Hydrogen

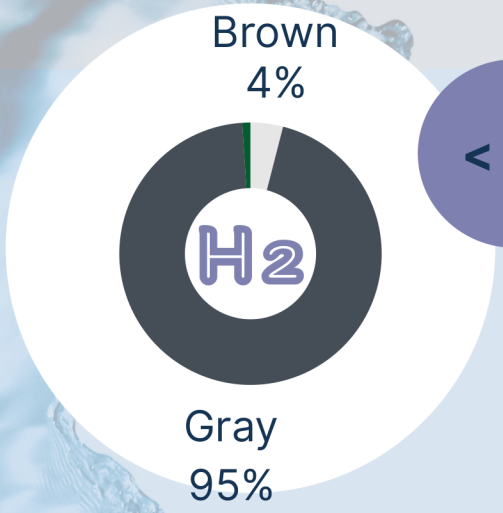
Fuel Properties

-273 °C

9.5 MJ/L

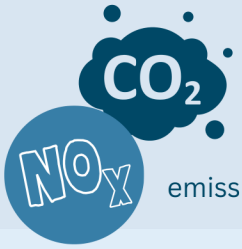
MGO
35
MJ/L

Lifecycle Emissions



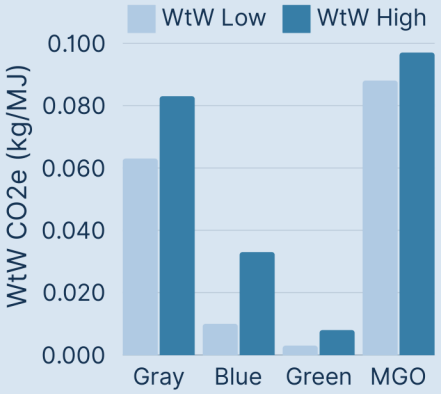
< 1%

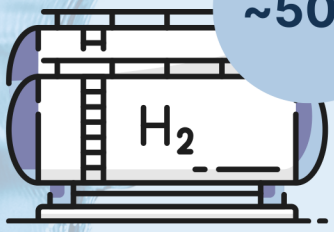
of hydrogen production is low-C



emitted during gray & blue production

emissions at stack



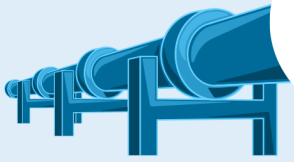


~50%

of LNG infrastructure could be transitioned

PILOT STAGE

Infrastructure



57%

(1600/2796 miles)

of global H2 pipelines are in the U.S.

2022 world demand
95 million metric tons
-
2030 renewable capacity
27 million metric tons

2022 renewable capacity
<1 million metric tons

Costs

$240 /kW

Propulsion system

$2,960/ m3

Fuel storage

$3M

Vessel upgrades

($/MJ)

($/MJ)

