MONNOYEUR

08 JUNE 2023

Alternative Fuels

Bram Cludts – Application Engineer

PRESENTATION PLANNING

So much info, so little time…

01 **FOUR PILLARS**
Or at least the most important ones…

02 **Hydrogen**
Lots of colors…

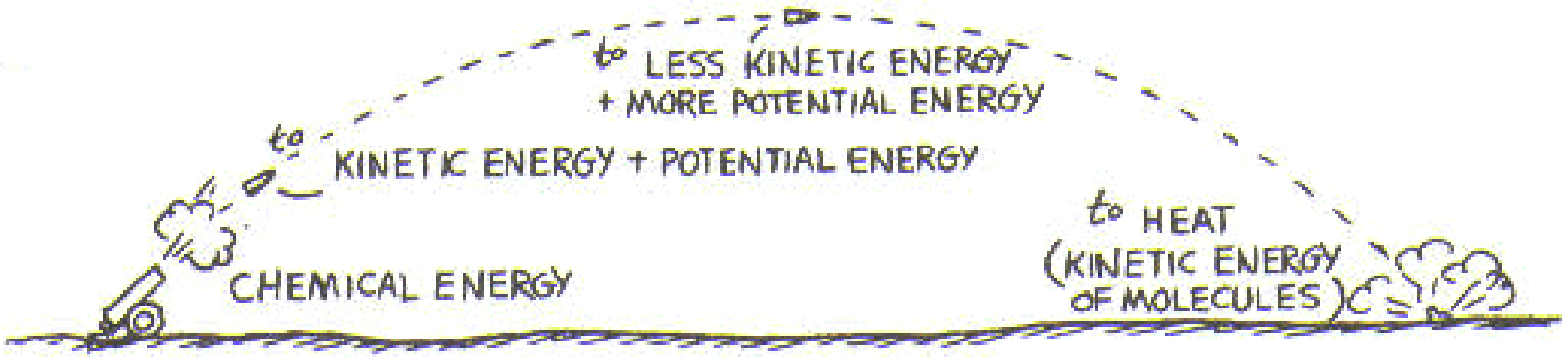
03 **Methanol**
Alcohol which you can't drink…

04 **Ammonia**
What is that smell…

05 **Renewable/Bio Diesel**
It's Diesel, but more sustainable…

What is shown?

First law of Thermodynamics – Law of conservation of Energy

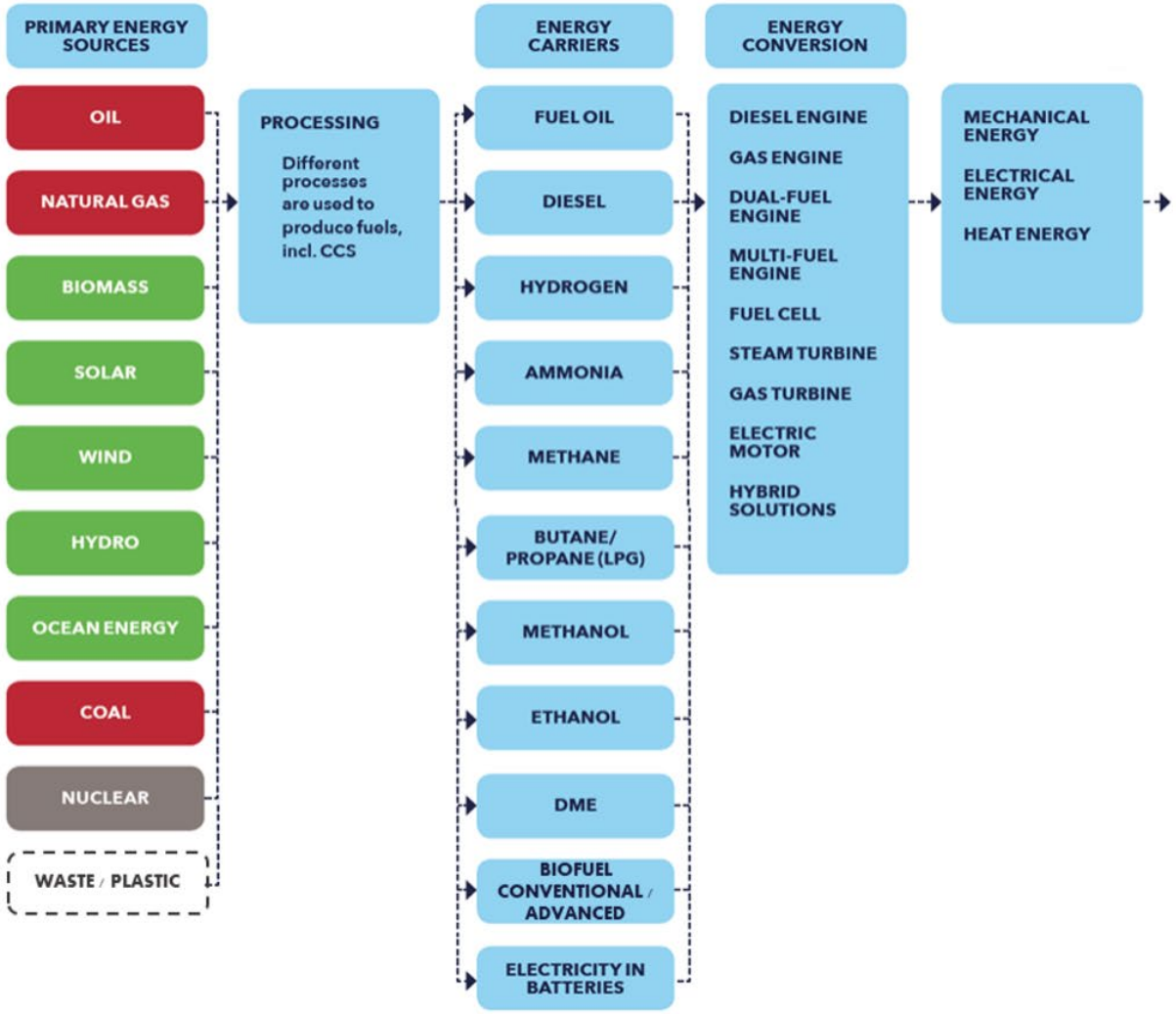


Energy Cannot Be Created or Destroyed

(It just changes forms)

