IMO Goals for CO_2 emissions – Are they achievable?

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Short term measures:
Those agreed within

2018 - 2023

Mid - term measures:
Those agreed within

2023 - 2030

- EEDI + other indicators of efficiency.
- Speed Reduction / optimization
- Promote Alternative fuels

- Uptake of Alternative fuels
- MBMs

EEDI

- EEDI is a sea trial snapshot (total calm sea).
- No connection to real ship efficiency.
- Reducing (strengthening) the EEDI requirement does not improve ship efficiency. It does reduce Safety !
- IMO is caught in a EEDI vicious circle.

Other Efficiency indicators:
A simple index to rate ships is attractive, but…

- **EFFICIENCY IS NOT …**

EEOI

FORS

EEDI

EVI

It is UTOPIA

ISPI

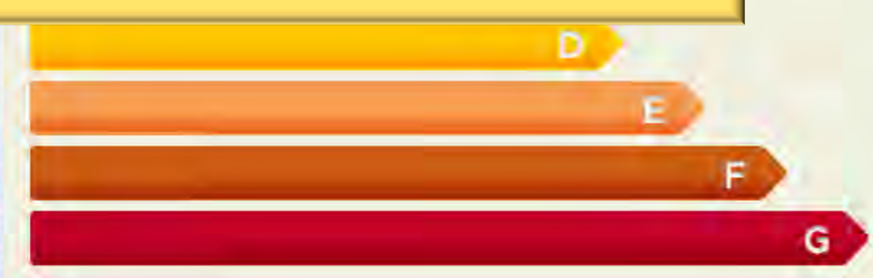
ESI

AER

2. SHIPS ARE NOT REFRIGERATORS!

SPEED LIMITS BY REGULATION ?

- ~~EEDI + other indicators of efficiency.~~
- Speed Reduction / optimization
- Promote Alternative fuels



What about SPEED LIMITS ?

Table 5 - Annual absolute CO_2 emission reduction potential for the three ship types under three alternative speed regimes

	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	Sum
10% speed reduction	67	68	70	72	73	75	76	78	79	80	81	82	83	985
20% speed reduction	123	127	130	133	136	139	142	145	146	148	150	152	154	1,825
30% speed reduction	169	174	179	183	187	191	195	199	201	[illegible]	[illegible]	[illegible]	[illegible]	[illegible],508

Good, But how many <u>more</u> ships will we need to satisfy world trade demand?

Table 7 - Growth of active fleet required in 2018 in terms of number of ships

	10% speed reduction	20% speed reduction	30% speed reduction
Container fleet	7% (6-8%)	15% (14-18%)	26% (23-30%)
Dry bulk fleet	6% (5-6%)	13% (12-14%)	22% (21-25%)
Crude & product tanker fleet	5% (5-8%)	12% (11-17%)	21% (18-29%)
Total	6%	[illegible]	[illegible]

(Percentage ranges in brackets give fleet growth ra...

How much CO_2 will be emitted to build these extra ships?

Table 8 - Gross* shi...

	[illegible]	20% speed reduction	30% speed reduction
Cont...	10%	23%	39%
Dry bulk fleet	9%	20%	34%
Crude & product tanker fleet	12%	28%	47%
Total	10%	22%	37%

* Laid-up and idle ships not subtracted.

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Trans RINA, Vol 152, Part A3, International Journal of Maritime Engineering
Jul-Sep 2010,

LIFE-CYCLE CO_2 EMISSIONS OF BULK CARRIERS:
A COMPARATIVE STUDY[1]