Ammonia

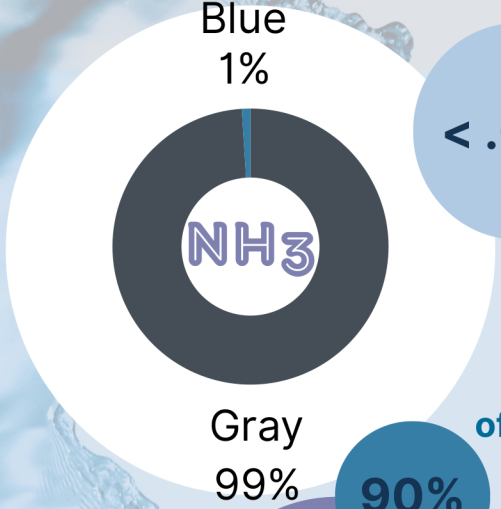
Fuel Properties

-33 °C

12.7 MJ/L

MGO **35** MJ/L

Lifecycle Emissions

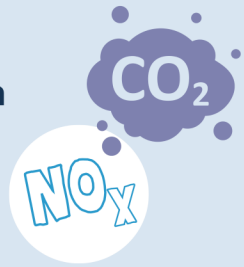


< .01%

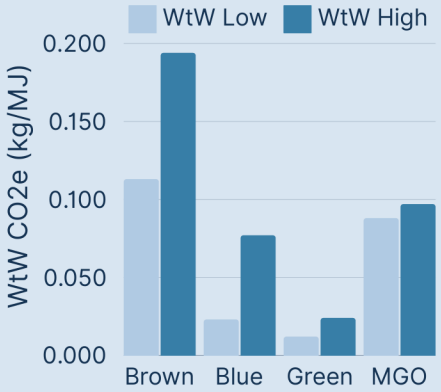
of ammonia production is green

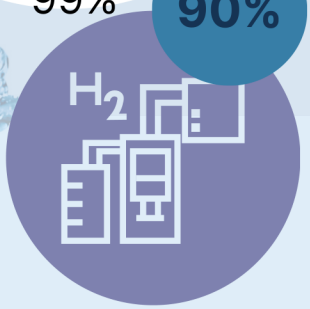
90%

of C emissions occur during H2 synthesis



SCR tech can reduce stack emissions





NH3 is a more effective carrier of H2 energy

Infrastructure

2020 world demand

182 million metric tons

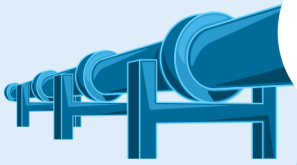
-

2040 renewable capacity

71 million metric tons

2020 renewable capacity
<1 million metric tons

PILOT STAGE



~63%

(3107/4971 miles)

of global NH3 pipelines are in the U.S.

Costs

$433 /kW

Vessel capital costs

CAPEX estimates vary $400-847/kW

~17%

cheaper fuel than methanol

cheaper fuel than hydrogen

~32%

($/MJ)

($/MJ)

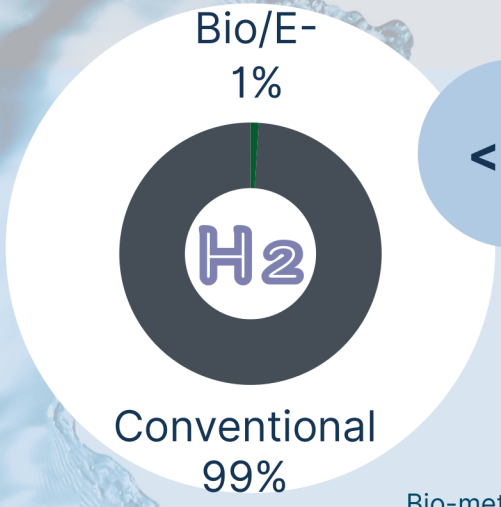
Methanol

Fuel Properties

20 °C

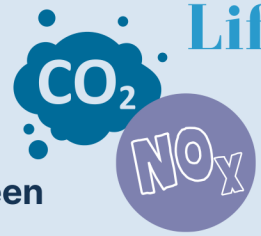
15.9 MJ/L

MGO 35 MJ/L



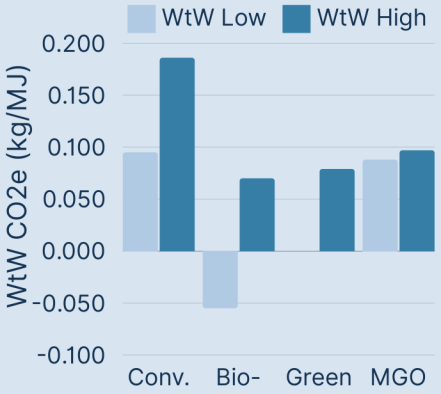
<1% of methanol production is green

Lifecycle Emissions



After treatment can reduce stack emissions

Bio-methanol can have net-negative GHG emissions depending on feedstock and process



Bunker-ready since 2023

138 vessels on the order book
exceeding orders for LNG or any other alt. fuel

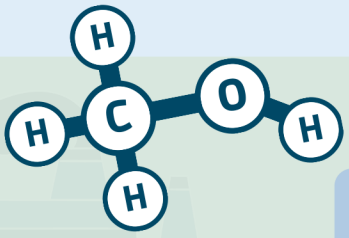
Infrastructure

2022 world demand
100 million metric tons
-
2050 renewable capacity
135 million metric tons

2022 renewable capacity
<1 million metric tons

READY TO DEPLOY

There are several methanol plants in service or under construction In the U.S.



