MGO | Low |
| Methane ($CH_4$) | -163 | Low | 1.6 | **Infrastructure under development, costly to transport** | **Reduced compared MGO** | **Medium / High** |
| Diesel ( $C_{16}H_{34}$ ) | 360 | Low | 1.0 | Infrastructure in place worldwide | Same as MGO | Low |

* Capturing CO2 results in lower production efficiency

# Challenges with Alternative Low Flashpoint Fuels

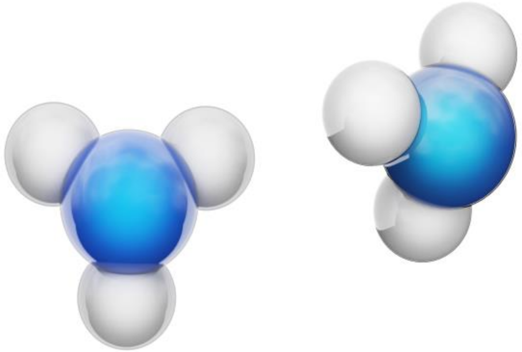
- Supply infrastructure
- Lack of marine fuel quality standards and other regulations
- Low overall industry experience level
- Fuel properties, i.e. flashpoint, toxicity, cryogenics, etc.
- Similar safety concepts to natural gas (i.e. double barriers, ventilation, gas detection, hazardous areas, etc.) but no single safety framework, fuel specific solutions, risk assessment

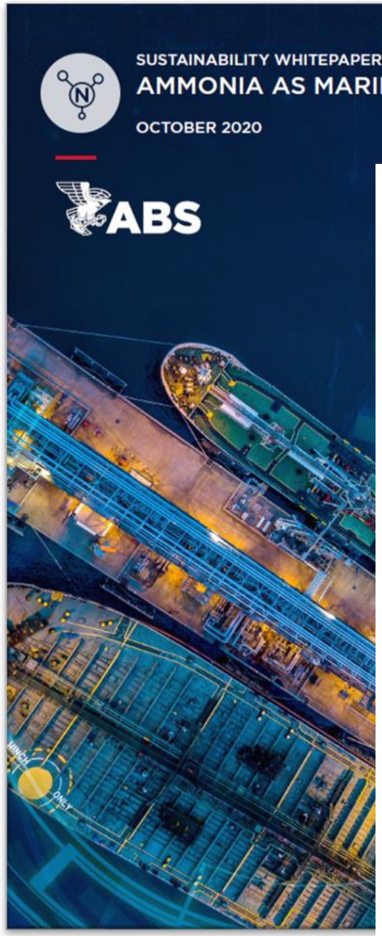
| | MGO | HFO | Methane (LNG) | Ethane | Propane | Butane | DME | Methanol | Ethanol | Hydrogen | Ammonia |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Chemical Composition | | | $CH_4$ | $C_2H_6$ | $C_3H_8$ | $C_4H_{10}$ | $C_2H_6O$ | $CH_3OH$ | $C_2H_5OH$ | $H_2$ | $NH_3$ |
| Boiling Point, deg.C 1bar | 180-360 | 180-360 | -161.5 | -89 | -43 | -1 | -25 | 65 | 78 | -253 | -33 |
| Density, kg/m^3 liquid | 900 | 991 | 430 | 570 | 500 | 600 | 670 | 790 | 790 | 76.9 | 696 |
| LHV, MJ/kg | 42.7 | 40.2 | 48 | 47.8 | 46.3 | 45.7 | 28.7 | 19.9 | 26.8 | 120.2 | 18.6 |
| Auto ignition temp, deg.C | 250 | 250 | 650 | 515 | 470 | 365 | 350 | 450 | 420 | 535 | 630 |
| Flash point, deg.C | >60 | >60 | -188 | -135 | -104 | -60 | -41 | 11 | 16 | - | 132 |
| Flammable Range, % vol in air | 0.6-7.5% | 0.6-7.5% | 5-15% | 2.9-13% | 1.9-9.5% | 1.5-8.5% | 3.3-18% | 5.5-26% | 3.5-15% | 4-74% | 15-28% |
| | | | | | | | | | | | |
| Energy density, MJ/lt | 38.4 | 39.8 | 20.6 | 27.2 | 23.2 | 27.4 | 19.2 | 15.7 | 21.2 | 9.2 | 12.9 |
| Volume comparison MGO | 1 | 0.96 | 1.86 | 1.41 | 1.66 | 1.40 | 2.00 | 2.44 | 1.82 | 4.16 | 2.97 |
| | | | | | | | | | | | |
| CO2 factor, kg CO2/kg fuel | 3.206 | 3.114 | 2.750 | 2.927 | 3.000 | 3.030 | 1.911 | 1.375 | 1.913 | 0 | 0 |
| Carbon content | 0.8744 | 0.8493 | 0.7500 | 0.7989 | 0.8182 | 0.8264 | 0.5214 | 0.3750 | 0.5217 | 0 | 0 |
| CO2, kg CO2/kWh | 0.2701 | 0.2787 | 0.2061 | 0.2205 | 0.2331 | 0.2385 | 0.2397 | 0.2486 | 0.2568 | 0 | 0 |

# Properties of Ammonia

**IDLH** – Immediately Dangerous to Life or Health

- $NH_3$ is a colorless inorganic compound
- $NH_3$ is carbon- and Sulphur-free and gives a clean combustion without generation of $CO_2$ or $SO_X$
- Liquefied by compression to approximately 8 bar
- Commonly stored at ~17 bar, to keep in liquid phase if ambient temperature increases
- **Toxicity**: 2,700 PPM at 10 min is IDLH by AEGL-3
- Relatively low volumetric energy density - impact on tank size






## AMMONIA SAFETY

| Ammonia Property | Value |
|---|---|
| Energy density (MJ/L) | 12.7 |
| Latent heat of vaporization (MJ/kg) | 188 |
| Heat of vaporization (kJ/kg) | 1371 |
| Autoignition temperature (°C) | 651 |
| Minimum ignition energy (mJ) | 680 |
| Liquid density ($kg/m^3$) | 600 |
| Adiabatic flame temperature at 1 bar (°C) | 1800 |
| Molecular weight (g/mol) | 17.031 |
| Melting point (°C) | -77.7 |
| Boiling point at 1 bar (°C) | -33.6 |
| Critical temperature (°C) | 132.25 |
| Critical pressure (bar) | 113 |
| Flammable range in dry air (%) | 15.15 to 27.35 |
| Cetane number | 0 |
| Octane number | -130 |



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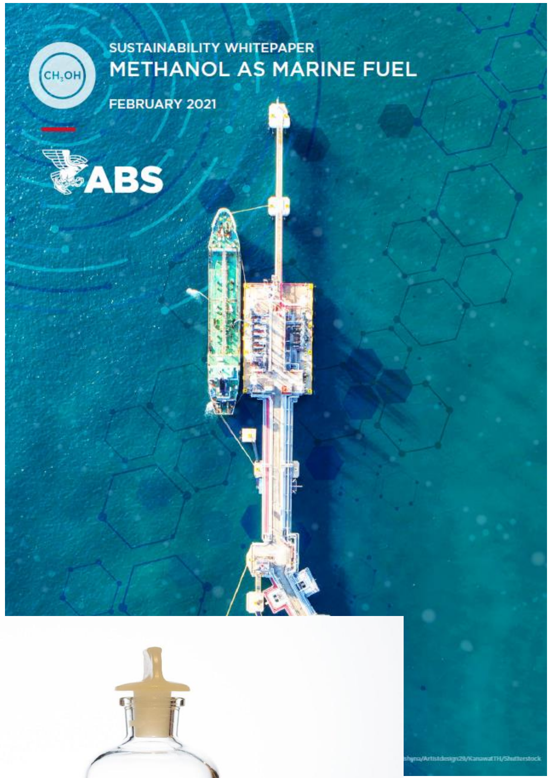
# Properties of Methanol

IDLH – Immediately Dangerous to Life or Health
NIOSH – National Institute for Occupational Safety and Health

- Methanol is a **colorless liquid, stored at atmospheric temperature and pressure**
- Methanol is the simplest alcohol and sulfur-free, giving clean combustion without generation of $SO_x$
- Relatively low volumetric energy density
- Flammability range 6% – 36.5%
- **Toxicity**: 6,000 ppm IDLH NIOSH
- Can be produced from natural gas and sustainable sources





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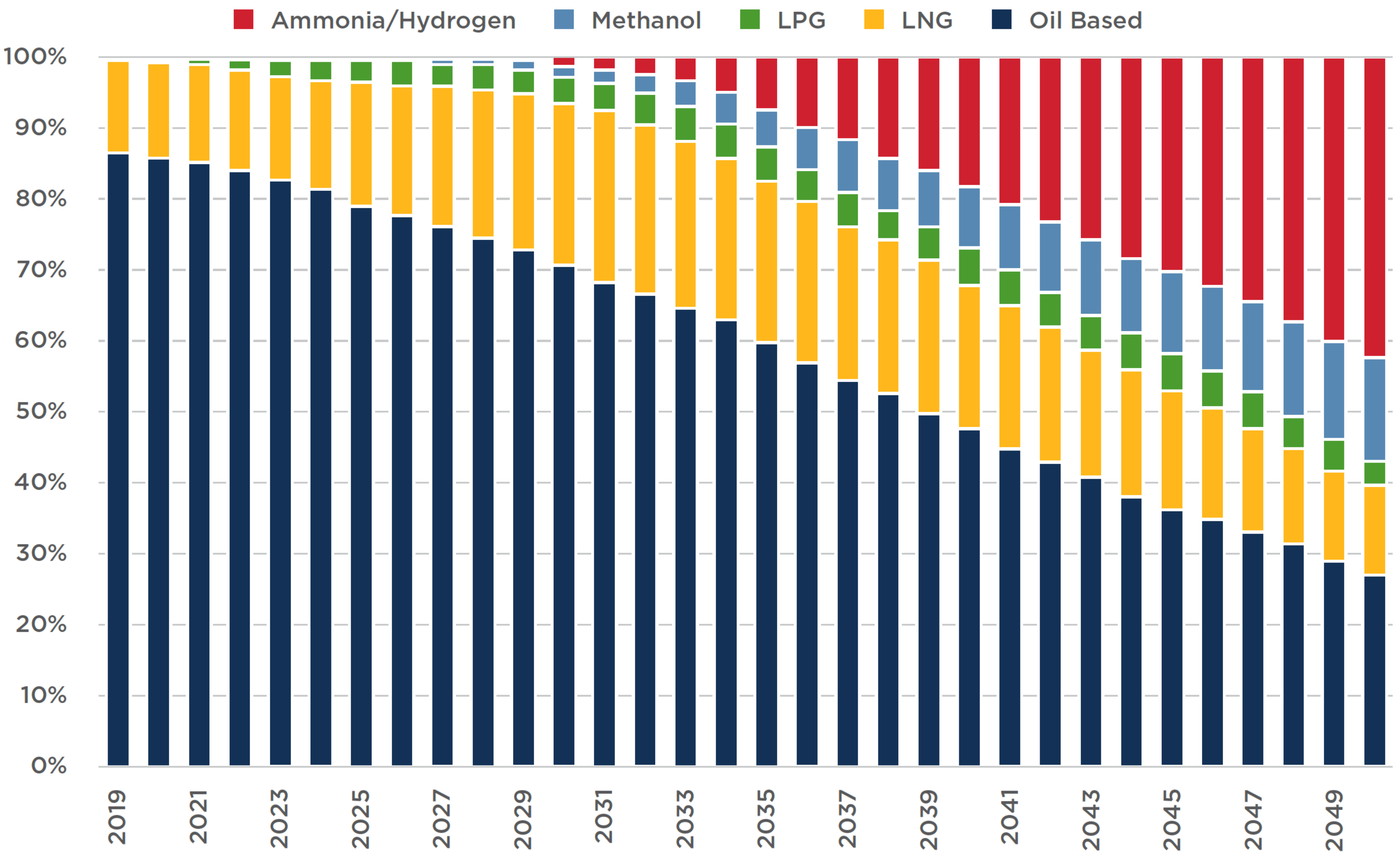
| METHANOL PROPERTY | VALUE |
|---|---|
| Energy density (MJ/L) | 15.7 |
| Heat of vaporization (kJ/kg) | 1098 |
| Autoignition temperature (°C) | 450 |
| Liquid density (kg/m3) | 798 |
| Adiabatic flame temperature at 1 bar (°C) | 1980 |
| Molecular weight (g/mol) | 32.04 |
| Melting point (°C) | -97.8 |
| Boiling point at 1 bar (°C) | 65 |
| Critical temperature (°C) | 239.4 |
| Critical pressure (bar) | 80.48 |
| Flammable range in dry air (%) | 6 – 36.5 |
| Cetane number | < 5 |
| Octane number | 109 |
| Flash point (°C) | 12 |
| Heavy Fuel Oil (HFO) equivalent volume | 2.54 |

# Potential Fuel Mix Forecast



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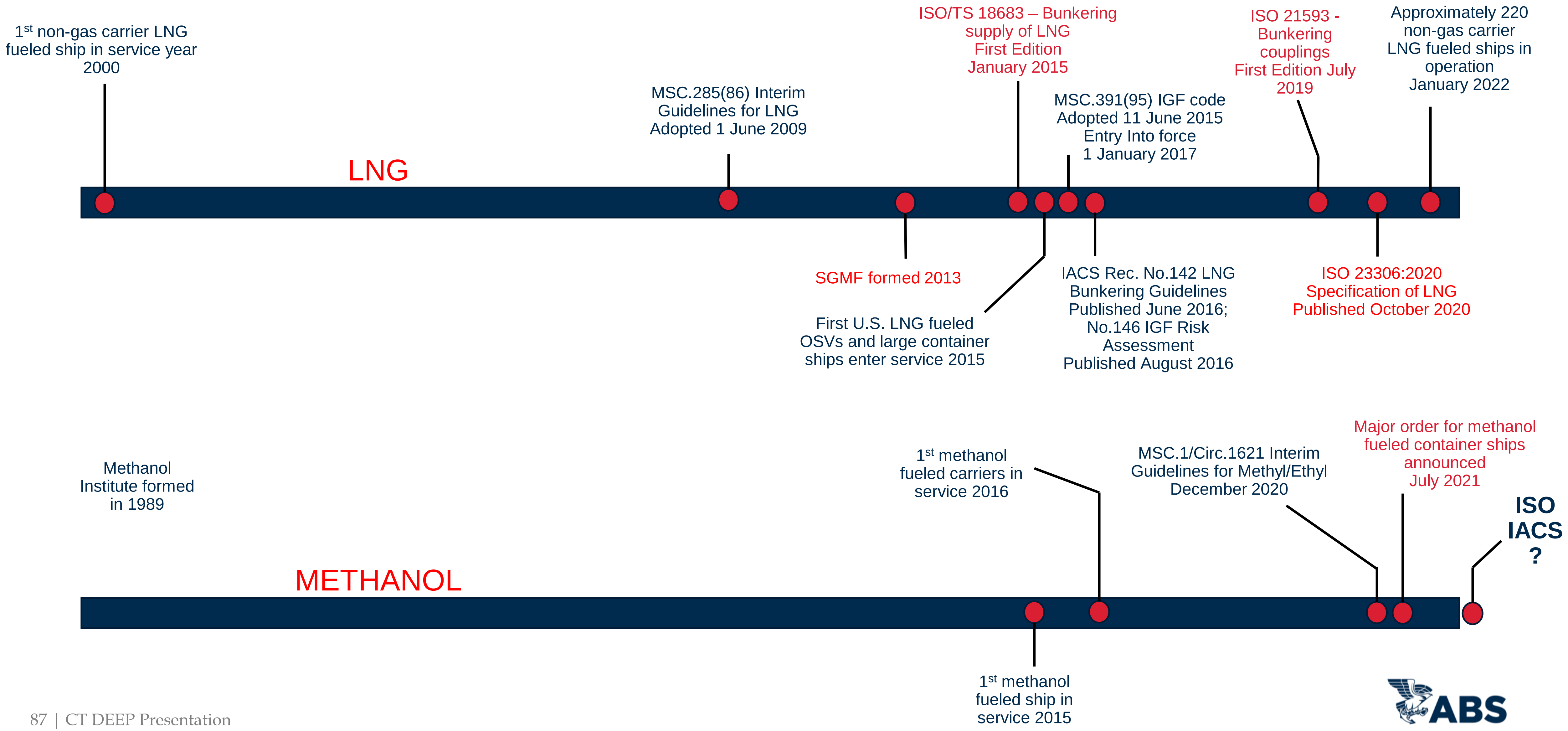
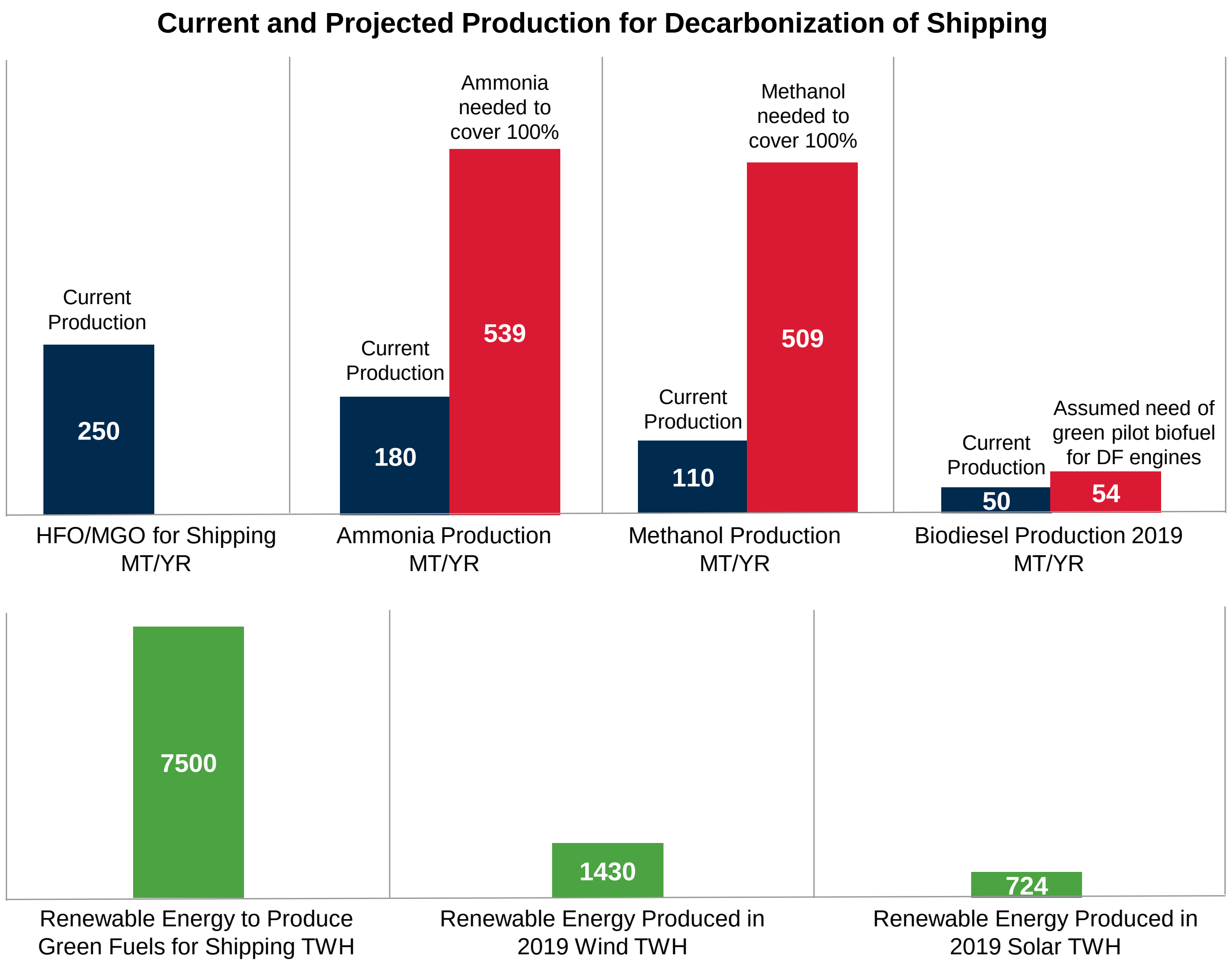
# Stages of Development