Energy flow

Alternative « Energy Carriers »



DME = Dimethyl ether = synthetic gas
CCS = Carbon capture and storage

FOUR PILLARS OF ALTERNATIVE FUELS

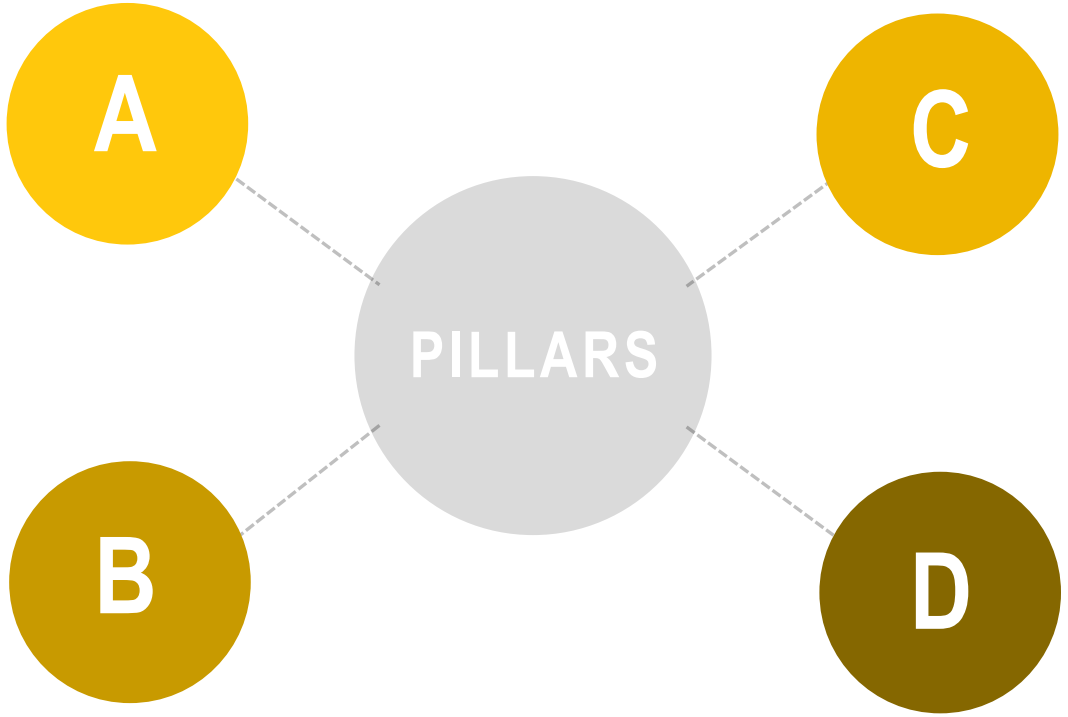
Or at least the most important ones…

Cost

Machine, Fuel, TCO

Ease of use

Storage, Transportation, Availability, Service



Dangers