Costs

$600 /kW Engine CAPEX

$10M Containership retrofit

2.5x Storage requirements

($/MJ)

($/MJ)

Biofuels

Fuel Properties

Gasification

FT Diesel

DME

FAME

Transesterification

Hydrogenation

HVO

14-43 °C

Temps < -3°C = fuel solidification

19.2 MJ/L

MGO **35** MJ/L

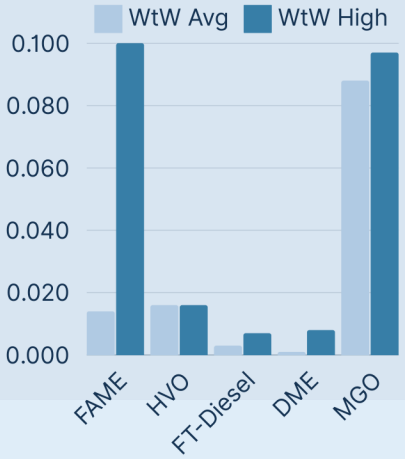
Lifecycle Emissions

Generally sulfur-free fuels

WtW varies widely depending on fuel type, feedstock, production and transportation assumptions

Biofuels have reduced NOx

except for some fuel types under low or high loads



Biofuels can be blended

with conventional fuels

0.93

million tons of blended biofuels were bunkered In 2022

READY TO DEPLOY

"Drop-in fuels"

commercial scale limited by sourcing sustainable feedstocks

Infrastructure

2022 world demand

170 million liters

-

2030 renewable capacity

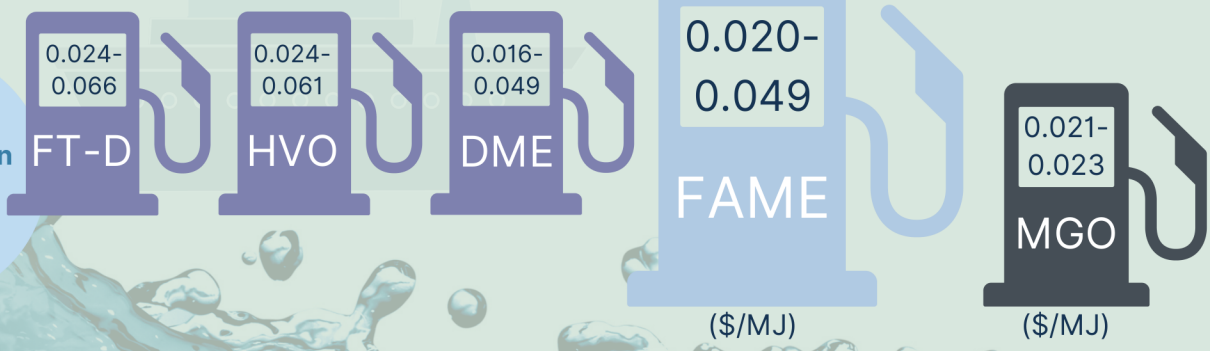
<8.5% of maritime demand

Costs

As drop-in fuels, CAPEX is minimal.

Additional cost primarily bunkering price due to lower energy of biofuels

FAME is the most common maritime biofuel



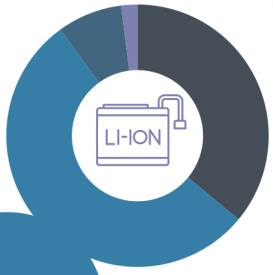
Electrification Fuel Properties

3
Li
Lithium
6.941

15 °C

Other 8%

Natural Gas 36%



Lifecycle Emissions

Batteries' potential

-77% acidification

-88% eutrophication

-78% ozone creation

SO_x

NO_x

54% **of California's grid is non-GHG and/or renewable energies**

55% **carbon dioxide abatement**
benefits of shore power are limited to at-berth operations

Requires specialized at-berth utility of dedicated system connections

Shore power is available at 10 U.S. Ports

Infrastructure

2023 active fleet

209 battery-assisted

-

36 battery-propelled

<0.1% of the global fleet's total installed engine power or DWT

76% **increase in CA state electricity demand by 2045**
relative to 2022

RESEARCH STAGE

$30.5 B
infrastructure cost to meet demand

Costs

Container: $1.14 per TEU

Cruise: $4.65 per passenger

Tanker: <0.01 per gallon oil

RoRo: $7.66 per vehicle

estimated costs of the new at-berth regulation

$7-83 M

CAPEX per berth upgrade
Port of Long Beach spent $185 million to facilitate its shore power

$500-900 K

Vessel upgrade CAPEX