# Production Scaling – The Challenge

- To replace the amounts of heavy fuel oil (HFO)/MGO currently used by the shipping sector, increased production of green fuels will be required
- If 100% is replaced by green ammonia or green methanol, a 4-5-fold increase in production capacity of those chemicals will be required
- A significant increase of renewable energy is required to produce the green fuels of the future to replace the HFO/MGO for shipping
- Compared to current worldwide wind/solar energy production, a 3-4-fold increase is needed, just to cover shipping decarbonization
- And even more additional renewable energy will be needed for decarbonization of other sectors




Source: Mærsk Mc-Kinney Møller Center for Zero Carbon Shipping



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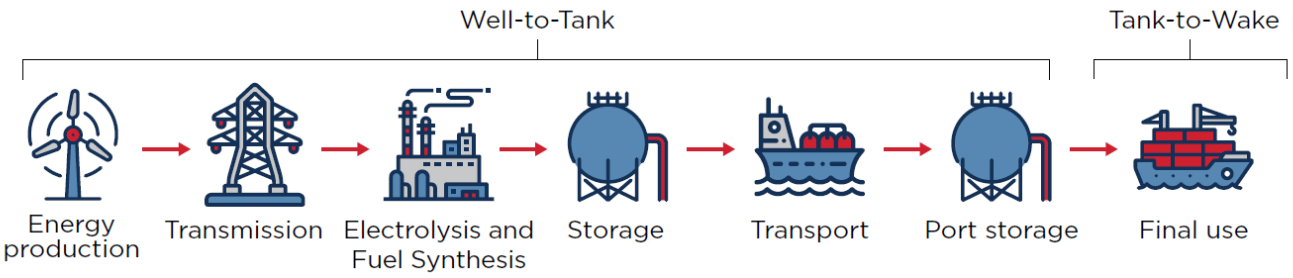
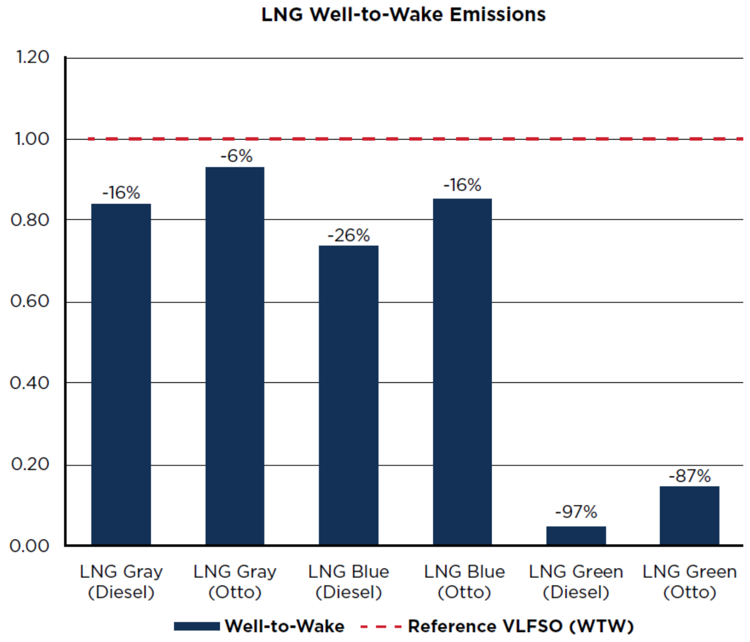
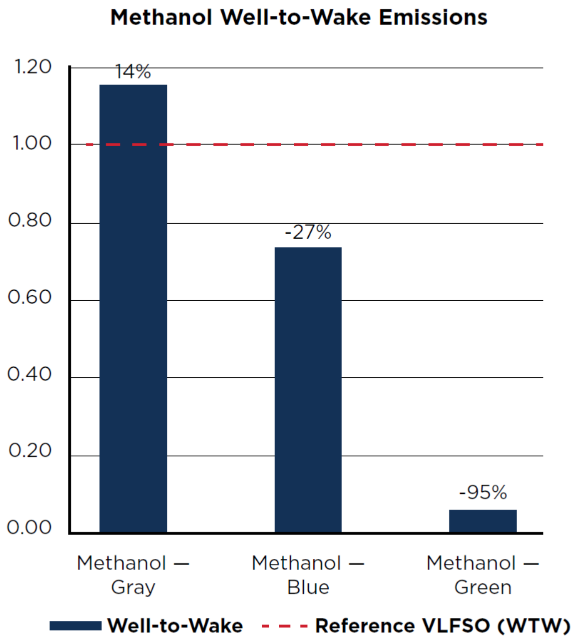
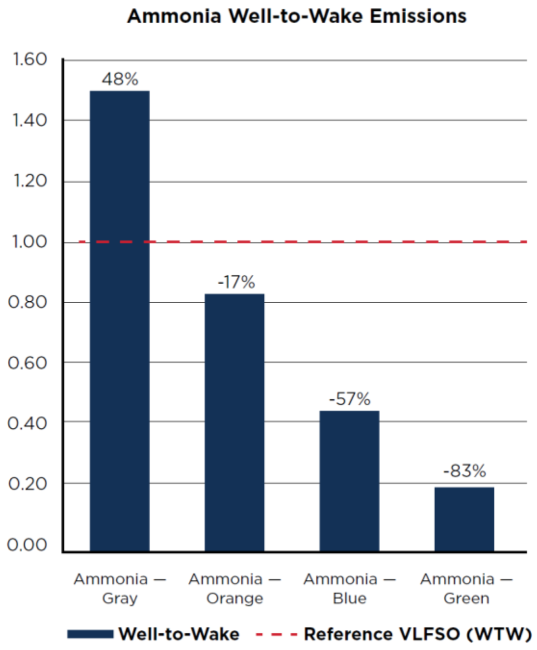
# Life Cycle Analysis of Alternative Fuels



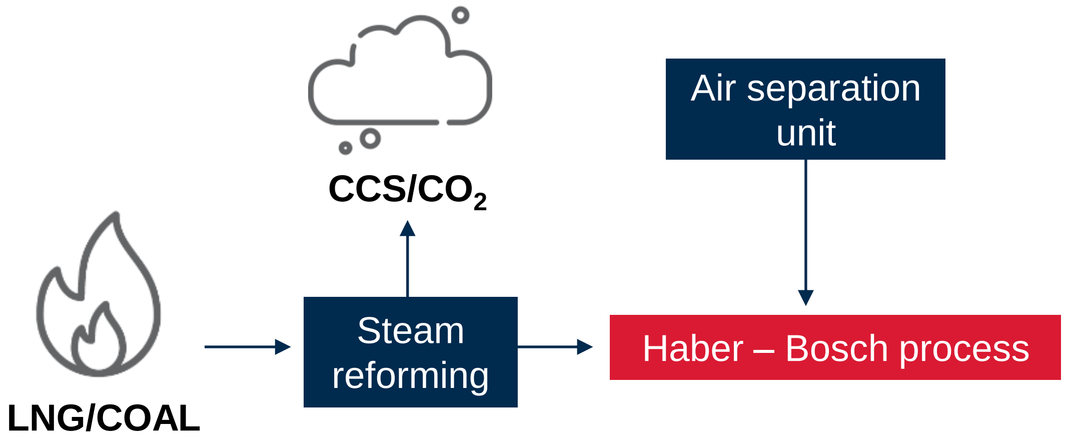



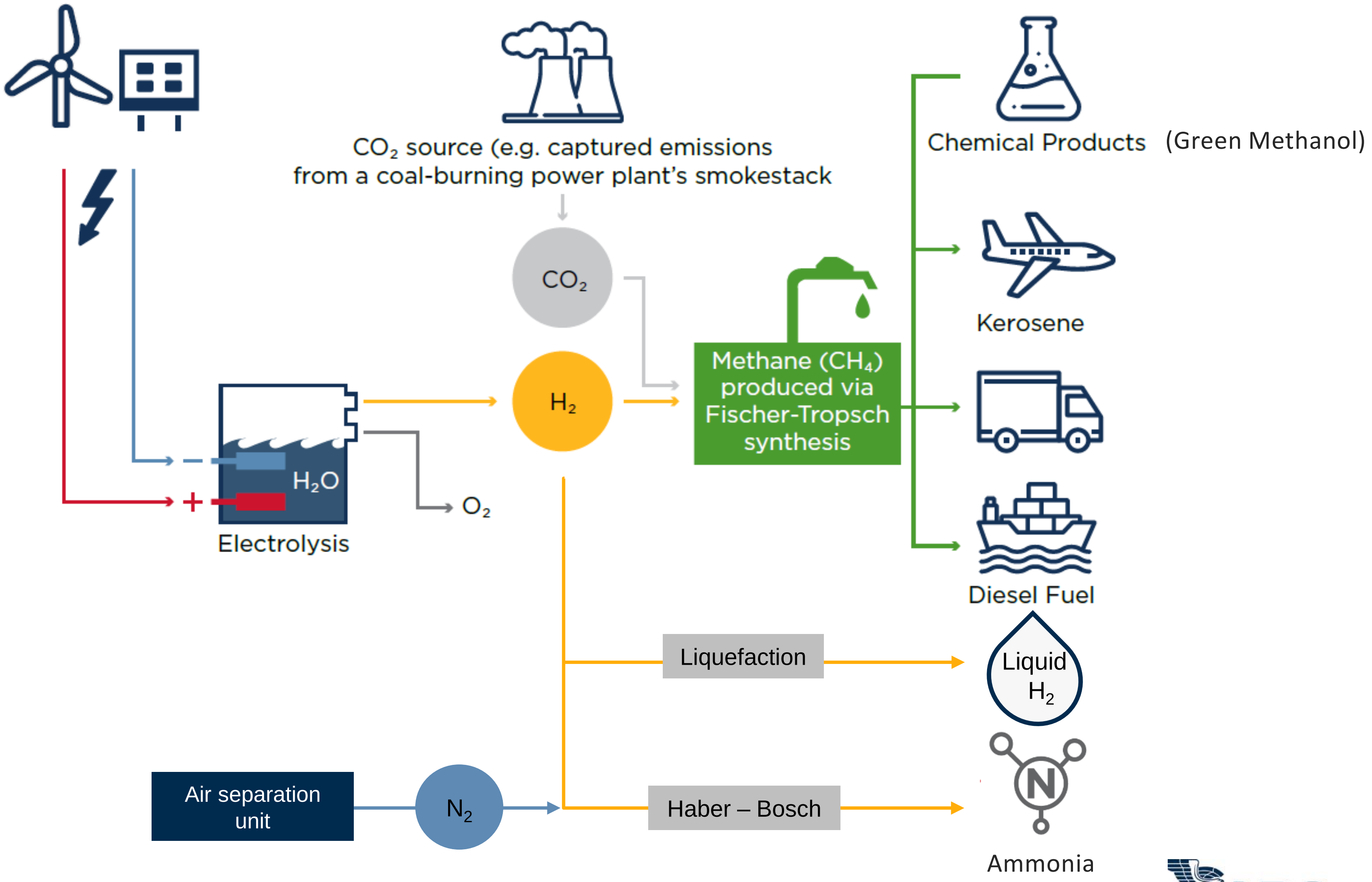
# Fuel Production - Brown vs. Blue

- The production pathways of ammonia and hydrogen are related
- Present – **Brown** ammonia
  - From fossil sources
    - Natural gas (60%) emits 1.6 tons of $CO_2$ per produced ton of ammonia
    - Coal (40%) emits 2.0 tons of $CO_2$ per produced ton of ammonia
  - Extraction of hydrogen and then synthesis with nitrogen
- Future – **Blue** ammonia
  - Using the carbon capture and storage (CCS) technology on brown ammonia production
    - Technology is being used today in small scale



# Fuel Production – Green

- Future – **Green** ammonia
  - **Green** hydrogen extracted from water by energy that comes from renewable electricity:
    - Solar farms
    - Wind farms
    - Hydro power
    - (Nuclear)
  - Synthesis with nitrogen
    - Nitrogen from air which contains 78% nitrogen



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# Key Takeaways

- Drivers for marine decarbonization are strong
- Safety and regulatory framework in place
- Experience and scope of dual-fuel technologies growing
- All alternative low-flashpoint fuels can provide solution for SOx compliance and potential for lower Vessel Energy Index
- Alt Fuels produced using renewable energy can provide route to zero and low carbon future
- Scaling the infrastructure to provide fuel for the future vessels will be a limiting factor





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# ABS Support

- We offer a suite of guidance documents and services to support your next alternative fuel project
- Need assistance? Contact us at sustainability@eagle.org
- Interested in learning more? Visit www.eagle.org/sustainability




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# Thank You

www.eagle.org

# Conservation Law Foundation (CFL)

# Challenges with Alternative Fuels

Chase Whiting, Conservation Law Foundation

November 4, 2022

conservation law foundation

# Measure twice. Cut once.

**A well-designed plan to decarbonize buildings is critical for Connecticut to meet state climate targets and prevent the worst harms of climate change.**

**A poorly designed plan could lock in high emissions and high costs and could leave Connecticut residents with stranded assets.**

**Alternative fuels should be used sparingly and strategically:**

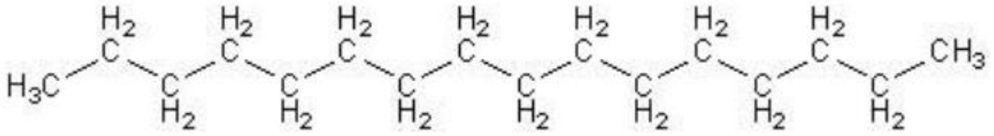
- Replace fossil fuels in applications that cannot otherwise be electrified.
- Not a viable climate solution when used at scale for heating buildings.

# Infrastructure & Emissions

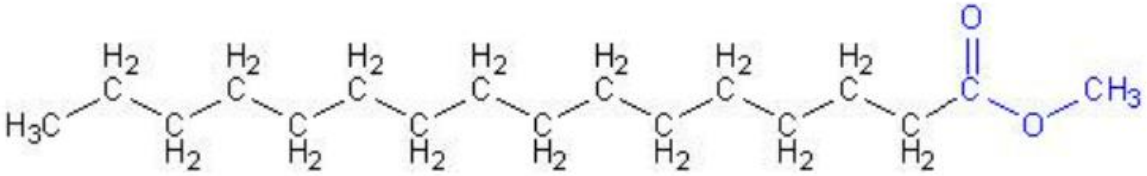
conservation law foundation

# Biofuels are a lot like fossil fuels when burned in thermal infrastructure

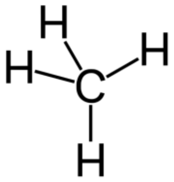
**Hydrocarbons:** Made from hydrogen and carbon



**Diesel**

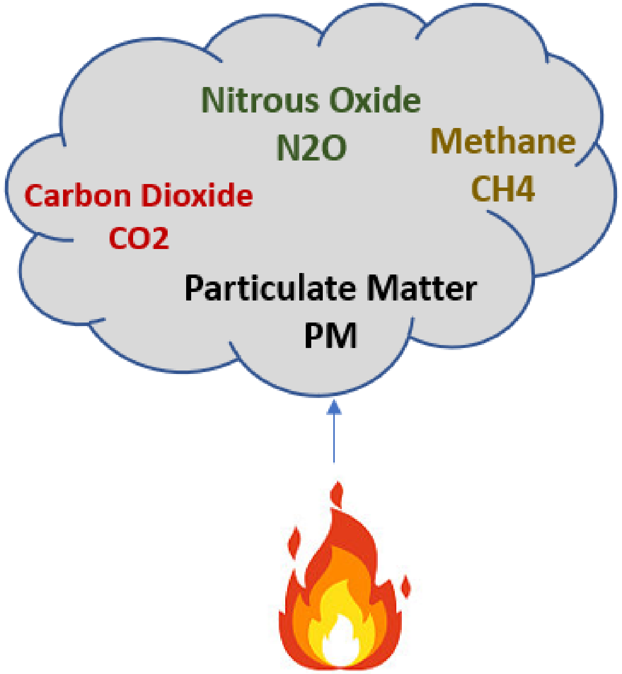


**Biodiesel**



**Natural Gas &**
**Renewable Natural Gas**

**They Cause Similar Emissions When Combusted**




conservation law foundation

# Biofuels’ infrastructure has process emissions

ENERGYWIRE

NATURAL GAS & 8 OTHERS

## Biogas releasing more methane than previously known — study

Researchers say methane emissions from biofuels "may jeopardize Paris Agreement targets."

BY: CAMILLE BOND | 08/10/2022 06:57 AM EDT

A new study reports that biogas, such as that produced from anaerobic digesters (pictured), releases more methane in its supply chain than previously believed. Biogas and biomethane are being viewed as renewable alternatives to natural gas.

“biomethane production may lose its advantages as a clean-energy technology and may jeopardize Paris Agreement targets if used extensively.”

Source: Bakkaloglu et al, *Methane Emissions Along Biomethane and Biogas Supply Chains Are Underestimated*, 5 One Earth 724-736 (2022).

Methane also leaks from pipeline distribution infrastructure and from home infrastructure, such as stoves.