ATEX, Harmful substance, Certificates

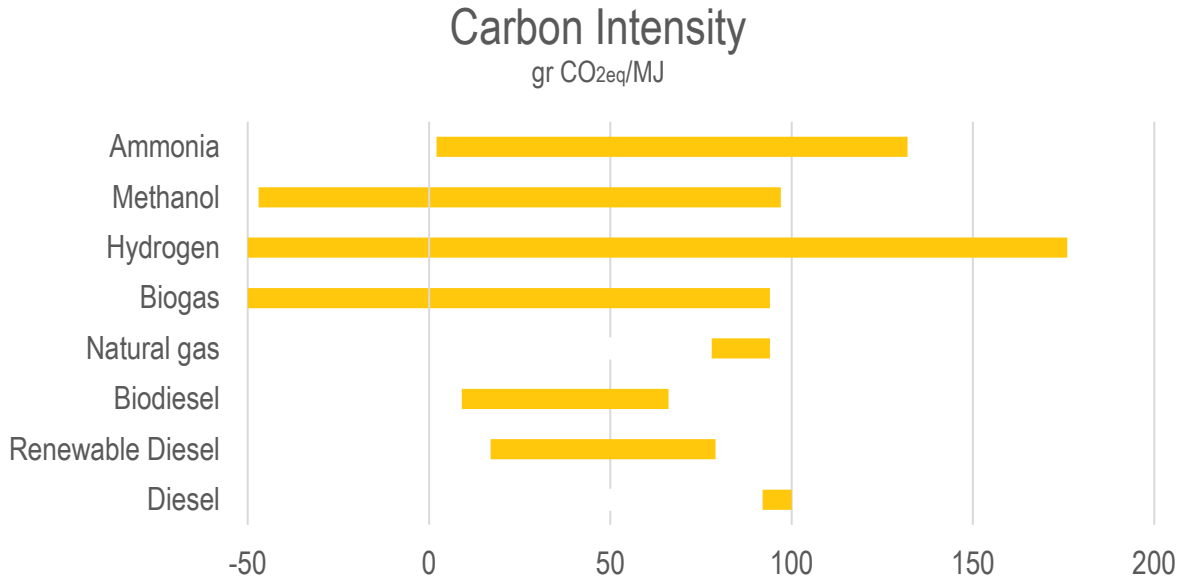
Emission

WTW, CO2eq

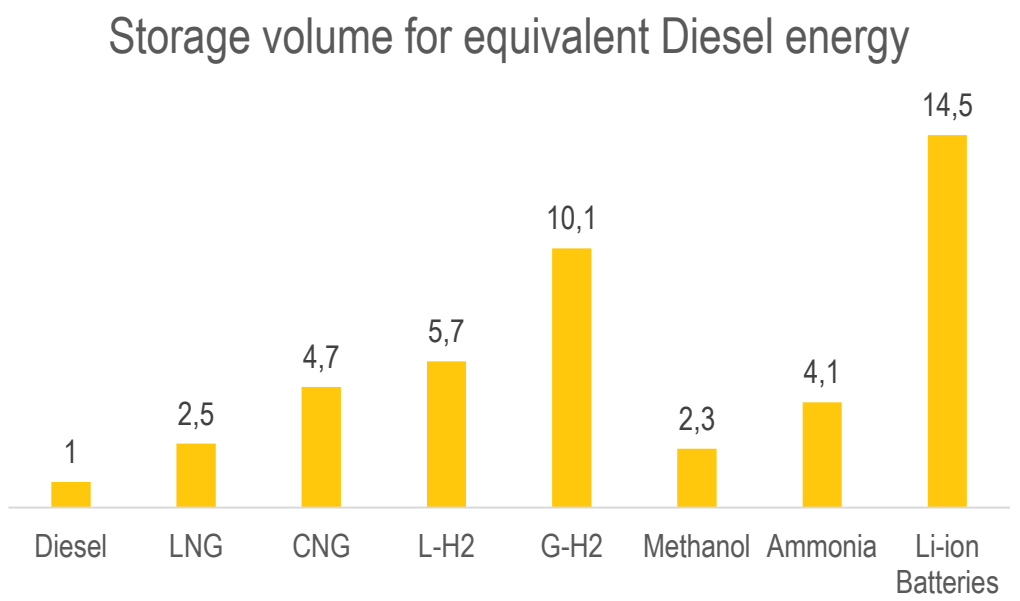
Quick Comparison

Emissions vs Ease of Use

- Focus on Well-to-Wheel emissions



- Volume needed to reach energy of Diesel

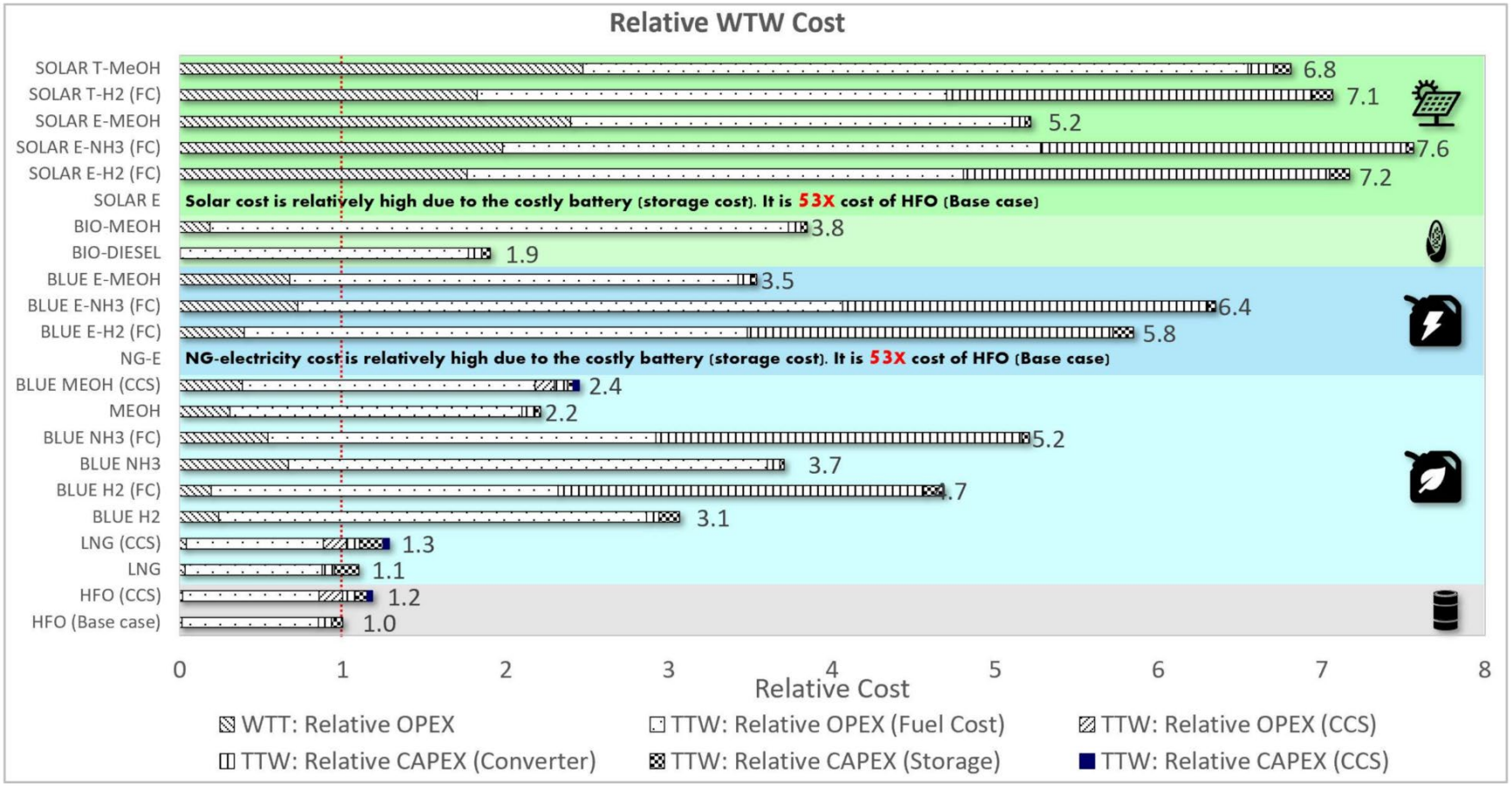


Source: Caterpillar