Ge…
Ship…
Har…
Pano…
Mana…

ABST…

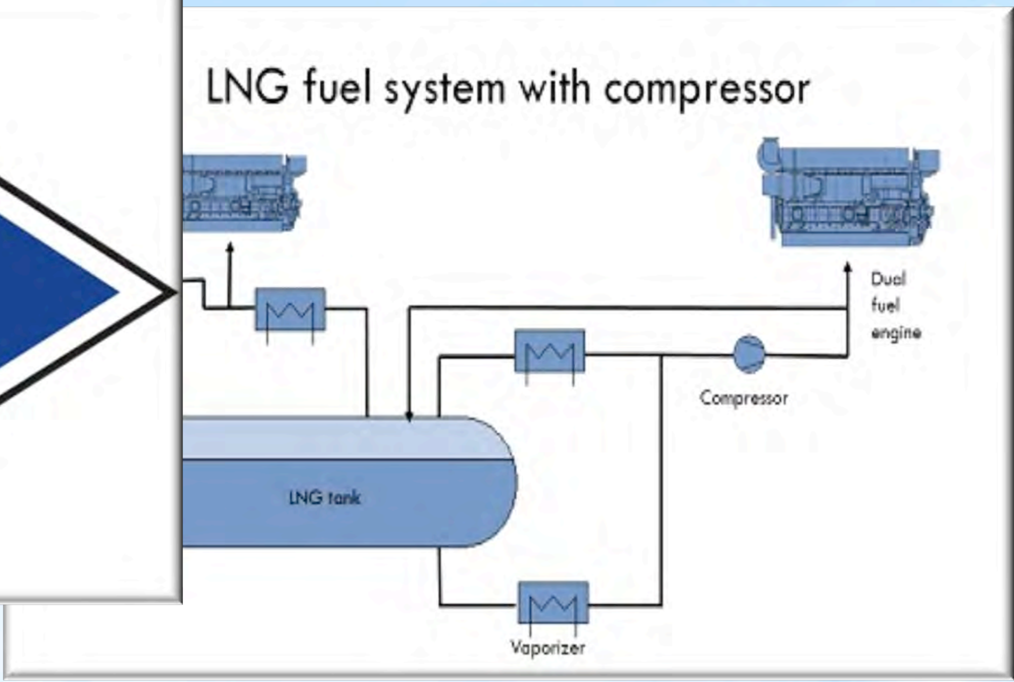
In orde… …ps have to be
built to … …nning, operating, maintaining
and repa… …ne is borne by society at large through market
mechanis… …tsos and Zachariadis (2005) had investigated through a cost/benefit
analysis how the average annual cost of ship transport varies with the corrosion

1) …
2) …
3) …
4) Does not …
5) Serious trade disruption
6) etc.- etc.

- ~~EEDI + other indicators of efficiency.~~
- Speed ~~Reduction~~ / optimization / ~~limits~~
- Promote Alternative fuels

Let's look at ALTERNATIVE FUELS

LNG



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Methane 25 times worse than CO_2 ? **86 times**

20% less CO2 when burned ? **Same or worse than diesel**

UN's IPCC 2013: 100 year: 34 times worse (not 25)
20 year: 86 times worse

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What About other Alternative fuels ?

Hydrogen

Methanol

LPG
(propane/butane)

Ammonia

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Some answers for CO_2 reduction are:

- ✓Hydrogen from renewable electrolysis
- ✓Better Batteries
- ✓Nuclear
- ✓Synthetic Fuels
- ✓New technology

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Biodiesel
Electricity
Ethanol
Hydrogen
Natural Gas
Propane