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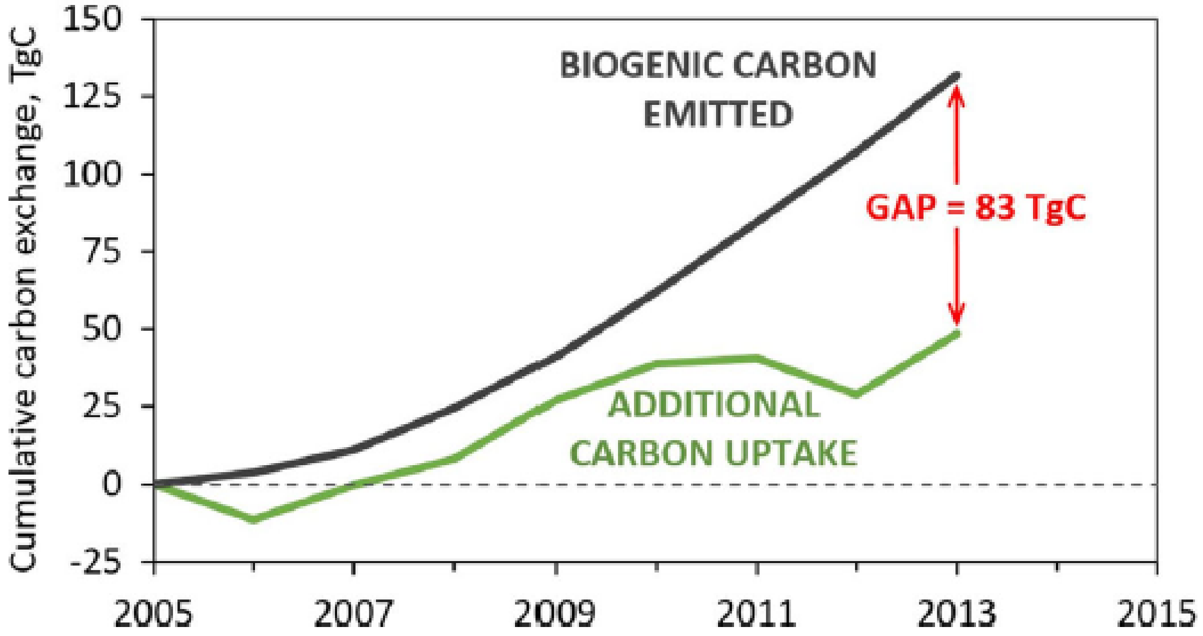
# Not all CO2 emissions are resequestered

**Fig. 4** Cumulative carbon emitted by U.S. biofuel use compared to cumulative additional carbon uptake on cropland




**The "Carbon Neutrality Gap": Only 37% of biofuel emissions were removed from the atmosphere, causing a *net increase* in atmospheric CO2**

Source: John DeCicco, *et al*, *Carbon balance effects of U.S. biofuel production and use*, 138 Climate Change 667-680 (2016).

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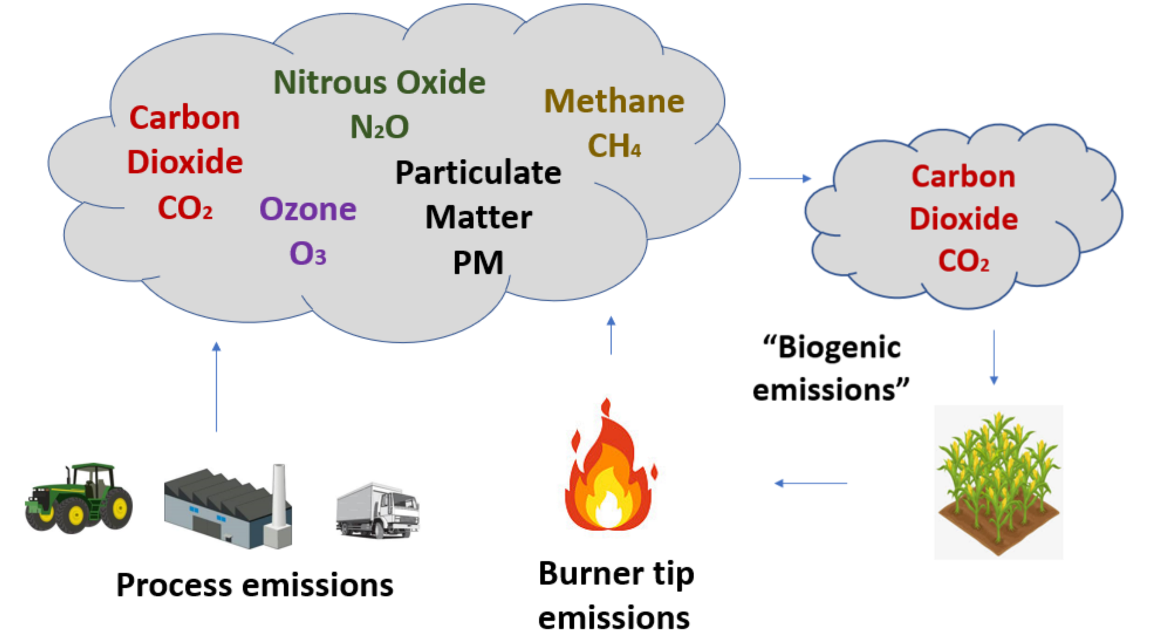
# Assumptions about biofuels overlook real emissions

In Connecticut's Greenhouse Gas Emissions Inventory, **"biofuels are treated as carbon neutral"** when they are burned for building heating.

Source: Connecticut Department of Energy and Environmental Protection, *Proposed Methodology for Electric-Sector GHG Accounting: Presentation*, 31 (Oct. 26, 2021).




**On paper, it looks like replacing fossil fuels with biofuels significantly reduces greenhouse gas emissions. However, the real greenhouse gas emissions caused by biofuels accumulate in the atmosphere and cause additional climate change.**

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# Infrastructure & Stranded Assets

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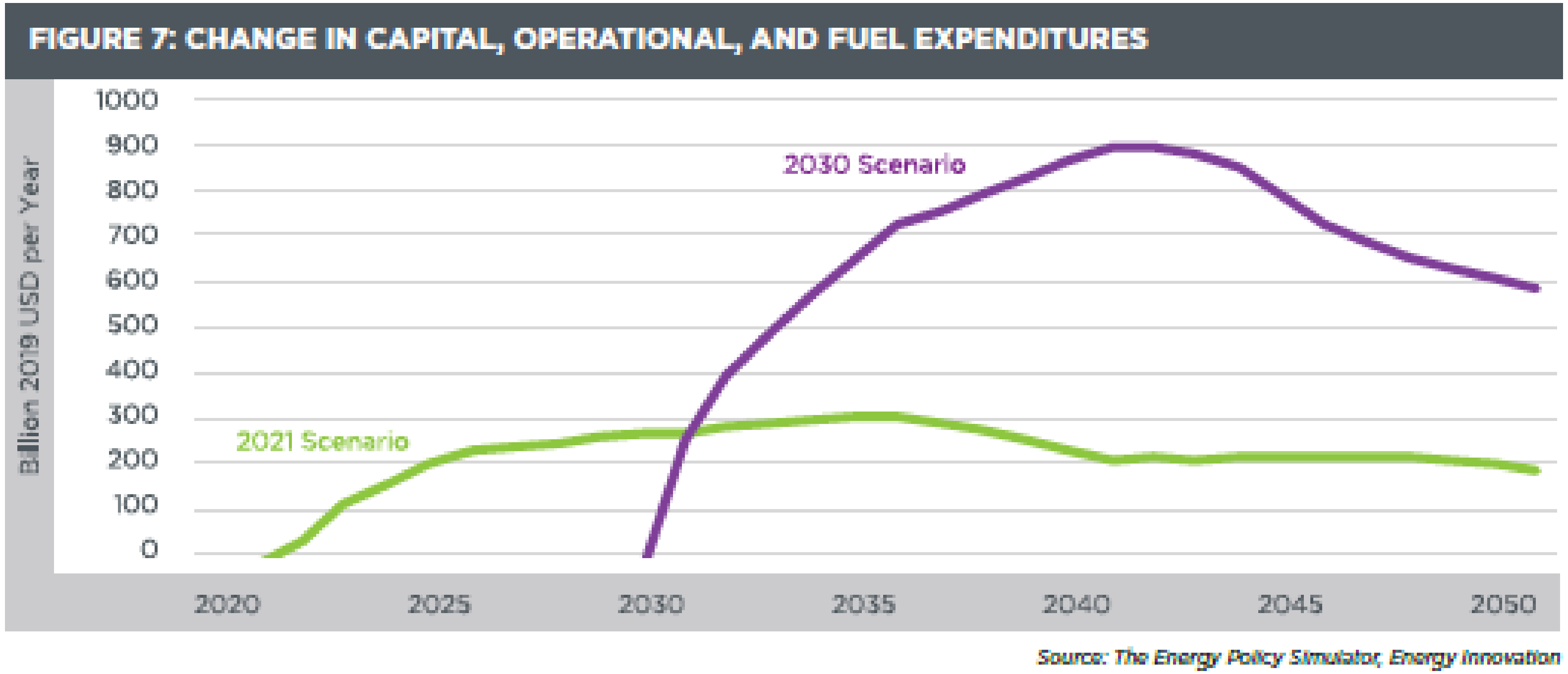
# Infrastructure decisions today determine costs tomorrow




"If we continue to buy and build polluting power plants, factories, and equipment for the next decade, and then decide we must make the clean energy transition fast to avoid climate damages, we will need to retire much more polluting equipment before the end of its functional life. And that isn't cheap."

Source: Hal Harvey, *et al*, *The Costs of Delay*, Energy Innovation Policy & Technology (2021)

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# Stranded Assets

A heating system installed today will likely last 20 years or longer. This means that all new heating systems should be consistent with state climate goals.

Installing biofuel compatible heating equipment is a risky investment because this infrastructure may need to be removed before the end of its useful life.

Residents could get stuck with high costs by having to replace relatively new and otherwise functional heating infrastructure.

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# High Costs

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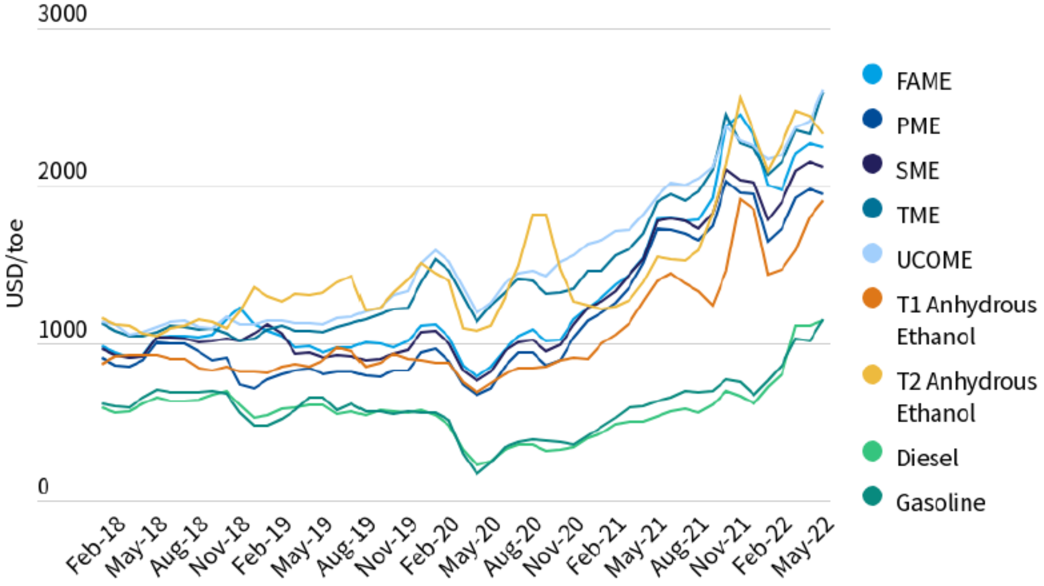
# Biofuels are expensive

**Biofuels have consistently been more expensive compared to fossil fuels over last several years**




Source: T&E analysis based on data provided by Stratas Advisors

**Figure 1: Recent wholesale price developments (USD/toe) across the main fossil fuels and biofuels** (FAME: Fatty Acid Methyl-Esters, PME: Palm Methyl Ester, SME: Soybean Methyl Ester, TME: Tallow Methyl Ester, UCOME: UCOME: Used Cooking Oil Methyl Ester, T1: EU bioethanol imports, T2: EU domestic bioethanol production).

"Depending on the feedstock, the energy delivered by biodiesel currently costs 70%-130% more than fossil diesel. Based on May 2022 prices, the mandatory blending of biofuels costs European citizens €17 billion more per year."

Source: T&E (Transport & Environment), *Billions Wasted on Biofuels* (June 2022).

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# Conclusion

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# Connecticut should not rely on biofuels as a climate strategy

Increased biofuel blending would:

1) Prolong Connecticut's reliance on fossil fuels.
2) Make it harder for the state to achieve its climate goals because of emissions from burning biofuels, from biofuel production and transport, and from the fossil fuels blended with biofuels.
3) Likely result in stranded assets, since it's probable that Connecticut would need to discontinue the use of blended biofuels before the infrastructure reaches the end of its useful life.
4) Probably increase heating costs for Connecticut residents.

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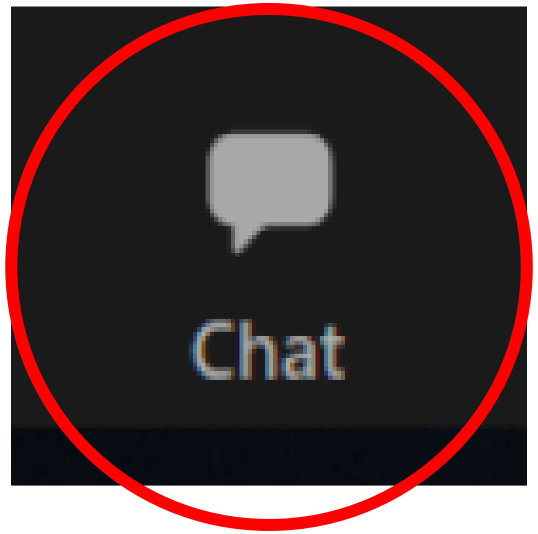
# Questions




At the conclusion of each panel DEEP will hold a brief question and answer period.

If you have a question for a presenter, please drop it into the chat to **Jeff Howard**. DEEP will pose as many questions as time allows to the speakers. Clarifying questions will be prioritized. Leading questions will not be accepted.

# Strategies for Optimal Use of Alternative Fuels

Robert Bell – CT Department of Transportation (DOT)

Tessa Weiss – RMI

Emily Kent – Clean Air Task Force (CATF)

Erin Childs - Strategen

(speaker order may vary)

BUREAU OF ENERGY AND TECHNOLOGY POLICY

# CT DOT


# Connecticut's Alternative Fuel Corridors

DEEP Technical Session: Alternative Fuels
November 4, 2022

Robert Bell
Connecticut Department of Transportation

# The Alternative Fuel Corridors Program


Section 1413 of the Fixing America's Surface Transportation (FAST) Act requires the U.S. DOT to **designate alternative fuel corridors** along the National Highway System.

Administered by the Federal Highway Administration (FHWA) to improve/promote an interstate network of stations to enhance the reliability/mobility of alternative fuel vehicles.

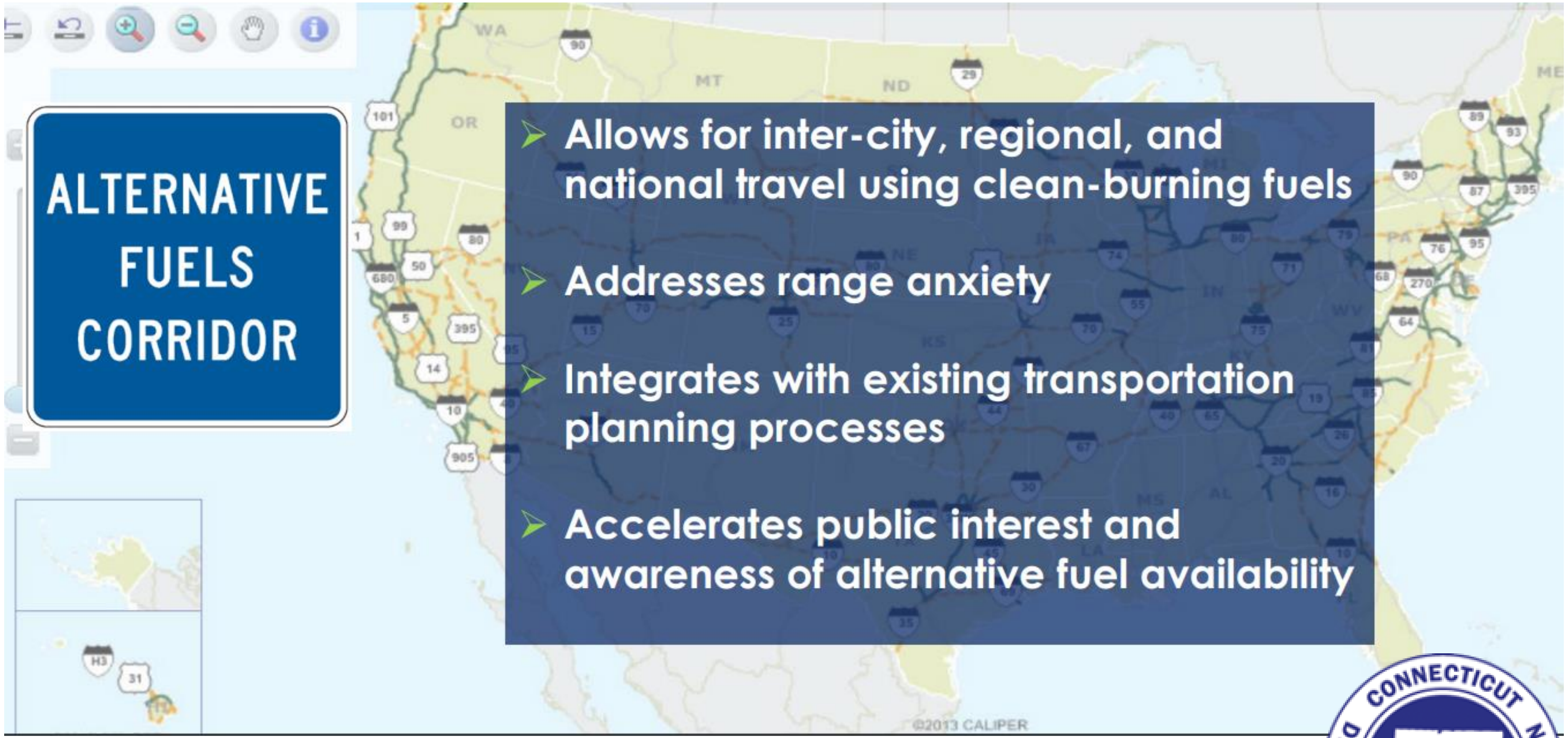
Designated national corridors along major highways are **identified by fuel type**:

- ➢ Plug-In Electric Vehicle Charging
- ➢ Hydrogen Fueling
- ➢ Propane (LPG) Fueling
- ➢ Natural Gas (CNG, LNG) Fueling

U.S. Department of Transportation
Federal Highway Administration

CONNECTICUT DEPARTMENT OF TRANSPORTATION

# Benefits of a National System



# Alternative Fuel Corridor Designation Process

- States apply to FHWA for Alternative Fuel Corridor designation
- FHWA reviews applications and designates a corridor either as:
  - Corridor Ready - A ***sufficient number*** of facilities exist on the corridor to warrant installation of highway signage (by fuel type)
  - Corridor/Signage Pending - An ***insufficient number*** of facilities currently exist on the corridor to allow for reliable corridor travel

# FHWA's Corridor-Ready Criteria

| EV | CNG | LNG | Hydrogen | Propane |
|---|---|---|---|---|
| Public Stations Only | Public Stations Only | Public Stations Only | Public Stations Only | Public Stations Only |
| 1 drivable mile from highway exit | 5 miles from highway | 5 miles from highway | 5 miles from highway | 5 miles from highway |
| 50 miles between stations | 150 miles between stations | 200 miles between stations | 100 miles between stations | 150 miles between stations |
| DCFC Only (no Tesla) | Fast fill, 3,600 psi | | | Primary stations only |

# Connecticut's Alternative Fuel Corridors

Connecticut is participant in Program since 2016

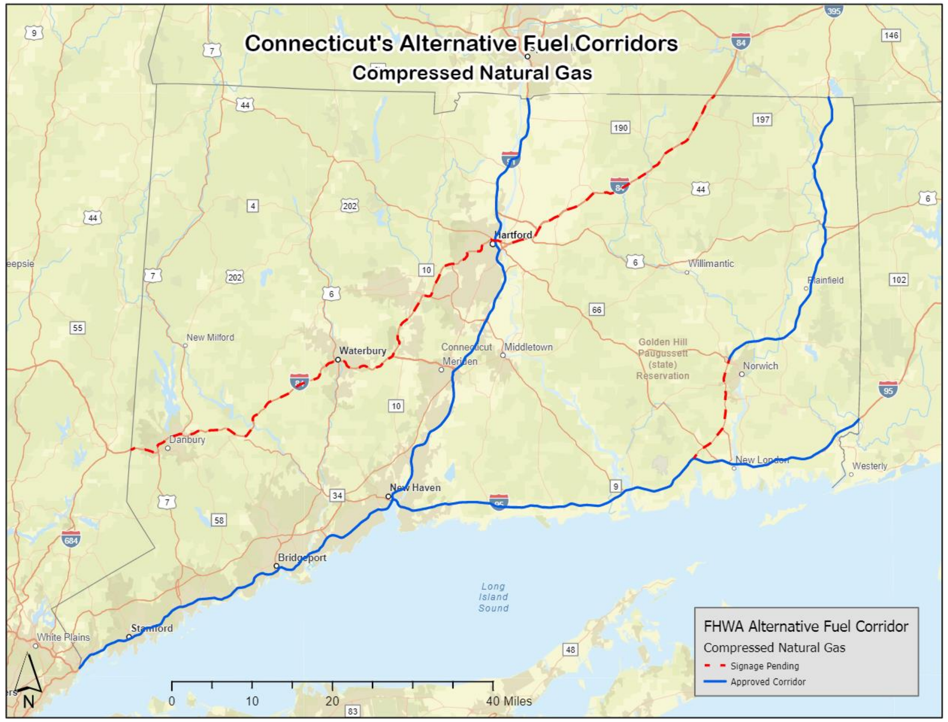

The following Interstate highways are

"FHWA Designated Corridors"

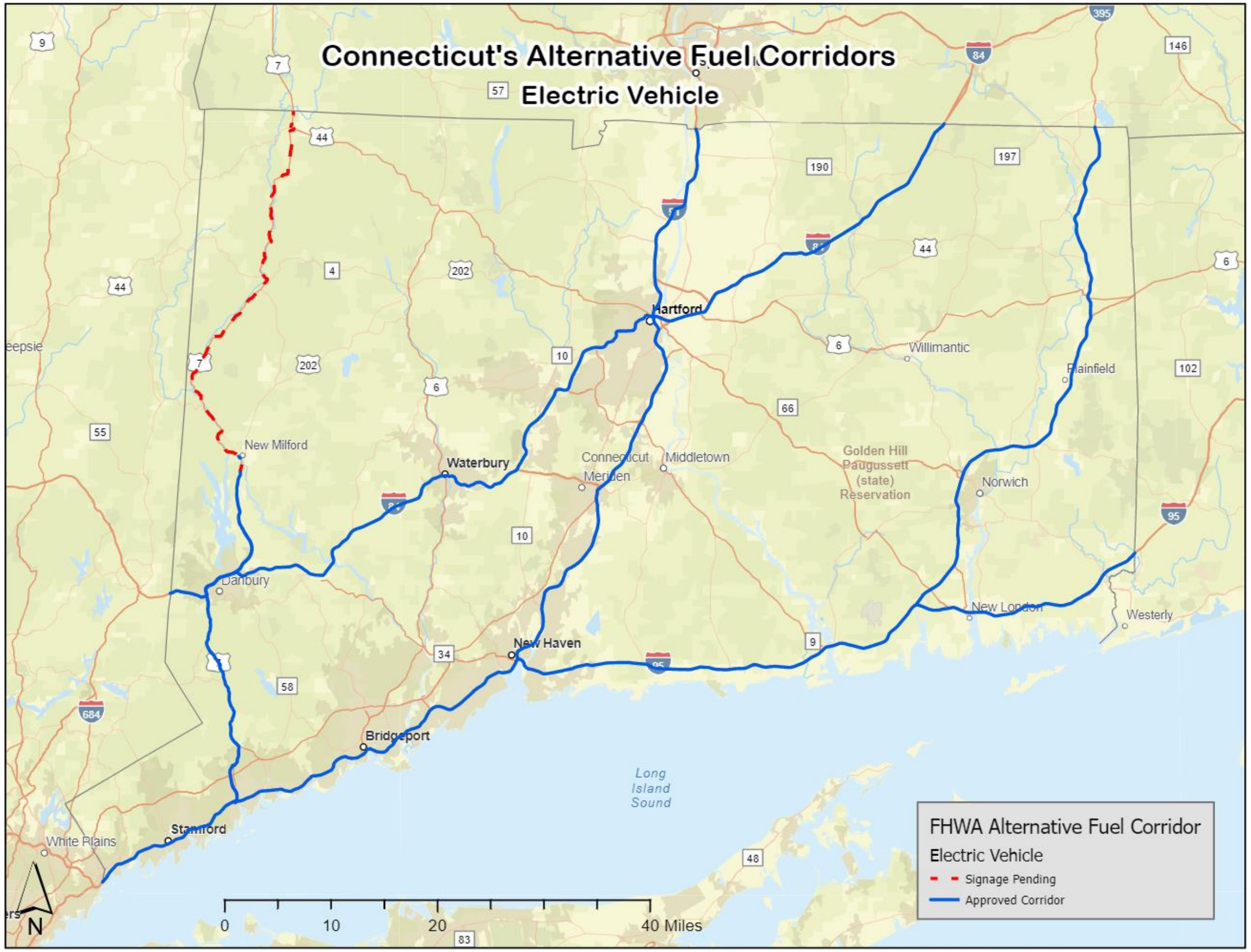
**EV**: I-84 (NY border to MA border)*
I-91 (New Haven to MA border)*
I-95 (NY border to RI border)*
I-395 (Waterford to MA border)
US 7 (between US 7/I-95 interchange in Norwalk and New Milford)

**CNG**: I-91 (New Haven to MA border)
I-95 (NY border to RI border)
I-395 (Norwich to MA border)

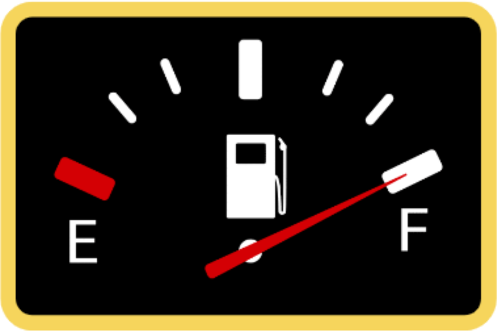
**LPG**: I-84 (NY border to MA border)
I-91 (between I-91/I-95 interchange in New Haven and the MA border)




# Connecticut's EV Corridors



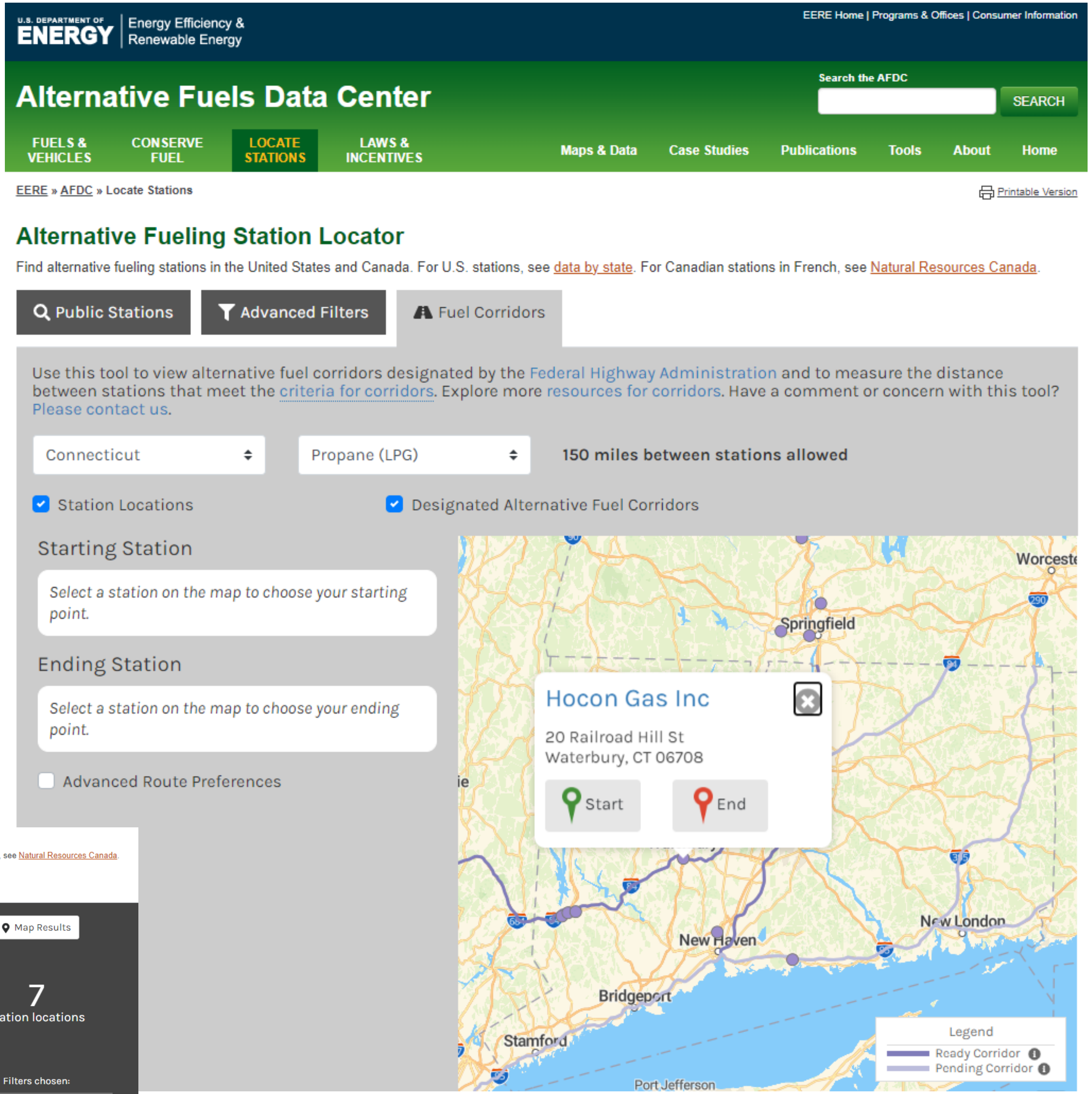
# Connecticut's Pending Corridors

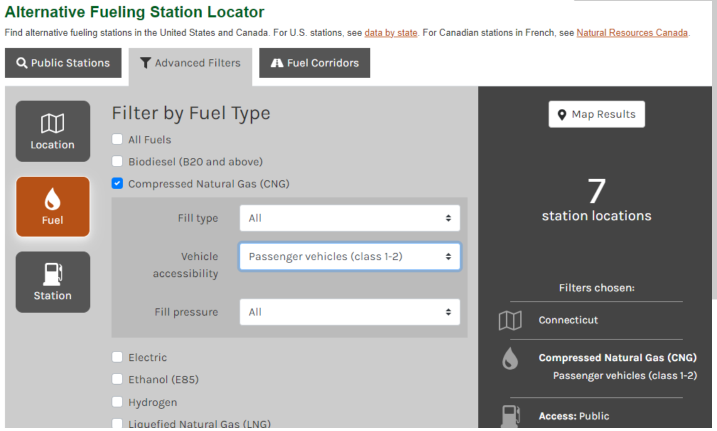



- **EV**: US 7 (New Milford to CT/MA border)
- **CNG**: I-395 (between the I-395/I-95 interchange in East Lyme and Norwich)
  I-84 (NY border to MA border)
- **LPG**: I-84 (between South Windsor and CT/MA border)
  I-95 (NY border to Guilford)
  I-395 (Waterford to MA border)
- **Hydrogen**: I-84
  I-91
  I-95
  I-395

**Corridor-Pending: DO NOT have sufficient fuel facilities to support alternative fuel vehicle travel**

# Alt. Fuels Data Center




[Alternative Fuels Data Center: Alternative Fueling Station Locator (energy.gov)]

# Current and Near-Term Activities

- opportunities/funding for building alternative fuel infrastructure along CT's Alt. Fuel Corridors
  - IIJA Formula Funding: NEVI Funds to Build out EV Fast Charging
    - $52 million over 5 years in CT
    - Phase 1 focused on AFCs

[Sustainability & Resiliency Unit (ct.gov)]


- IIJA Discretionary Funding: Community & Corridor Charging grant program
  - $2.5B nationwide in community grants for EV charging, plus Hydrogen, Natural Gas, and Propane fueling infrastructure
  - FHWA's Notice of Funding Opportunity not released yet

# CTDOT's Alternative Fuel Coordinator


- Participates in state, regional, and national discussions and activities around alternative fuel technologies
  - Close coordination with FHWA Office
  - Foster awareness of alternative fuel availability
- Monthly meetings with Connecticut Clean City Coordinators
  - Discuss opportunities and identify challenges/solutions to fleet concerns
  - Collaborate on resource for fleets looking at incorporating alt. fuels
- Work with OEMs and Fueling Distributors to understand challenges/needs to promote Alt. Fuels within the state
- Works with MPOs, COGs, DEEP and others to identify future Alt. Fuel Corridors

CONNECTICUT DEPARTMENT OF TRANSPORTATION

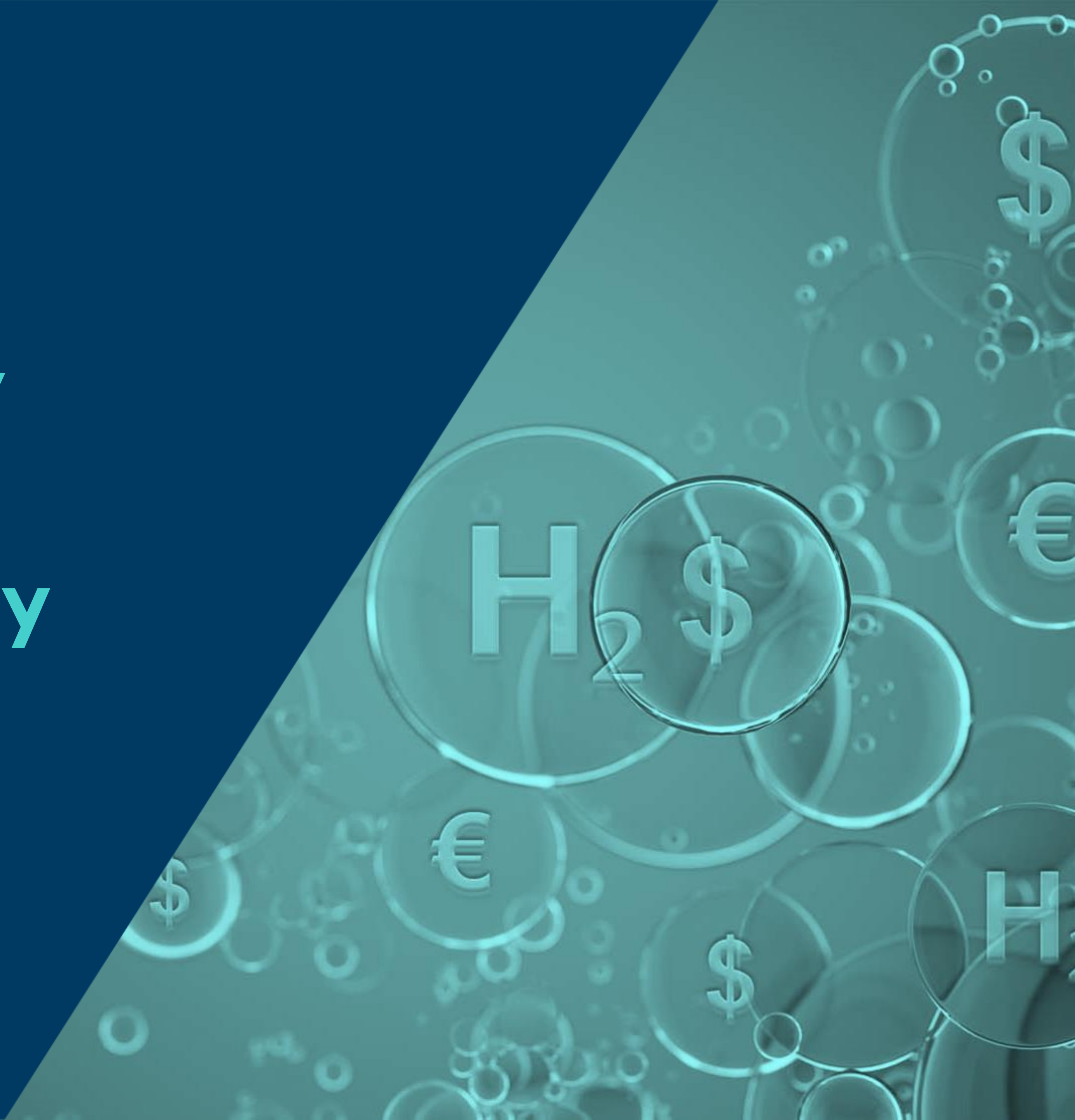
# For Additional Information Please Contact

**Jennifer Reilly**
Connecticut Department of Transportation
Alternative Fuel Coordinator
Jennifer.Reilly@ct.gov
860-594-2143

# RMI

RMI
ENERGY. TRANSFORMED.