Quick Comparison

Total cost (in Marine shipping applications)

- HFO: Heavy Fuel Oils
- CCS: Carbon Capture Solution
- WTW: Well to Wheel
- WTT: Well to Tank
- TTW: Tank to Wheel
- FC: Fuel Cell

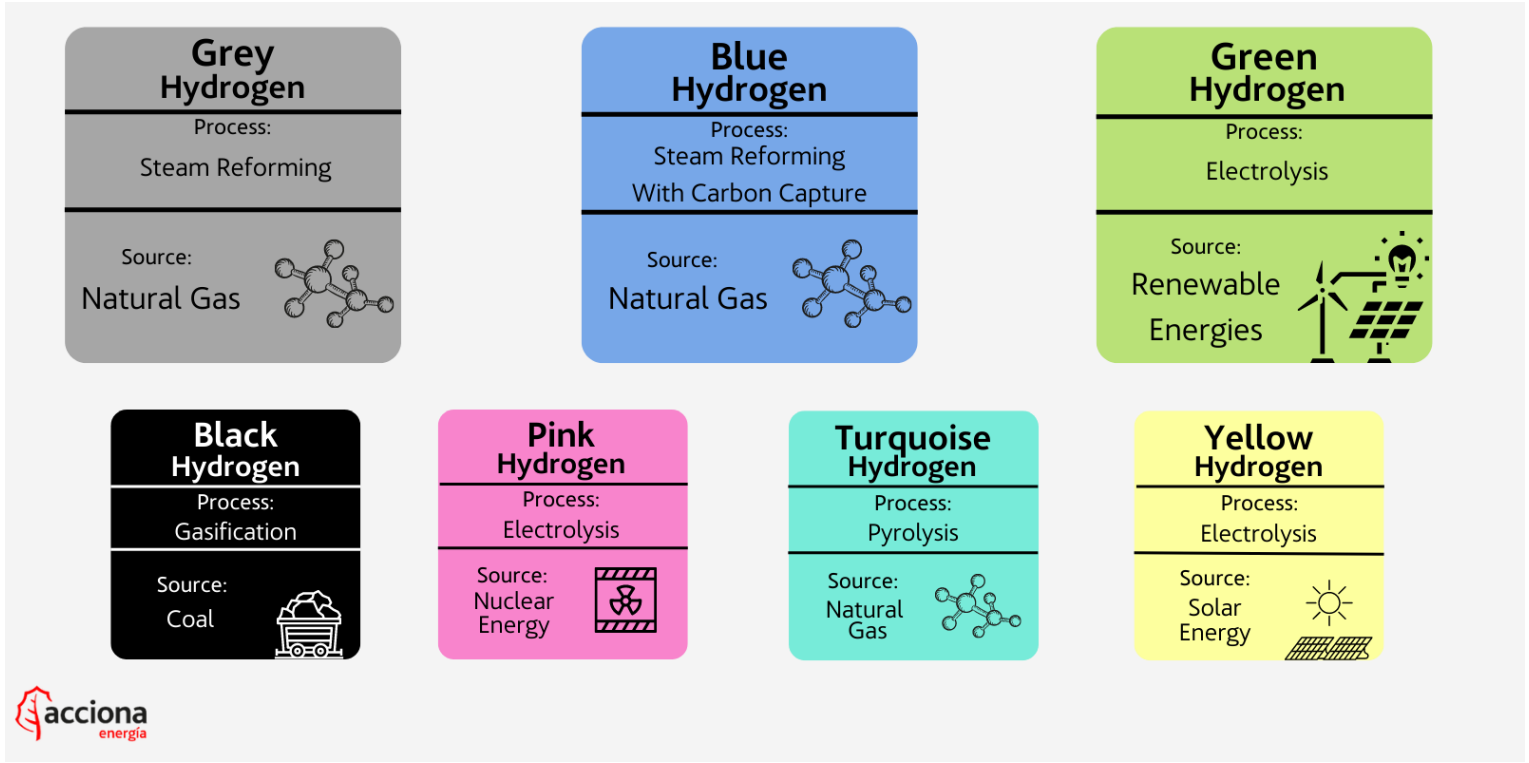


Source: A Comparison of Alternative Fuels for Shipping in Terms of Lifecycle Energy and Cost - 2021

Hydrogen

Lots of colors…

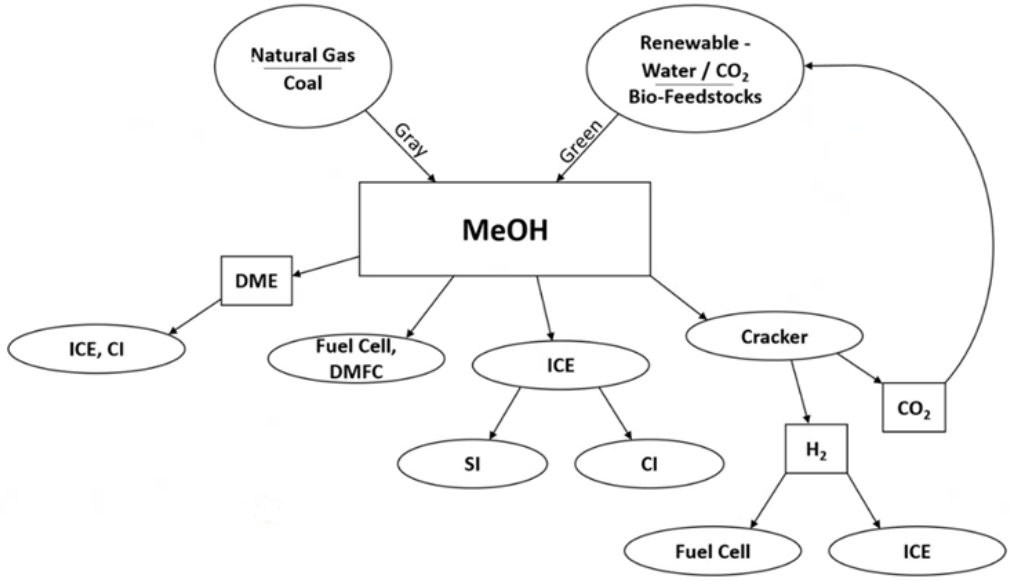
- Cost
  - Relatively high
- Ease of use
  - Liquification requires high energy
  - Compressed up to 700 bar
- Dangers
  - Burn spectrum
  - Flames invisible
- Emission
  - Lean burn, low Nox
  - Or 0 emission
- Caterpillar working on technology
- EODev genset



Methanol

Alcohol which you can't drink…

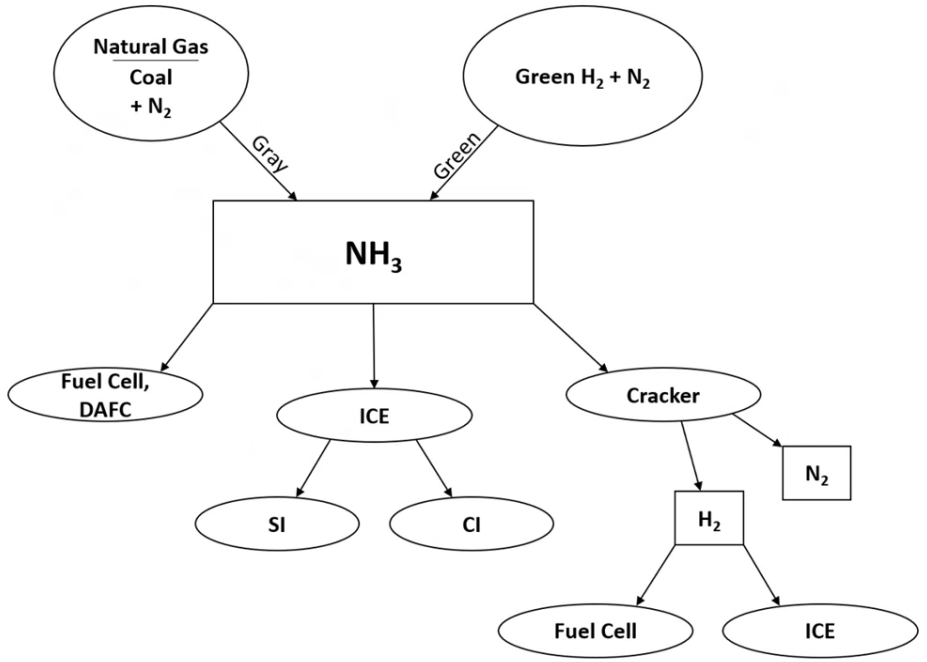
- Cost
  - Overall good
- Ease of use
  - Efficiency vs Diesel
- Dangers
  - Formaldehyde from partial combustion
  - Hygroscopic
- Emission
  - Low emission
  - High energy needed
- Caterpillar working on technology



Ammonia

What is that smell…

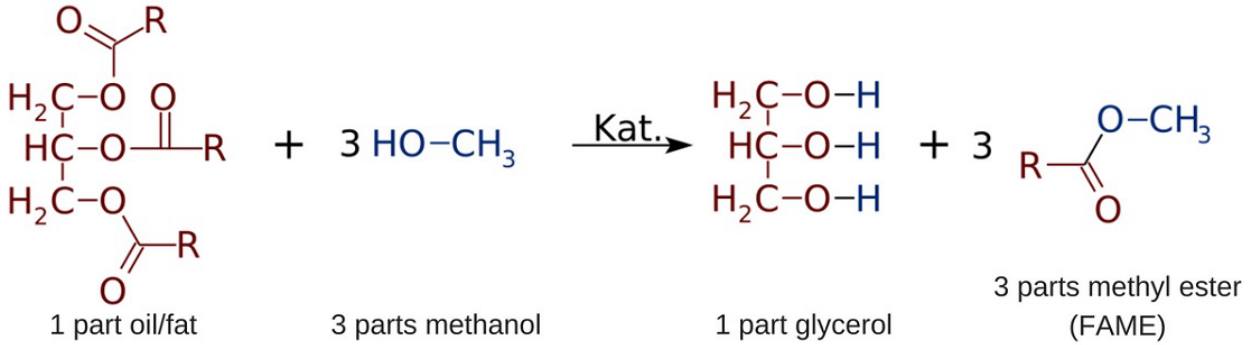
- Cost
  - Costly production
- Ease of use
  - SCR and AMOX required
  - Transportation of H_2
- Dangers
  - Corrosion
  - Poisonous
- Emission
  - Overall good
  - N_2O ~ 273x more potent GHG than CO_2
- Caterpillar will not work on technology