# Why Prioritize Low Carbon Fuels for Industry and Heavy Transport?



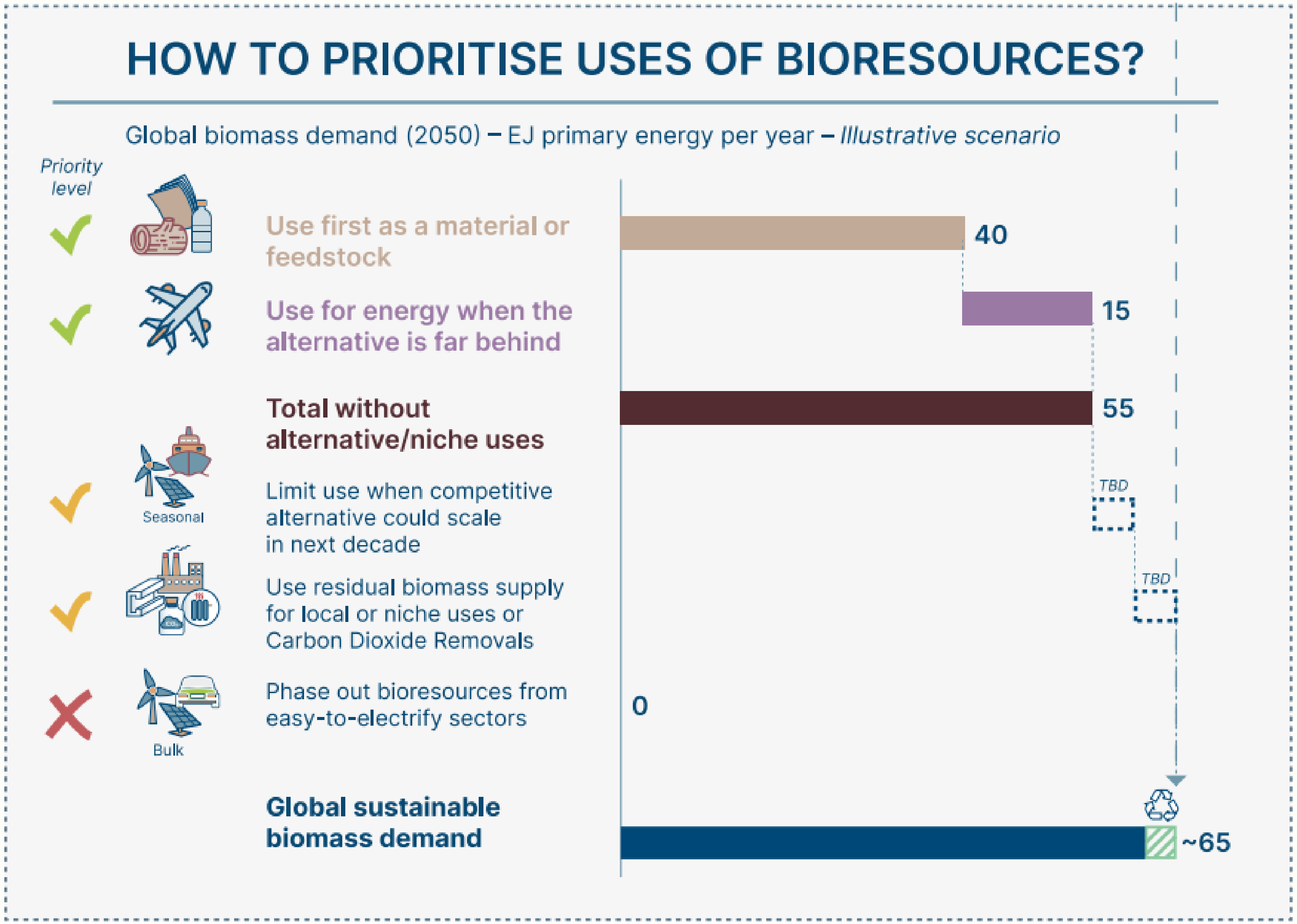
**Tessa Weiss**

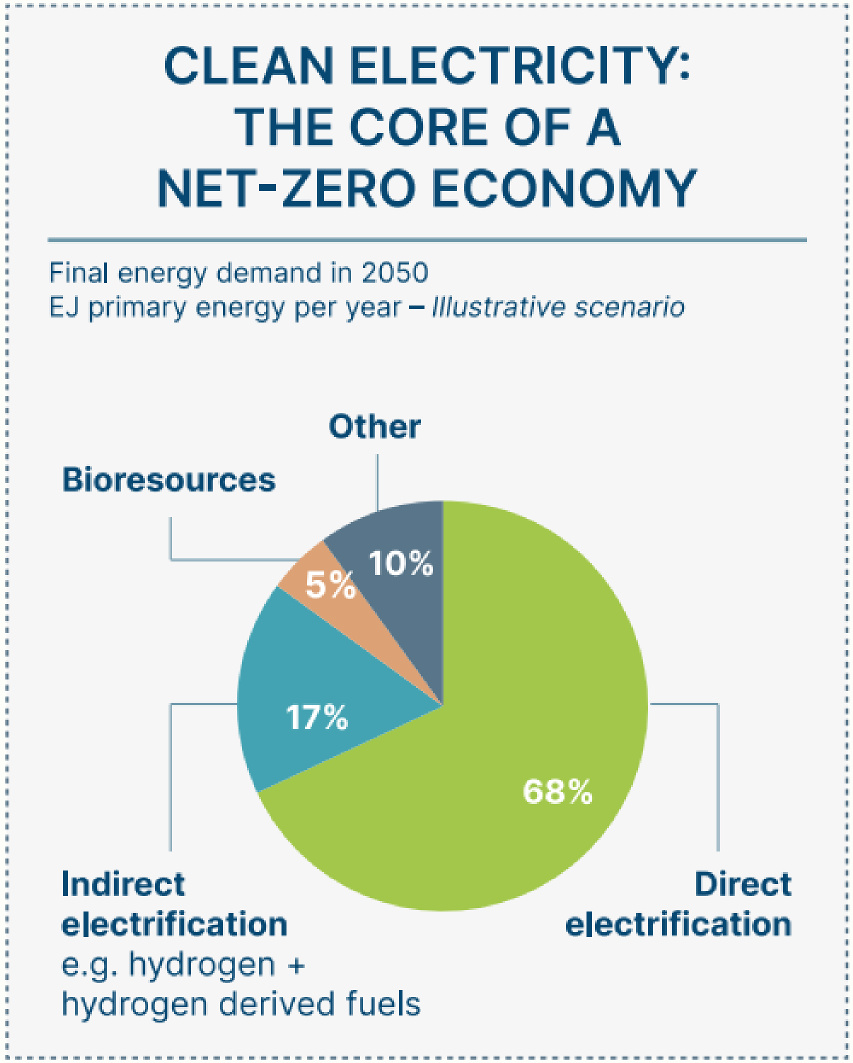
**November 4, 2022**

# Summary

- Priorities exist for biofuels and hydrogen given **limited biofuel availability** and the **need for system-wide efficient use of renewable electricity.**
- **Direct electrification should be prioritized** whenever possible- it is more efficient, cheaper, and can bring human health and broader environmental benefits.
- **Hydrogen is a necessary**, and sometimes the only, solution **to decarbonize industrial and heavy transport processes**, and must be prioritized for use in these sectors.
- **Sustainable aviation fuels**- biofuels and synfuels- and a central solution to **aviation decarbonization**.

# Limited supply of sustainable biofuels at scale forces prioritization for use in only applications with no decarbonization alternatives.



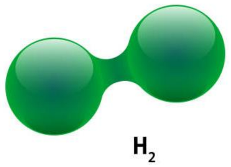



Source: ETC, *Bioresources within a Net-Zero Emissions Economy*

# The scale of non-fossil power required for 2050 decarbonization targets motivates a need to efficiently use renewable electricity.


Current global power production

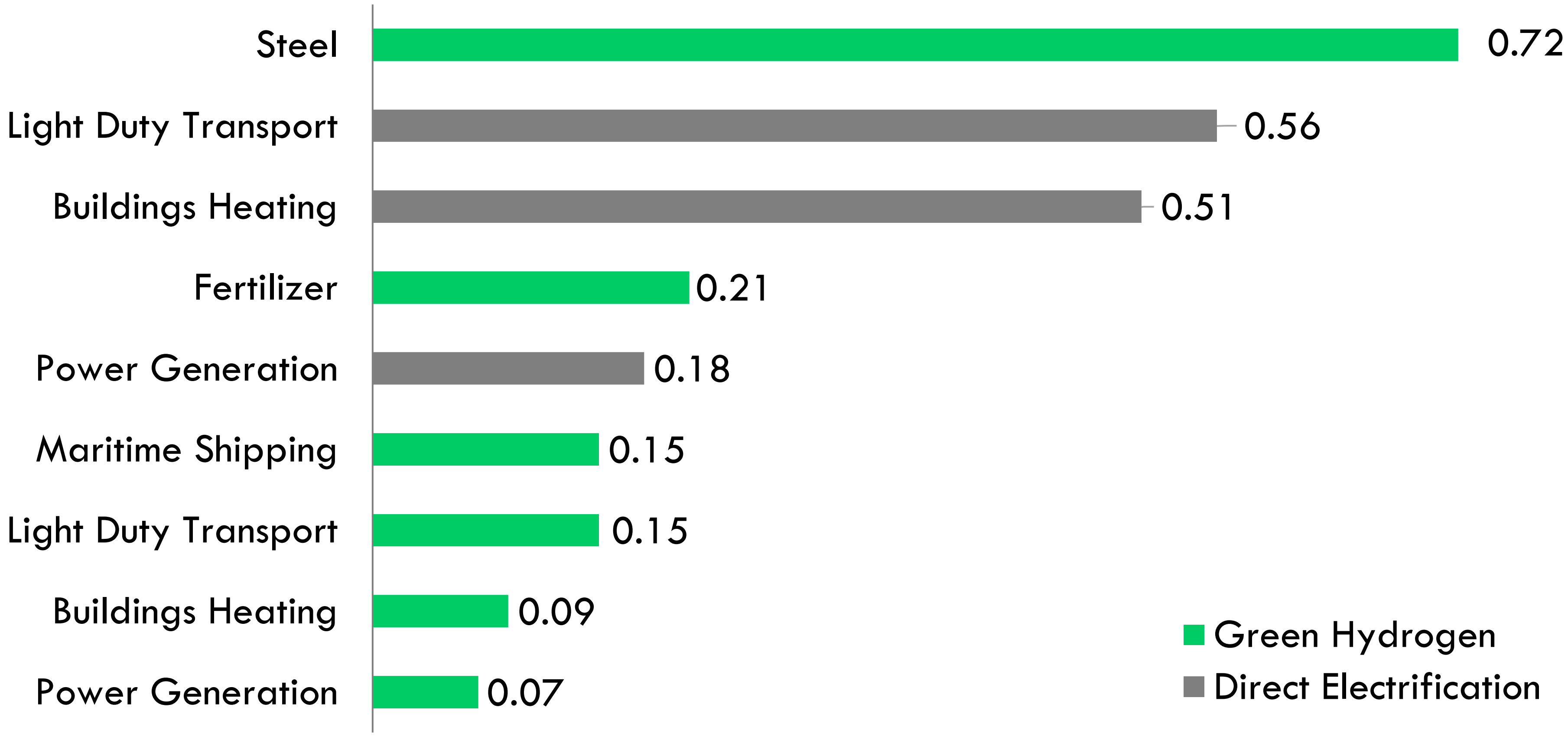
Economic and Population growth




Hydrogen for Industrial Decarbonization

# Direct electrification provides a higher abatement impact for renewable electricity compared to hydrogen's use to decarbonize these sectors.

**Reduction of GHG emissions**
$kgCO_2$ / kWh renewable power



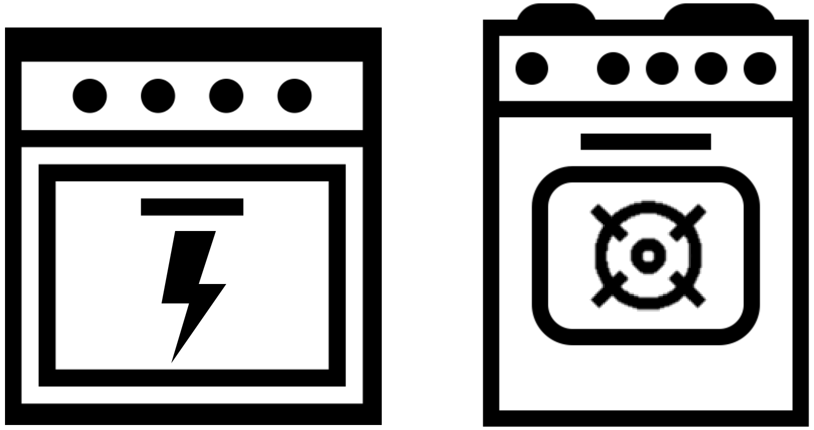



Source: RMI analysis

# Direct electrification can bring benefits to human health and reduce environmental risks.

**Over 28,000 deaths per year from building air pollution**

Homes with gas stoves have **50 - 400%** higher $NO_2$ emissions than homes with electric stoves



**2,598 Incidents**
**603 Injuries**
**122 Deaths**
**from methane leaks**

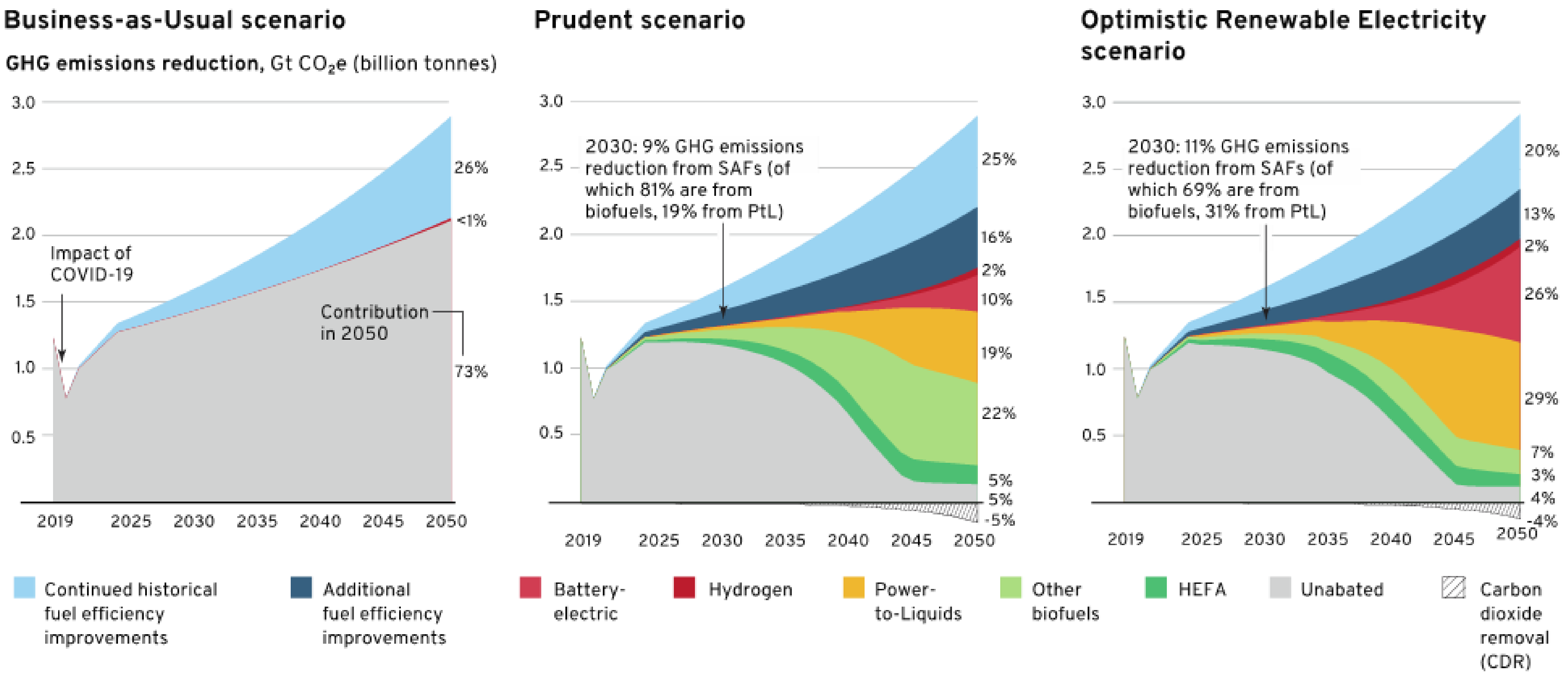
Source, air pollution: RMI analysis
Source, methane leakage hazard: US PIRG, Environment America, Frontier Group

# Industry and heavy-duty transport cannot be electrified and must use low carbon fuels and feedstocks to decarbonize.

Available Decarbonization Options:

| | Electrification | Hydrogen | Synfuels | Biofuels |
|---|---|---|---|---|
| **Steel Manufacturing** | | $H_2$ replaces coking coal | | |
| **Fertilizer Production** | | $H_2$ needed as feedstock | | |
| **Maritime Shipping** | Short haul only | $H_2$ (short haul), ammonia (long haul) | Methanol (long haul) | Limited availability |
| **Heavy Duty Trucking** | Urban and regional trucking | Needed for long distance, no home base routes | | |
| **Aviation** | Short haul only, future solution | Future solution | Future solution | Drop-in fuels |

# Sustainable aviation fuels are a near and long-term priority for aviation as they can drop-into existing aircraft and meet range requirements.