Biodiesel

It's Diesel, but more sustainable…

- FAME
  - Fatty Acid Methyl Ester
- Cost
  - Easy production
  - Overall cheap
- Ease of use
  - Limited storage time
  - Highly water absorbant/high oxygen level
- Dangers
  - Derating up to 8%
  - Limit blend up to 20%
- Emission
  - Overall good



Renewable Diesel

It's Diesel, but more sustainable…
And even better than the last

- HVO
  - Hydrotreated vegetable oil
- Cost
  - Overall cheap
  - More expensive than FAME
- Ease of use
  - High storage time
  - Production in feedstocks → refinery
  - Blend up to 100% - Caterpillar compatibel - EN15940 vs EN590
- Dangers
  - No derating with Caterpillar
  - 5% higher fuel consumption
- Emission
  - 90% CO_{2eq} reduction

Renewable Diesel

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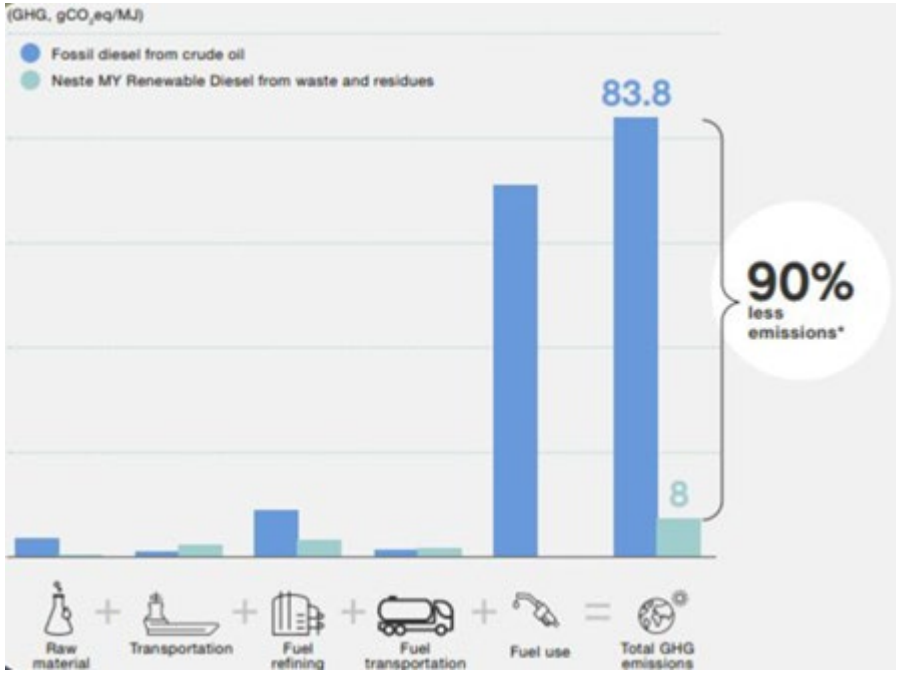
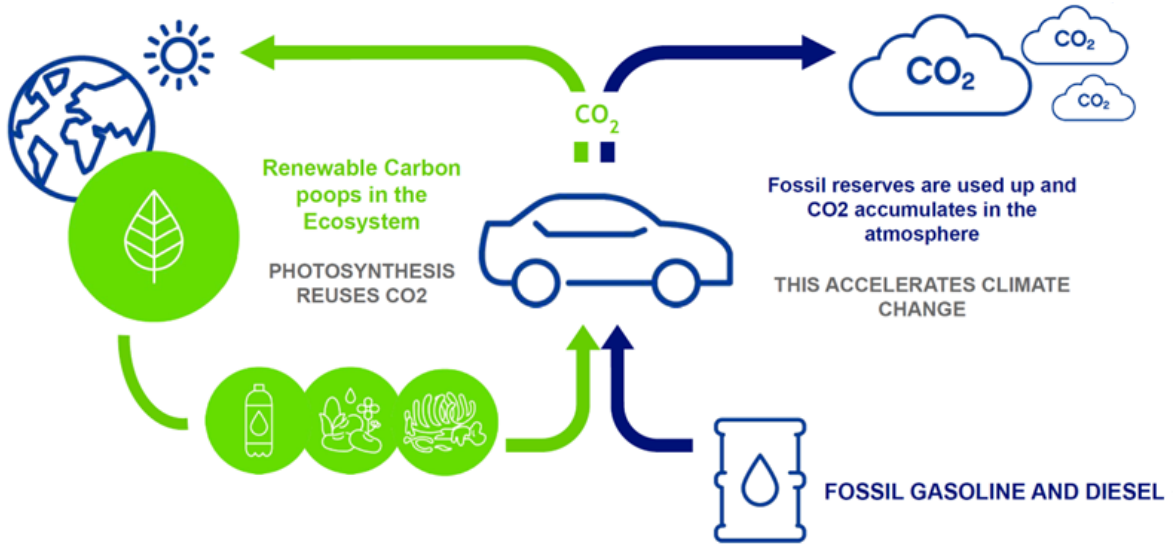


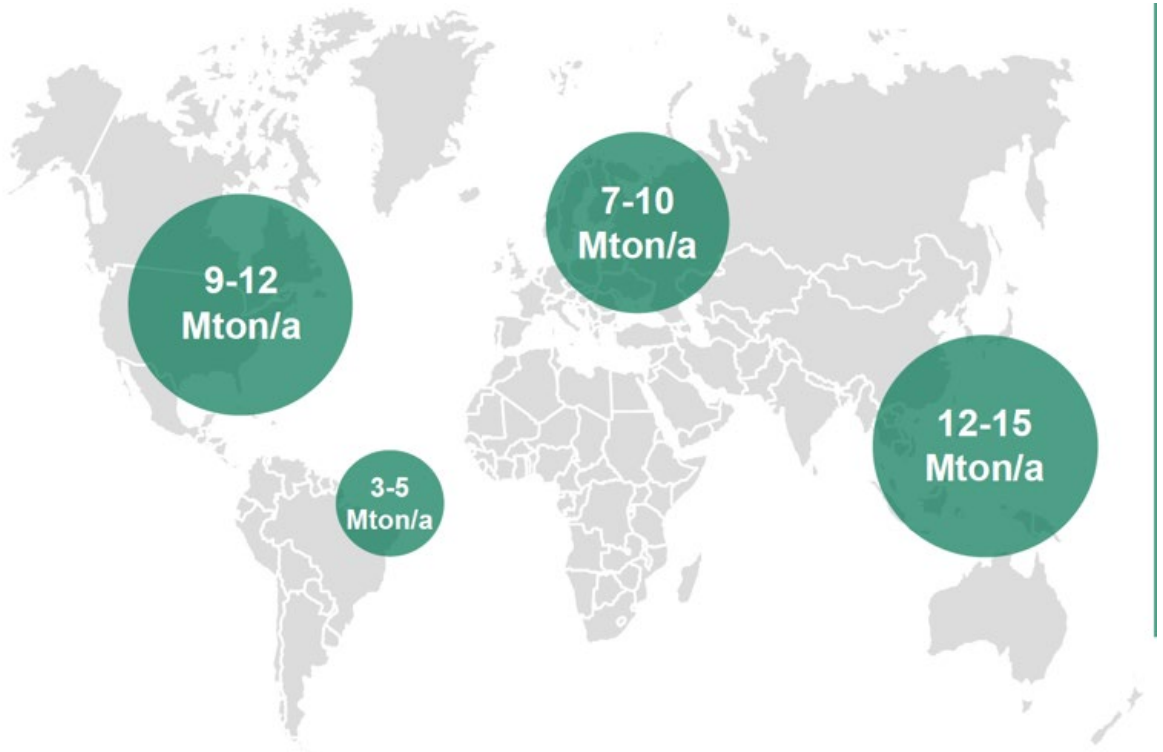


Source: Neste – NESTE MY

Renewable Diesel

It's Diesel, but more sustainable…
And even better than the last

- Production capacity by 2030
    - Increasing waste and residu
- No interference with food industry
- Other potential sources
    - Beyond 40 Mton/a
- 92% waste and residu
- Will be saturated



Source: Neste – NESTE MY

Renewable/Bio Diesel

It's Diesel, but more sustainable…

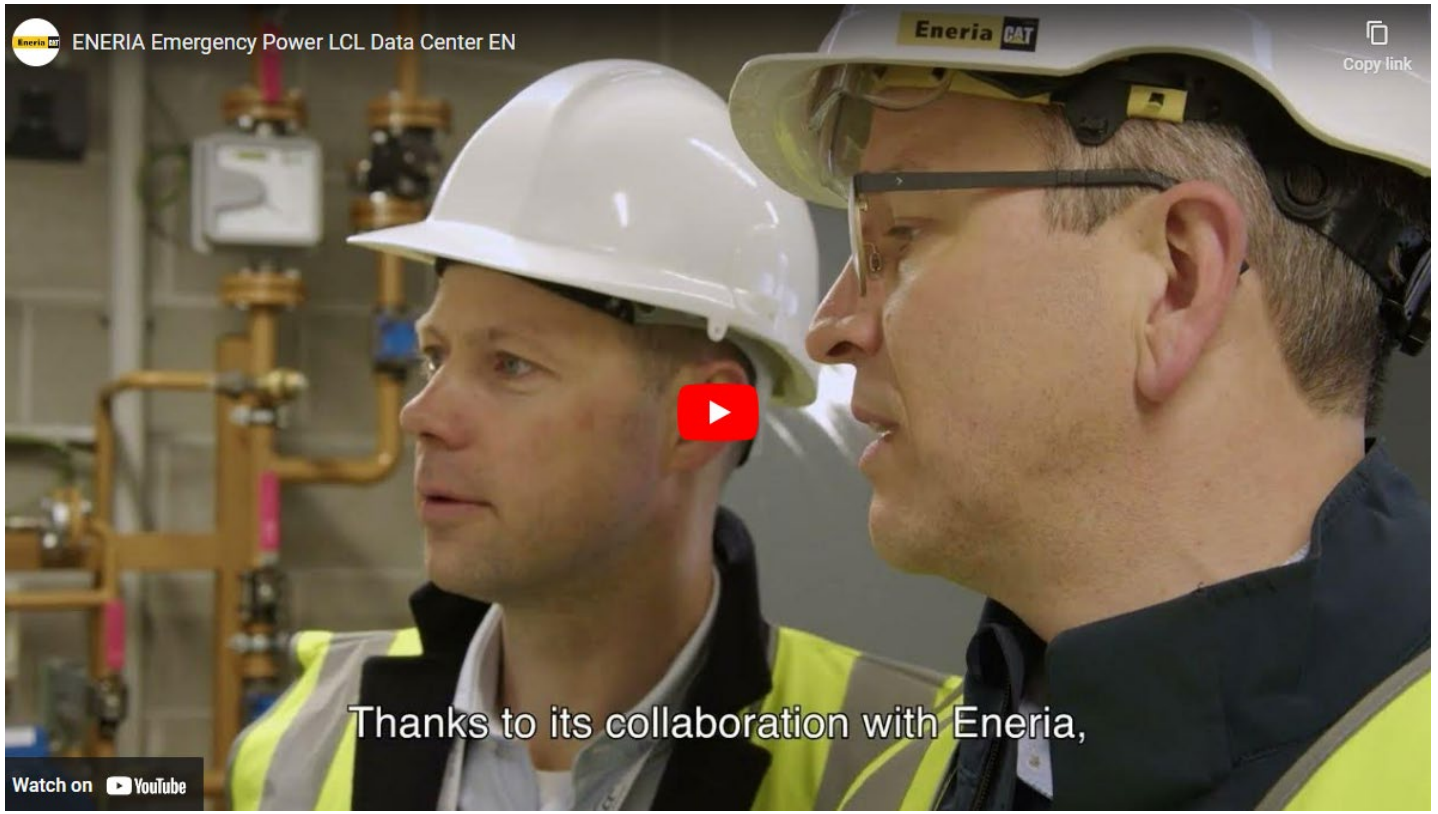
	Conventional fossil diesel	Renewable Diesel HVO	Biodiesel (FAME / RME / UCOME)
Raw material	Crude oil	Renewable raw materials	Waste and residue vegetable oil
Chemical composition	C_nH_{2n+2} + aromatics	C_nH_{2n+2}	O II H_3C-O-C-R
Oxygen (wt-%)	≈ 1 (in B7)	0	≈ 11
Cetane number	> 51	> 70	> 51
Aromatics (vol-%)	~5	0	0