Source: MPP analysis

# Thank you!

# CATF

CLEAN AIR TASK FORCE

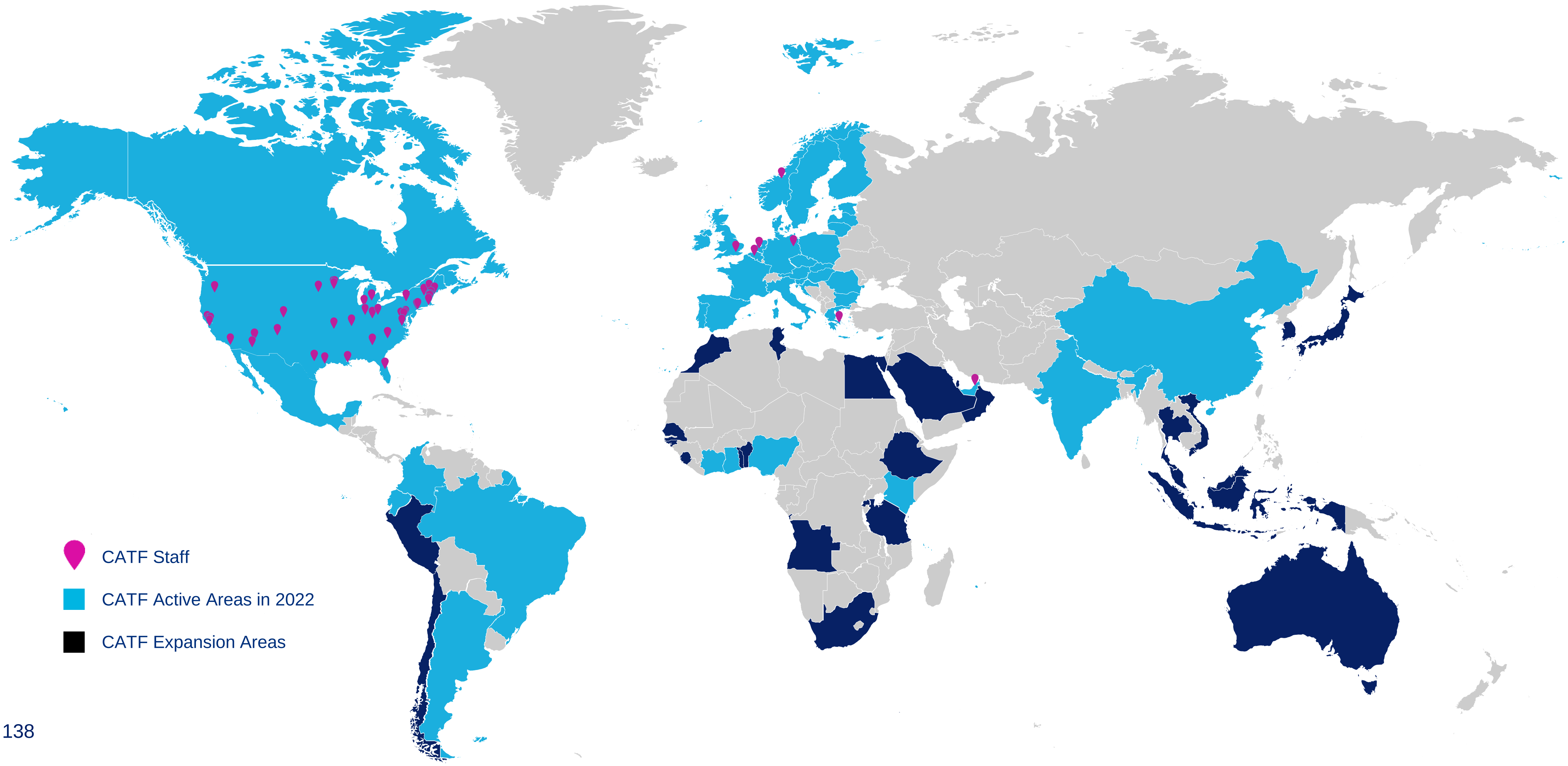
# Zero-Carbon Fuels Overview

November 4, 2022

# CATF’s Mission:

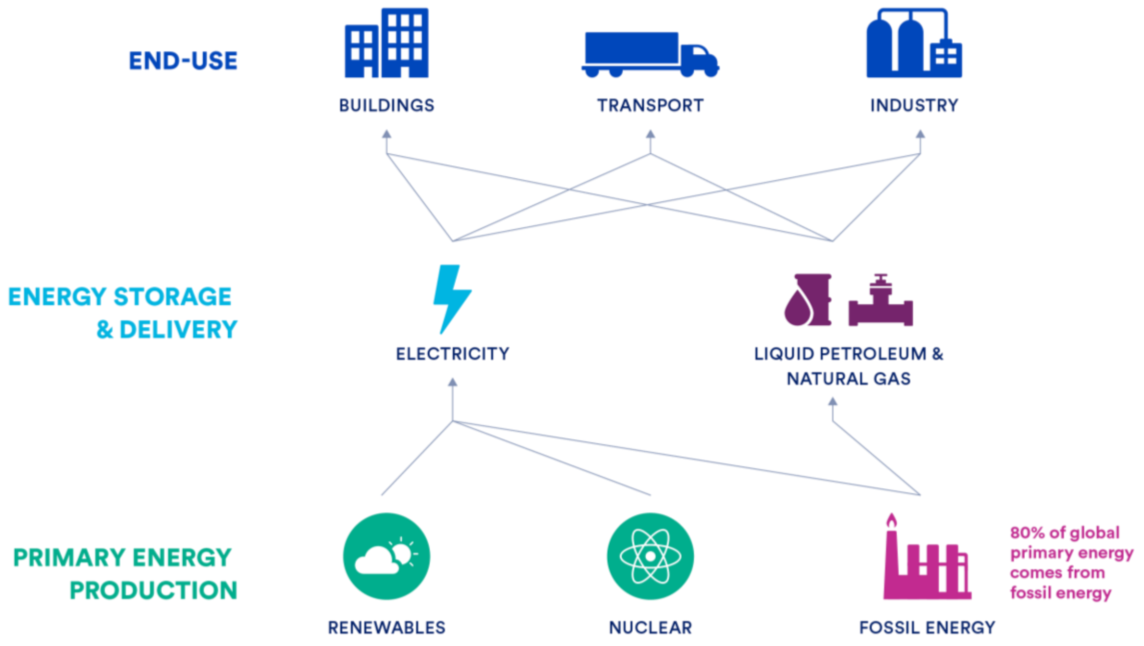
Lead the way to an affordable, zero carbon energy system by advocating for pragmatic policies, new business strategies, and advanced technologies.

# Where we have been active and where we are expanding

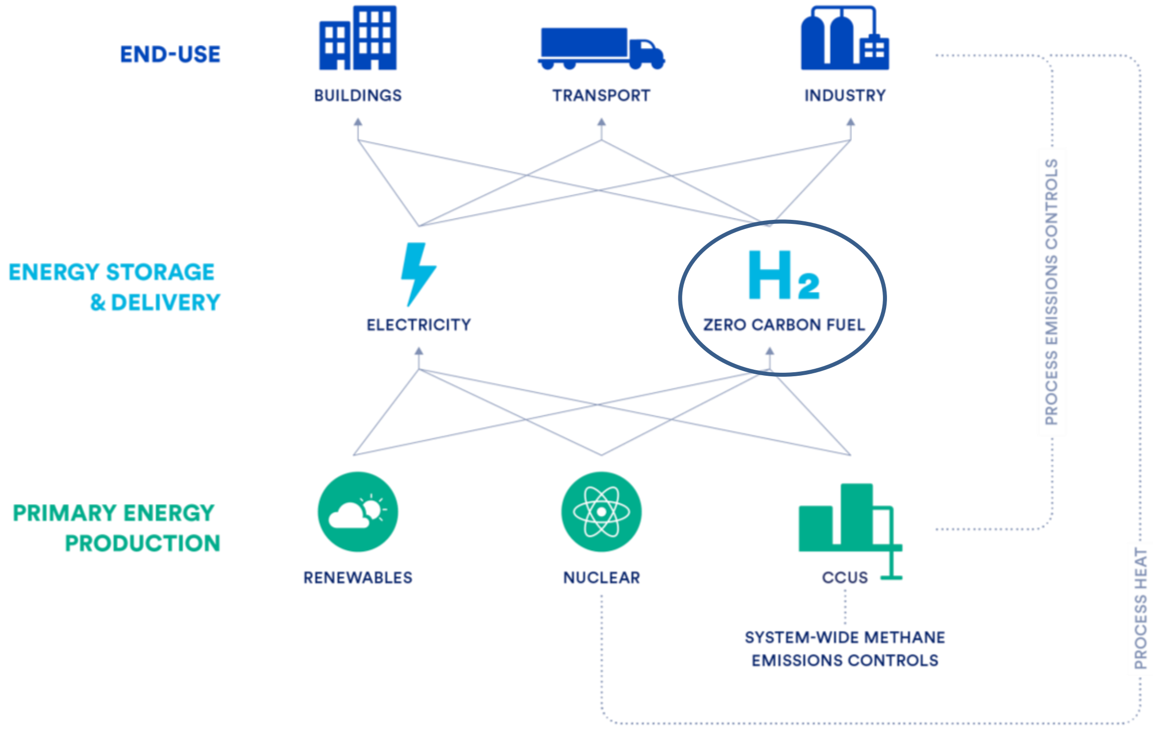


# What we need to do

## Carbon Intensive Energy System




## Decarbonized Energy System



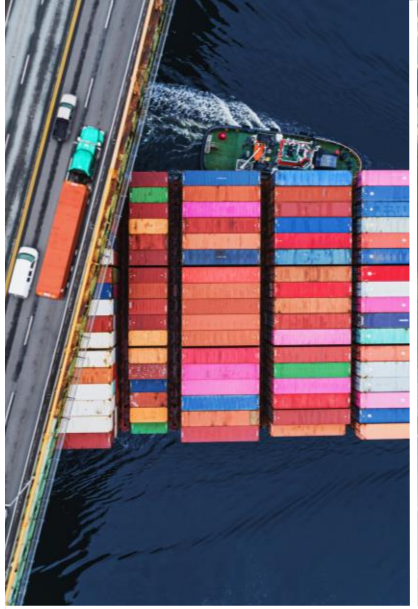
# Zero-Carbon Fuels (ZCF)

**80%** **of end-use energy is currently provided by fuel molecules like coal, natural gas and refined petroleum.**

In the future, **many fuel end users will convert that consumption into electricity.**

Despite critical efforts to expand electrification, **there are many sectors of the economy where electrification is not a viable alternative to molecules. This is because the fuel performance requirements are so high, that it cannot be commercially delivered through electrification alone.** For these sectors, replacement fuels are required that do not emit carbon when consumed.

Zero-carbon fuels—specifically hydrogen and ammonia—are fuels that do not emit carbon dioxide when consumed and can replace existing high-emitting fuels.

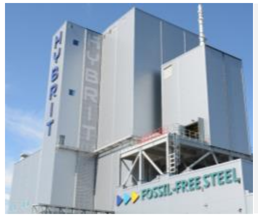


# Hydrogen's eventual role in full economy-wide decarbonization may be limited in scope, but it probably won't be a niche role


**Marine Vessels**
1 B tpy $CO_2$
6 EJ $H_2$ @ 50%

**Balancing**
~ 1 B tpy $CO_2$
18 EJ H2 @ 10%

**Heavy Trucking**
~ 2 B tpy $CO_2$
13 EJ $H_2$ @ 50%




**Ironmaking**
~ 2 B tpy $CO_2$
6 EJ $H_2$ @ 50%

**Aviation**
~ 1 B tpy $CO_2$
6 EJ $H_2$ @ 40%

**Process Heat**
~ 2 B tpy $CO_2$
10 EJ $H_2$ @ 25%

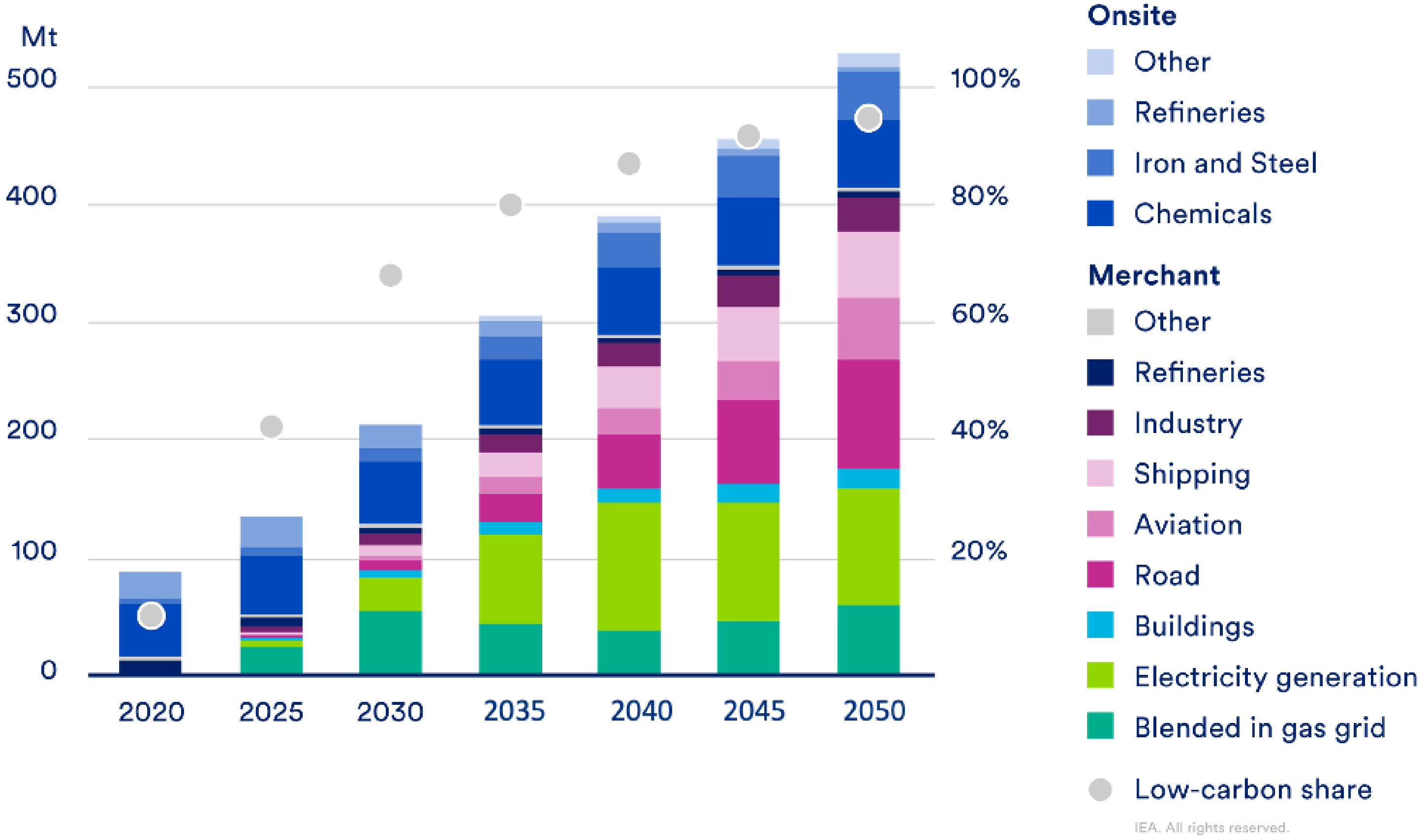
*NOTES ON HYDROGEN DEMAND: Except for power system balancing, CO2 values represent approximate current total global emissions from the indicated activity and EJ values illustrate potential H2 demand assuming the stated % of current demand is replaced with hydrogen. Power system balancing CO2 represents potential CO2 if assumed balancing energy was provide by natural gas. Total potential demand total ~70 EJ including ~5 EJ from building heating (~10% today's demand) and ~5 EJ from ammonia fertilizer production. Marine fraction reflects bulker and containership fraction of current marine fuel consumption. Trucking fraction reflects current fuel consumed in US on trips more than 300 km from base. Aviation fraction reflects half of fuel currently consumed on trips more than1500 km. Process heat fraction assumes electrification and CCS apply to 75% of fuel consumption. Ironmaking fraction assumes CCS and hydrogen split current market size. 1.5%/yr growth suggests >100 EJ/yr could be needed by 2050. All values intended for illustration only.*

# Projected Zero-Carbon Fuels Demand

IEA Predicts that global hydrogen demand will increase from 90 Mt/y to **530 Mt/y by 2050**

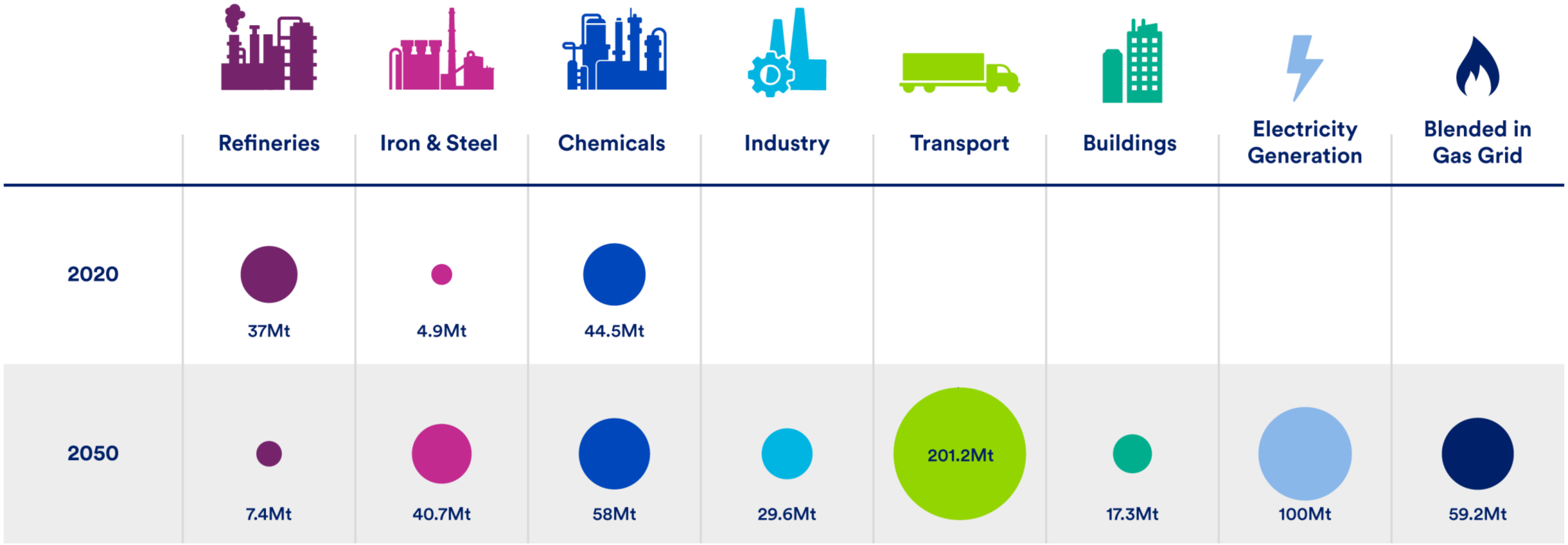
- 46% of hydrogen produced by 2030 is low-carbon
- By 2050, 38% of hydrogen is fossil-based with CCS.