Source: Neste – NESTE MY

HVO success story

With our partners at LCL

- Testing HVO vs normal Diesel
  - Mixing at different %
  - Better cold start capabilities
  - Very similar responses
  - G3 requirements
- 1st Datacenter to adopt HVO100 for emergency power



SHORT RECAP

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Or at least the most important ones…

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Lots of colors…

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There are lots of options when it comes to alternative fuels. Every one of them has pro's and con's, but each one will be more applicable in a certain field than the other one. When investigating which fuel is interesting in which field, we need to keep in mind the four main pillars in our decision progress.
Please feel free to contact Eneria to aid you in your decision progress.

Quick Comparison

Overview (in Marine shipping applications)

Marine Fuel	Onboard fuel mass ● = Light ■ = Medium ▲ = Heavy	Onboard fuel volume ● = Small ■ = Medium ▲ = Large	Relative WTW Energy ● = Low ■ = Medium ▲ = High	Relative WTW Cost ● = Low ■ = Medium ▲ = high	Relative WTW GHG Emissions ● = Low ■ = Medium ▲ = High	Relative Non-GHG Emissions ● = Low ■ = Medium ▲ = High	WTT Scalability ● = Scalable ■ = Challenging ▲ = Unlikely	Fuel safety ● = Safe ■ = Intermediate ▲ = Dangerous	Regulations & guidelines ● = Available ■ = Amendment ▲ = N.A.	Technology readiness ● = Commercial ■ = Small scale ▲ = R&D	Total Scores
HFO (base case)	●	●	●	●	▲	▲	●	●	●	●	78.3
HFO (ICE,CCS)	●	●	■	●	●	▲	●	●	●	■	85.3
NG-LNG (ICE)	●	●	●	●	■	●	●	●	●	●	82.4
NG-LNG (ICE,CCS)	●	●	■	●	●	●	●	●	●	■	86.6
NG-H2 (ICE)	●	■	■	●	●	●	●	▲	■	■	73.8
NG-H2 (FC)	●	■	●	■	●	●	●	▲	■	■	74.2
NG-NH3 (ICE)	●	■	■	■	●	●	●	▲	▲	■	65.1
NG-NH3 (FC)	●	●	■	■	●	●	●	▲	▲	■	66.8
NG-MeOH (ICE)	●	●	■	●	▲	●	●	■	■	■	62.5
NG-MeOH (ICE,CCS)	●	●	▲	●	■	●	●	■	■	■	67.0
NG-E (EM)	▲	▲	●	▲	●	●	●	●	●	●	65.6
BLUE-E-H2 (FC)	●	■	■	▲	●	●	■	▲	■	■	62.1
BLUE-E-NH3 (FC)	●	●	▲	▲	●	●	■	▲	▲	■	55.2
BLUE E-MeOH (ICE)	●	●	▲	■	▲	●	■	■	■	■	48.5
BIODIESEL (ICE)	●	●	●	●	●	■	■	■	●	■	85.9
BIO-MeOH (ICE)	●	●	■	■	●	■	■	■	■	■	72.6
SOLAR E (EM)	▲	▲	●	▲	●	●	▲	●	●	●	65.5
SOLAR-E-H2 (FC)	●	■	■	▲	●	●	▲	▲	■	■	63.4
SOLAR-E-NH3 (FC)	●	●	■	▲	●	●	▲	▲	▲	■	58.7
SOLAR E-MEOH (ICE)	●	●	▲	■	●	●	▲	■	■	■	62.8
SOLAR-T-H2 (FC)	●	■	■	▲	●	●	▲	▲	■	■	62.7
SOLAR-T-MeOH (ICE)	●	●	▲	▲	●	●	▲	■	■	■	57.3

Source: A Comparison of Alternative Fuels for Shipping in Terms of Lifecycle Energy and Cost - 2021

QUESTION TIME

Someone has to go first