Global hydrogen and hydrogen-based fuels in IEA NZE 2021



# Global hydrogen and hydrogen-based fuels use in the IEA's NZE

Initial focus: converting existing users to low-emissions hydrogen
Longer-term: expanding use of hydrogen and hydrogen-based fuels across additional end-users




*Values are approximate

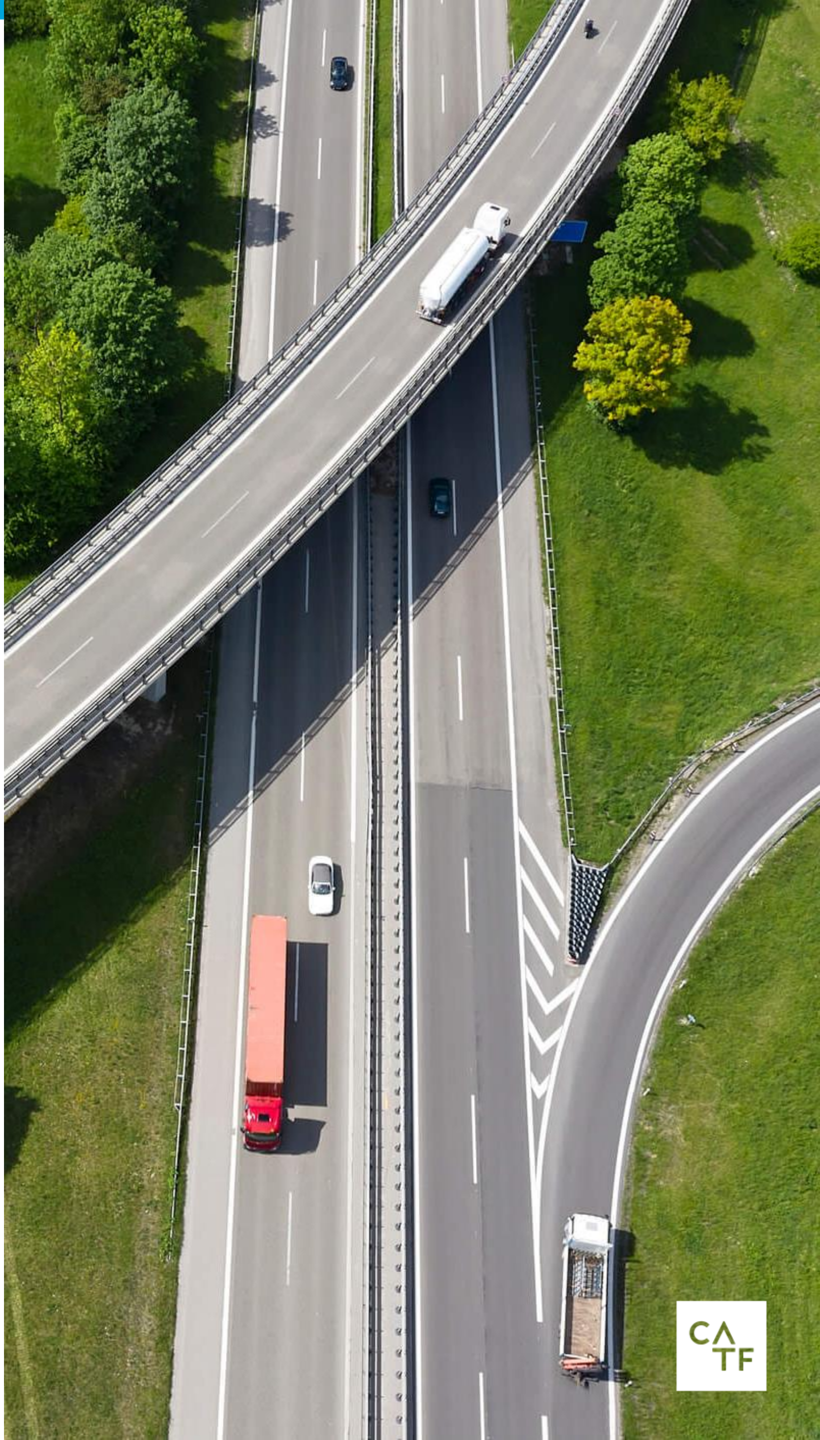
# Zero-carbon fuels production pathways

We refer to fuels that are not only zero- carbon at the point of use, but that are also produced in ways that aim to minimize greenhouse gas emissions, resulting in very low $CO_2$-equivalent emissions across the value chain.

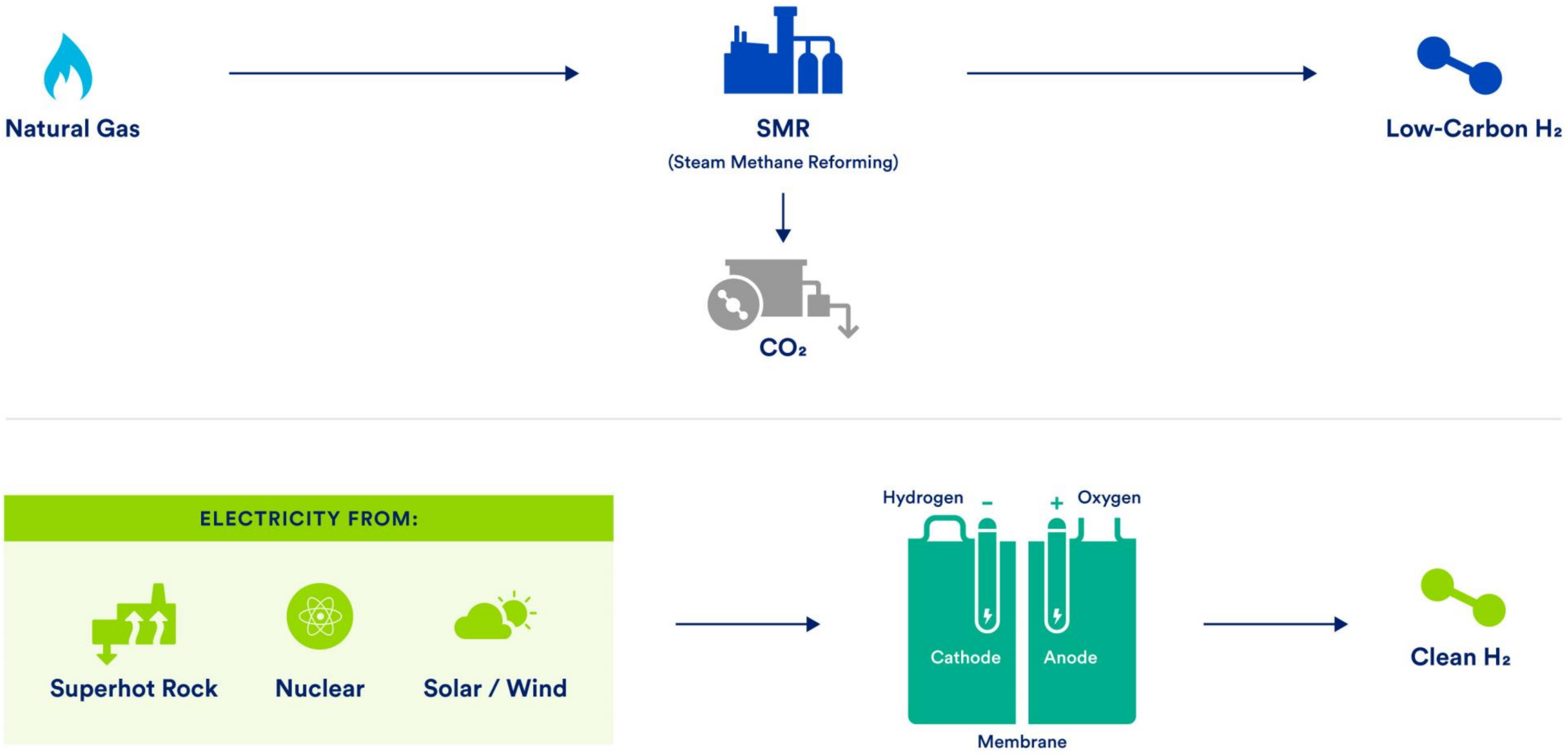
**Clean hydrogen can be produced in multiple ways**, through electrolysis using zero-carbon electricity, methane reforming using natural gas with carbon capture and upstream methane control, etc.

**Clean hydrogen is the whole point.** What constitutes “clean” depends on context and should evolve over time, but at a minimum:

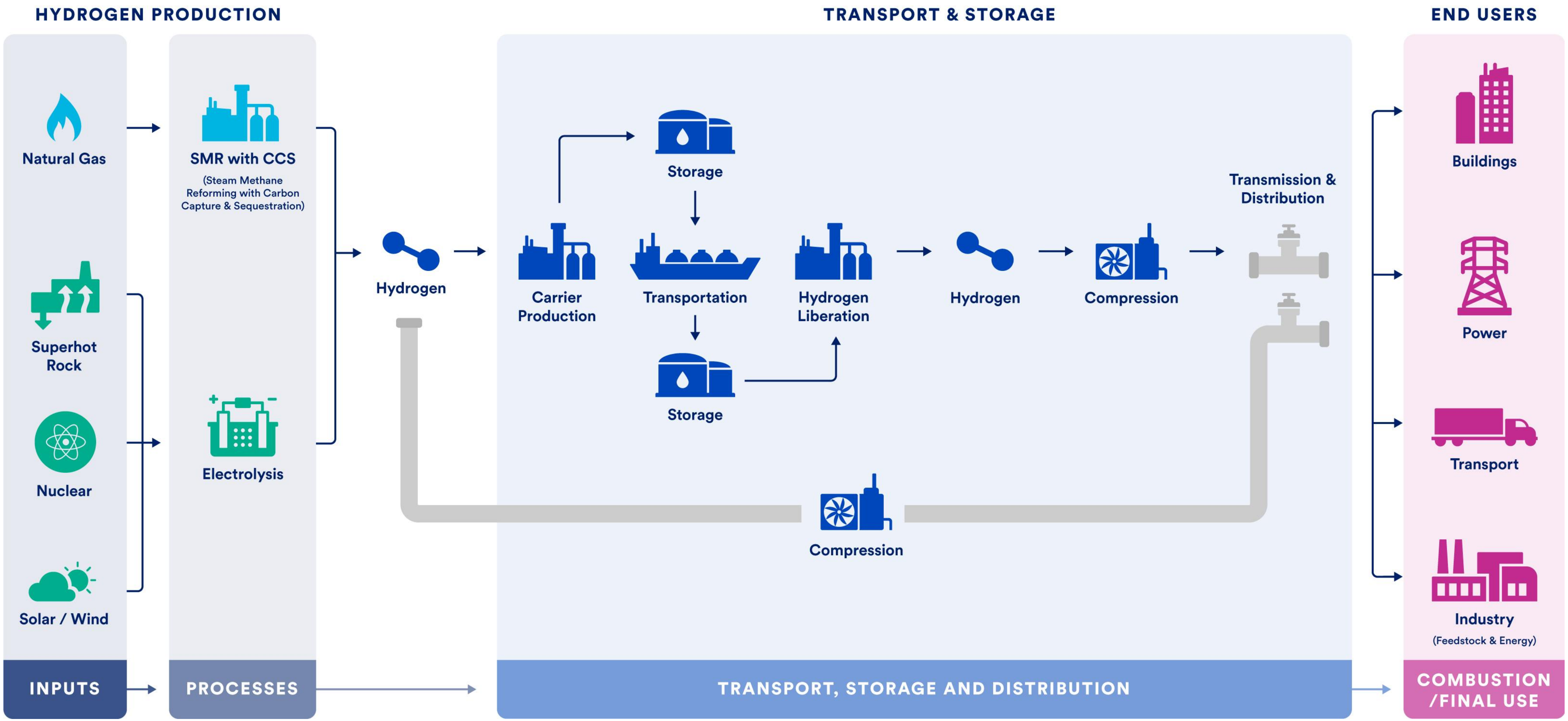
- Gas-based production must feature very high level of carbon capture for reformers, extremely low methane loss rates upstream, low $CO_2$ intensity of process electricity
- Electrolytic production must utilize electricity that is renewable or clean



# Hydrogen production pathways



# Hydrogen Supply Chain

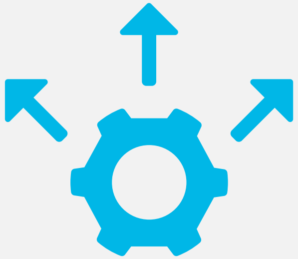


# Zero-Carbon Fuels Challenges

- The key challenges for zero-carbon fuels are costs, infrastructure development and markets.
- Costs are currently too high to compete with incumbent high-emitting fuels without public policy support.
- Reductions in costs will require large-scale deployment through markets that recognize the greenhouse gas benefits of these fuels.
- Other challenges include the lack of an attractive ecosystem for financing and investing in zero-carbon fuels projects.
- In the transport sector, the fuel costs comparison is closer, but costs and available fueling infrastructure is the problem.
- Certification schemes and frameworks for lifecycle analysis (LCA) of hydrogen’s greenhouse gas (GHG) intensity are also needed

## Zero-Carbon Fuels


**Reduced Cost**



**Wide Deployment**

# What is happening on hydrogen in the United States?

**Regional Clean Hydrogen Hubs**
Provision in the Infrastructure Investment and Jobs Act of 2021

**Hydrogen Production Tax Credit (PTC)**
Provision in the Inflation Reduction Act of 2022

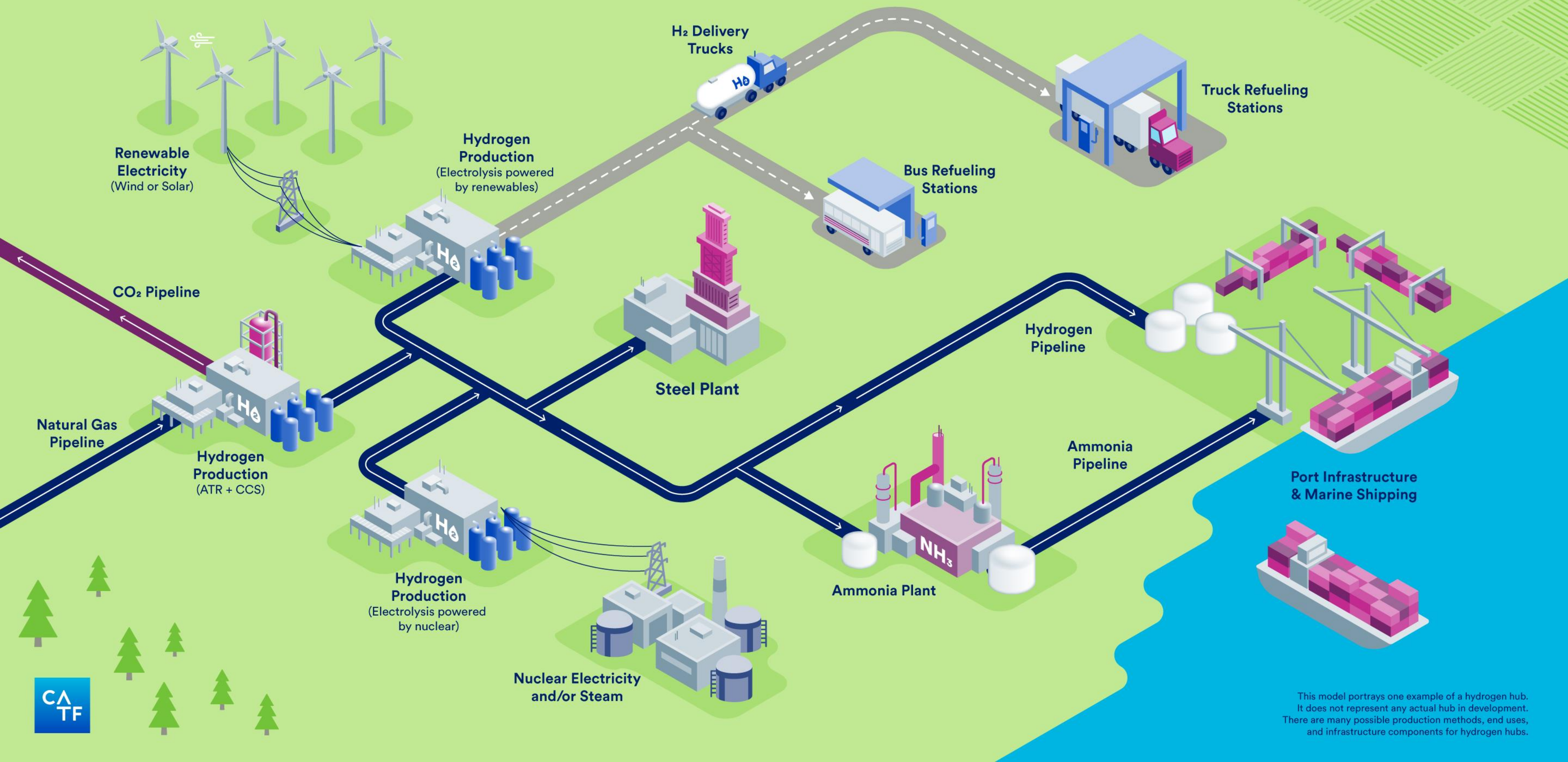
**Coons/Cornyn Hydrogen Infrastructure Initiative**
Proposed bills for ports, trucks, industry, and infrastructure financing

**Trucking**
EPA Vehicle Emissions Regulations & California’s Advanced Clean Truck Regulation

**Marine**
Proposed bills for emissions fees or standards from marine shipping; Ports decarbonization funding from IIJA and IRA

**Aviation**
R&D Funding and Sustainable Aviation Fuel tax credit from IIJA and IRA

# What is a hydrogen hub?




This model portrays one example of a hydrogen hub.
It does not represent any actual hub in development.
There are many possible production methods, end uses,
and infrastructure components for hydrogen hubs.

# What kinds of state-level policy could be needed?

- A focus on the hard-to-abate sectors, many of which are new end-users for hydrogen (R&D, Contracts for Differences, etc.)
- Support for developing/emerging hydrogen hub efforts in your region, particularly for low-GHG intensity production
- Significant local outreach, education, and planning to include potentially-impacted communities in the process and develop intentional, community-beneficial development plans
- Hydrogen leak management, including: R&D on needed technologies or infrastructure, regulatory frameworks to encourage minimizing of leaks in the design of infrastructure, and requiring leak detection and repair (LDAR) in hydrogen-supportive policies
- Support for and research into certification schemes and frameworks for lifecycle analysis (LCA) of hydrogen's greenhouse gas (GHG) intensity

# Thank You!

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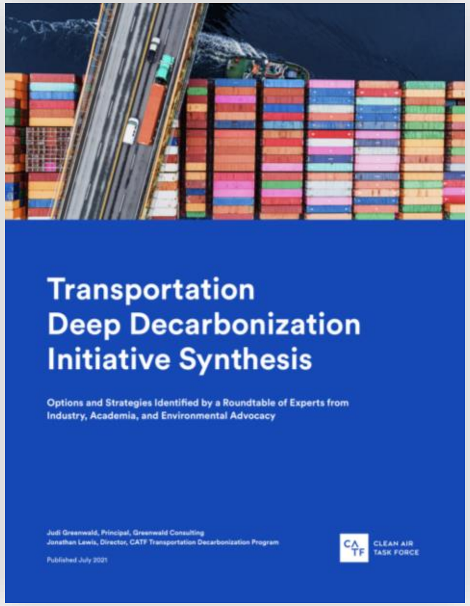
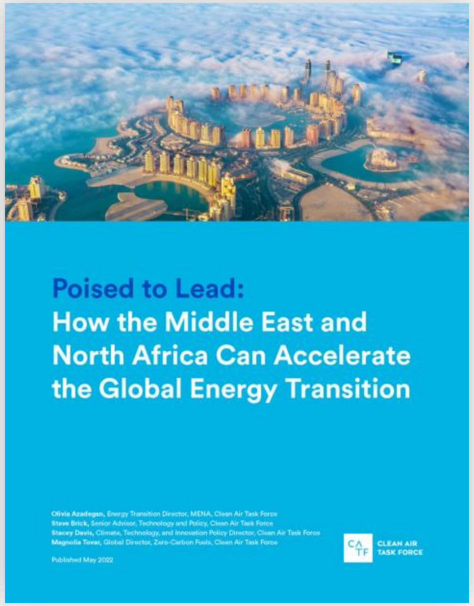
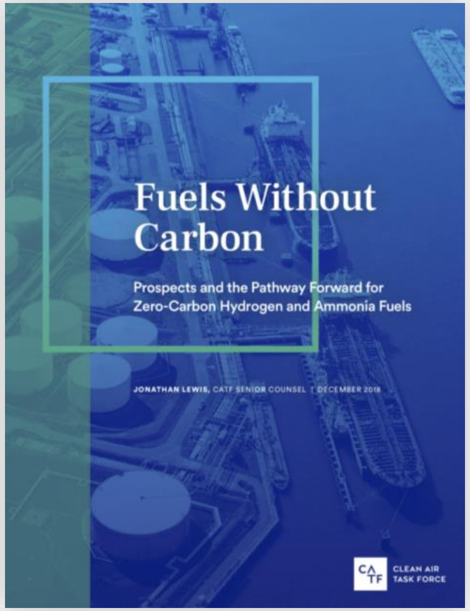
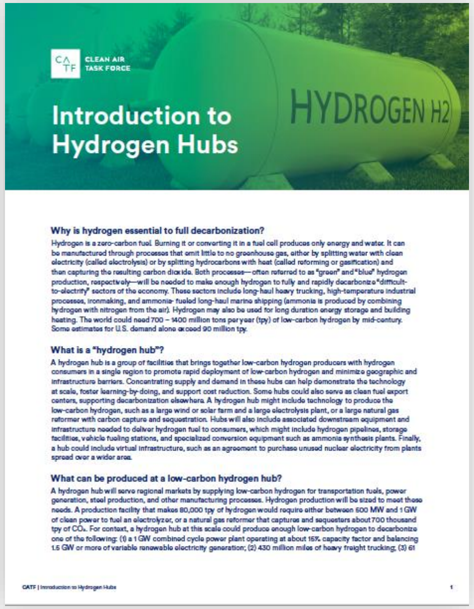
- @cleanaircatf
- ekent@catf.us



# Strategen

STRATEGEN

# Hydrogen Study – Feasibility and Recommendations
# A Look at Progress on Special Act 22-8

**Erin Childs | Strategen Consulting**
**November 4th, 2022**

# Strategen is helping to facilitate thoughtful development of hydrogen hubs

Erin Childs

Director

- Strategen's Emerging Technologies team has been supporting hydrogen ecosystem and hub development across the US, including
  - Hydrogen hub visioning and stakeholder engagement in Los Angeles led by Green Hydrogen Coalition (GHC), to assess hydrogen offtake potential and associated impacts on pollution, water availability, and workforce transition requirements
  - Convening the Western Green Hydrogen Initiative (WGHI), a collaborative effort of state energy officials and policymakers to discuss opportunities for green hydrogen to support regional energy, economic, and environmental needs.
- Currently, our team is supporting the Connecticut Green Bank in fulfilling the requirements of Special Act 22-8 to convene a Hydrogen Task Force and associated work groups to develop recommendations for the Connecticut Legislature

## Client & Work Examples

GREEN HYDROGEN COALITION

QUI TRANSTULIT SUSTINET

DMME Virginia Department of Mines Minerals and Energy

pennsylvania DEPARTMENT OF ENVIRONMENTAL PROTECTION

CONNECTICUT GREEN BANK

# Special Act 22-8 requires the Green Bank to convene the Hydrogen Task Force to provide recommendations to develop a clean hydrogen economy in Connecticut

The Task Force will:

1. Provide a review of regulations and legislation needed to guide the development and achievement of hydrogen economies of scale
2. Provide recommendations for workforce initiatives to prepare the state for hydrogen-fueled energy-related jobs
3. Examine how to position the state to take advantage of competitive incentives and programs created by the federal Infrastructure Investment and Jobs Act
4. Identify funding and tax preferences for building hydrogen-fueled energy facilities at brownfield sites through the Targeted Brownfield Development Grant and Loan program.
5. Recommend funding sources for developing hydrogen-fueled energy programs and infrastructure.
6. Examine the sources of potential clean hydrogen, including, but not limited to, wind, solar, biogas and nuclear.
7. Recommend potential end uses of hydrogen-fueled energy.

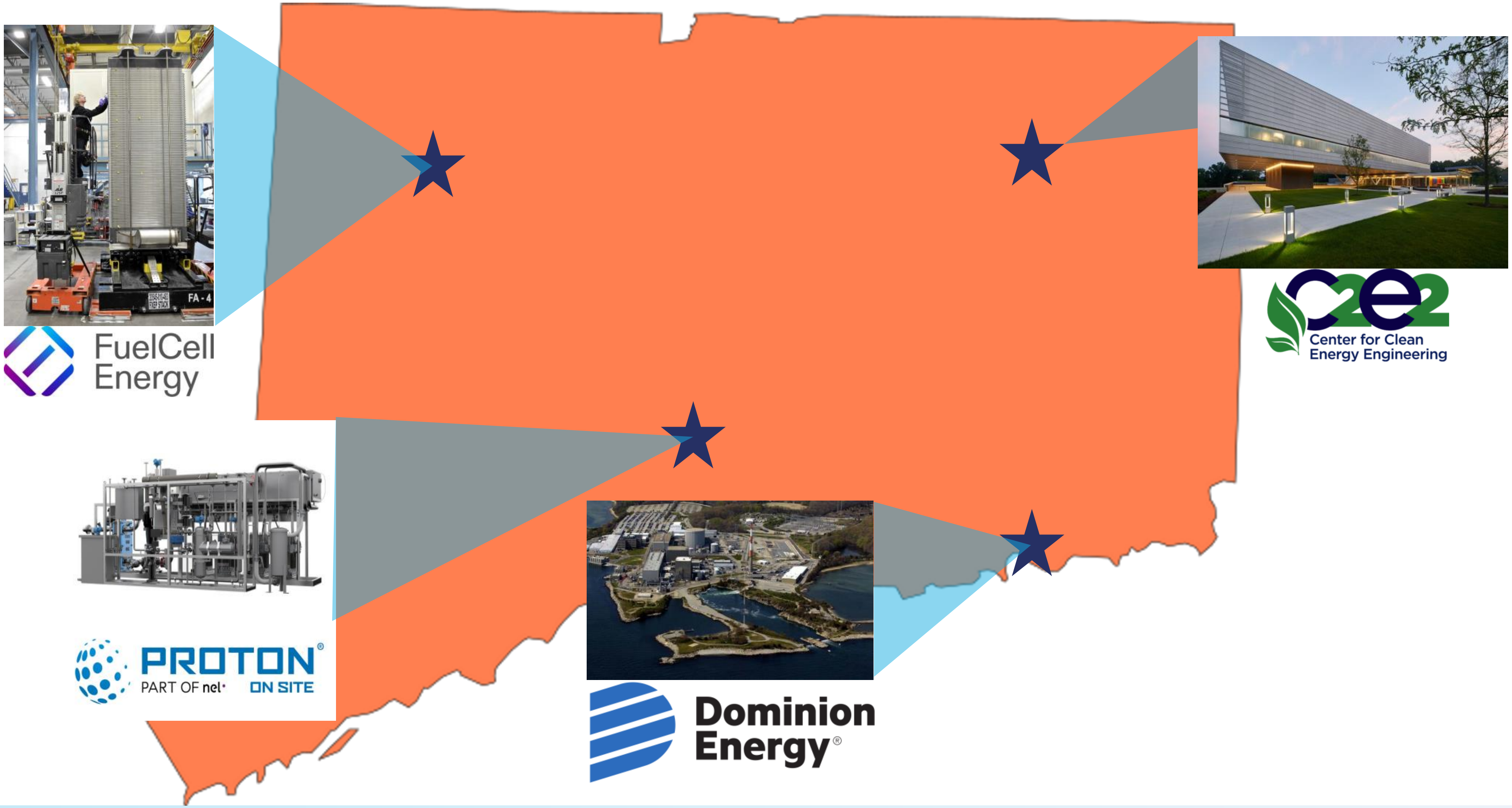
# Strategen is supporting CT Green Bank in administering the Hydrogen Task Force and developing legislative recommendations

| Policy and Workforce Development | Funding | Hydrogen Sources | Hydrogen Infrastructure | Hydrogen Uses |
|---|---|---|---|---|
| Chaired by: Commissioner Katie Dykes, DEEP<br>Chairman Marissa Gillett, PURA | Chaired by: Commissioner Katie Dykes, DEEP<br>Alexandra Daum, DECD | Chaired by: Ugur Pasaogullari, UCONN<br>Kathy Ayers, Nel Hydrogen | Chaired by: Adolfo Rivera, Avangrid<br>Chris Capuano, Nel | Chaired By: Joel Rinebold, CCAT<br>Digaunto Chatterjee, Eversource<br>Frank Reynolds, Avangrid |
| Will identify legislation and workforce initiatives needed to guide the development of clean hydrogen. | Will identify funding sources for developing hydrogen-fueled energy programs and infrastructure. | Will identify potential sources of clean hydrogen and relative merits | Will identify infrastructure needed to support scaled and cost-effective hydrogen economy | Will identify potential and priority end uses for hydrogen |

**Cross-Cutting Issues:** Environmental Justice, Supply Chain, Safety, R&D, and Insurance

All Task Force and Working Group meetings are open to the public, and we encourage stakeholder participation!
Please contact Jennifer Gorman (jgorman@strategen.com) to get involved.

# Tours of hydrogen-related facilities and national lab involvement have provided opportunities for Task Force education



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# States and national governments are beginning to adopt definitions for clean, renewable, or green hydrogen

| | Hydrogen Type (e.g. clean, renewable, green) | Based on a carbon intensity calculation | Technology agnostic (e.g. includes biomass, biogas, electrolysis, nuclear) | Electrolysis with renewables only | Excludes use of fossil fuels |
|---|---|---|---|---|---|
| US DOE | Clean | X | X | | |
| Montana | Green | | X | | X |
| Washington State | Renewable | | X | | |
| Oregon | Renewable | | X | | X |
| Australia | Clean | | X | | |
| Canada | Green | | | X | X |
| Canada | Low Carbon Intensity | X | X | | |
| Chile | Green | | | X | X |
| France | Renewable | X | | X | X |
| France | Low Carbon | X | X | | |
| Germany | Green | | | X | X |
| Sweden | Renewable/Clean | | X | | |
| CertifHy | Green | X | X | | X |
| CertifHy | Low Carbon | X | X | | |

STRATEGEN

# Coordinated policy and regulatory drivers are informing and driving public and private sector investment

## Definitions

States and Countries are defining clean hydrogen eligibility in similar ways.

Increasingly, definitions based on a carbon intensity range are emerging.

Additional specification focuses on feedstock type (i.e., must be renewable or must be non-fossil fuel).

## Legislation

In the last 3 years, hydrogen specific legislation has skyrocketed. Hydrogen bills have typically been focused on a particular end use, such as:

Mobility
Gas and Electric Generation
Industrial Uses

A smaller set of hydrogen related bills provide specific grant funding, authorize specific studies, or address safety provisions

## Funding & Incentives

Some States offer incentives or funding for clean hydrogen production, distribution, or use. Incentive types include:

Tax Credits
Tax Exemptions
Electrolytic Tariffs

Examples of grants and loans for hydrogen-related topics include:

RD&D
Renewable Deployment
Infrastructure Development

# The California legislature has allocated significant funding for hydrogen-related programs and projects

| | |
|---|---|
| $140M | For long-duration storage projects throughout the state to support grid reliability |
| $550M | To deploy new zero or low emissions distributed backup assets (i.e., fuel cells) |
| $383M | To implement ZEV charging infrastructure programs |
| $200M | To identify transportation-related climate vulnerabilities and develop and implement programs to adapt infrastructure |
| $1.5B | For heavy-duty zero-emissions vehicles |
| $2.2B | To provide 5,000 MW of reliability reserves |

*$3.8 billion will be allocated in the summer pending additional discussions with the Legislature.*

# Robust stakeholder has helped to highlight areas of addition focus and research

| Industry Participants | Environmental Participants | Labor Organizations |
|---|---|---|
| + How do proposed offtake areas align with industry activity and interest, and what can we do to support near-term hydrogen deployment opportunities?<br><br>+ What steps can we take to ensure an inclusive approach to supporting hydrogen industries?<br><br>+ How can we approach end use support and prioritization recognizing continued technology advancement and improvements? | + How can we ensure that hydrogen production and usage is prioritized to address reduction of climate and local pollutants?<br><br>+ What steps can we take to ensure that hydrogen deployment does not unduly extend the life of fossil infrastructure?<br><br>+ What steps can be taken to continue to create transparency and visibility in hydrogen planning processes? | + How will hydrogen market development impact the existing workforce?<br><br>+ What skills will workers need to contribute to the hydrogen economy? Are these transferrable from current jobs?<br><br>+ How can we provide support for a just transition for workers in the fossil fuel industry? What training programs may be appropriate? |

# There are multiple ways to get involved in the Hydrogen Task Force!

## Written Comment Opportunity

The Hydrogen Task Force is planning to offer a written comment opportunity for stakeholders to provide feedback.

## Upcoming Meetings

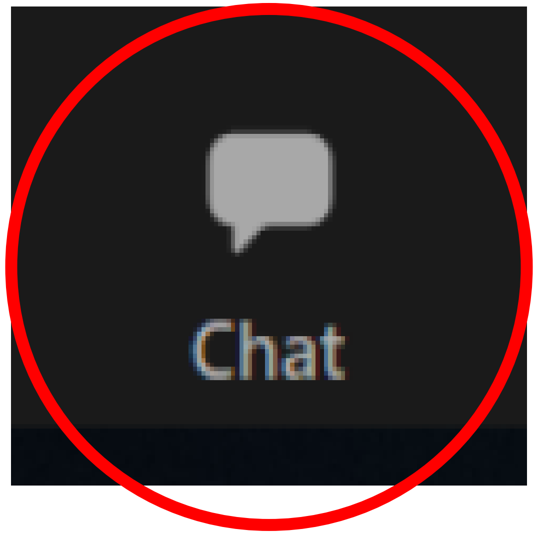
+ Task Force: Nov. 8, 10am-Noon
+ Sources WG: Nov. 17, 11am-Noon
+ Infrastructure WG: Nov. 17, 3-4pm
+ Funding WG: Nov. 18, 10:30-Noon
+ Uses WG: Nov. 22, Noon-1pm
+ Policy & WF Dev WG: Nov. 29, Noon-1pm

## **Review Materials**

All Task Force and Working Group materials are publicly available on the Green Bank's Task Force website. Meeting minutes are also translated into Spanish.

# Questions?

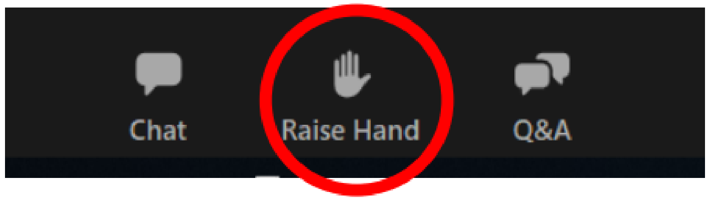
# <u>Questions</u>

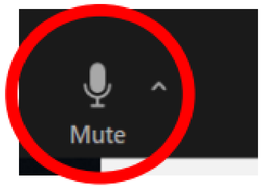



At the conclusion of each panel DEEP will hold a brief question and answer period.

If you have a question for a presenter, please drop it into the chat to **<u>Jeff Howard</u>**. DEEP will pose as many questions as time allows to the speakers. Clarifying questions will be prioritized. Leading questions will not be accepted.

# Public Comments




**Lower left of the screen**

If you would like to make a comment during the public comment periods:

- Please use the “Raise Hand” feature if you would like to speak
- After any interested elected officials have provided their comments, you will be invited to provide your comment in the order the hands were raised
- Please unmute yourself, state your name and affiliation
- Given time limitations, please limit your comment to 2 minutes.
- After your comments, please remember to click the “Mute” button

# General Public Comment

BUREAU OF ENERGY AND
TECHNOLOGY POLICY

# WRAP UP

Thanks for joining our technical session today!

**Written comments** related to this session, or the general Comprehensive Energy Strategy can be submitted to:

1. BETP's Energy Filings web page – or –
2. Via email to DEEP.EnergyBureau@ct.gov

**All information on upcoming Comprehensive Energy Strategy technical sessions and written comment opportunities can be found on the CES webpage**

This slide deck and a recording of this session will be posted on the CES webpage

Written Comments related to this technical session are due
Monday, November 21, 2022, at 5:00 p.m. ET

BUREAU OF ENERGY AND
TECHNOLOGY POLICY

# Thank you for joining!

Questions? DEEP.EnergyBureau@ct.gov

BUREAU OF ENERGY AND TECHNOLOGY POLICY