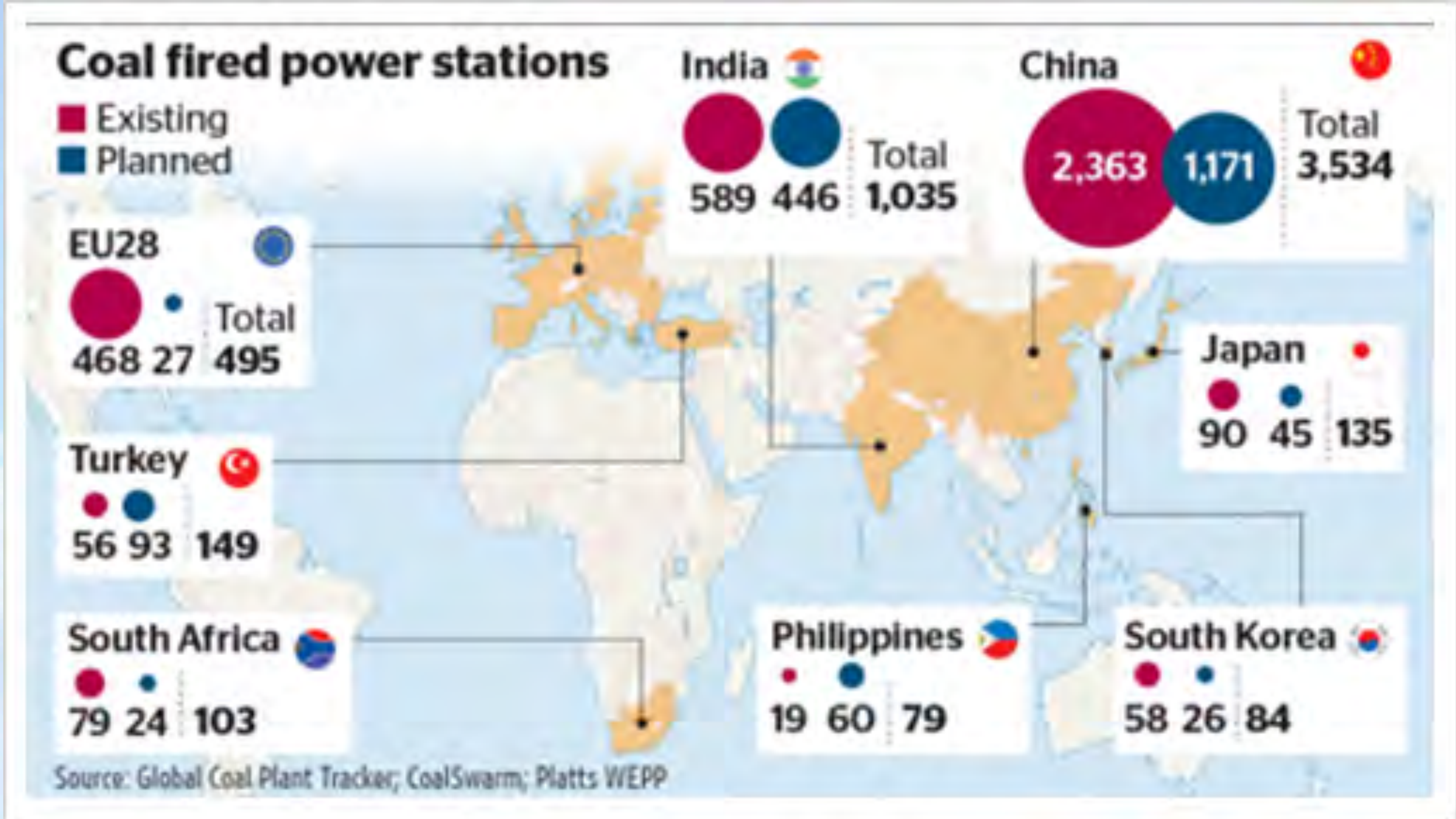

Ευχαριστώ

References (sample only)

1. Methane Emissions from Natural Gas Bunkering Operations in the Marine Sector: A Total Fuel Cycle Approach, James J. Corbett, Ph.D. University of Delaware, Heather Thomson, Ph.D. University of Delaware, James J. Winebrake, Ph.D. Rochester Institute of Technology**, US MARAD**, 21 November 2015
2. Comparing Lifecycle Greenhouse Gas Emissions from Natural Gas and Coal, Mark Fulton, Global Head of Climate Change Investment Research, **Deutsche Bank**, August 25, 2011
3. Methane emissions from LNG-powered ships higher than current marine fuel oils, **European Commission** DG Environment News Alert Service, http://ec.europa.eu/environment/integration/research/research_alert_en.htm, 28 January 2016
4. A bridge to nowhere: methane emissions and the greenhouse gas footprint of natural gas, Robert W. Howarth Department of Ecology & Evolutionary Biology, Cornell University, Ithaca, New York 14853, 2014, Energy Science & Engineering published by the **Society of Chemical Industry** and John Wiley & Sons Ltd.
5. Climate Impacts of Natural Gas Production and LNG Export , A Synopsis of Current Science, August 2014, various Authors, web searchable by title.
6. *"Decarbonizing Maritime Transport: Pathways to zero carbon-shipping by 2035", **OECD**, at* https://www.itf-oecd.org/decarbonising-maritime-transport
7. Intergovernmental Panel on Climate Change (**IPCC**), Climate Change 2013: Physical Science Basis, Anthropogenic and Natural Radiative Forcing, p. 714

Appendix

COAL is DEAD then ??



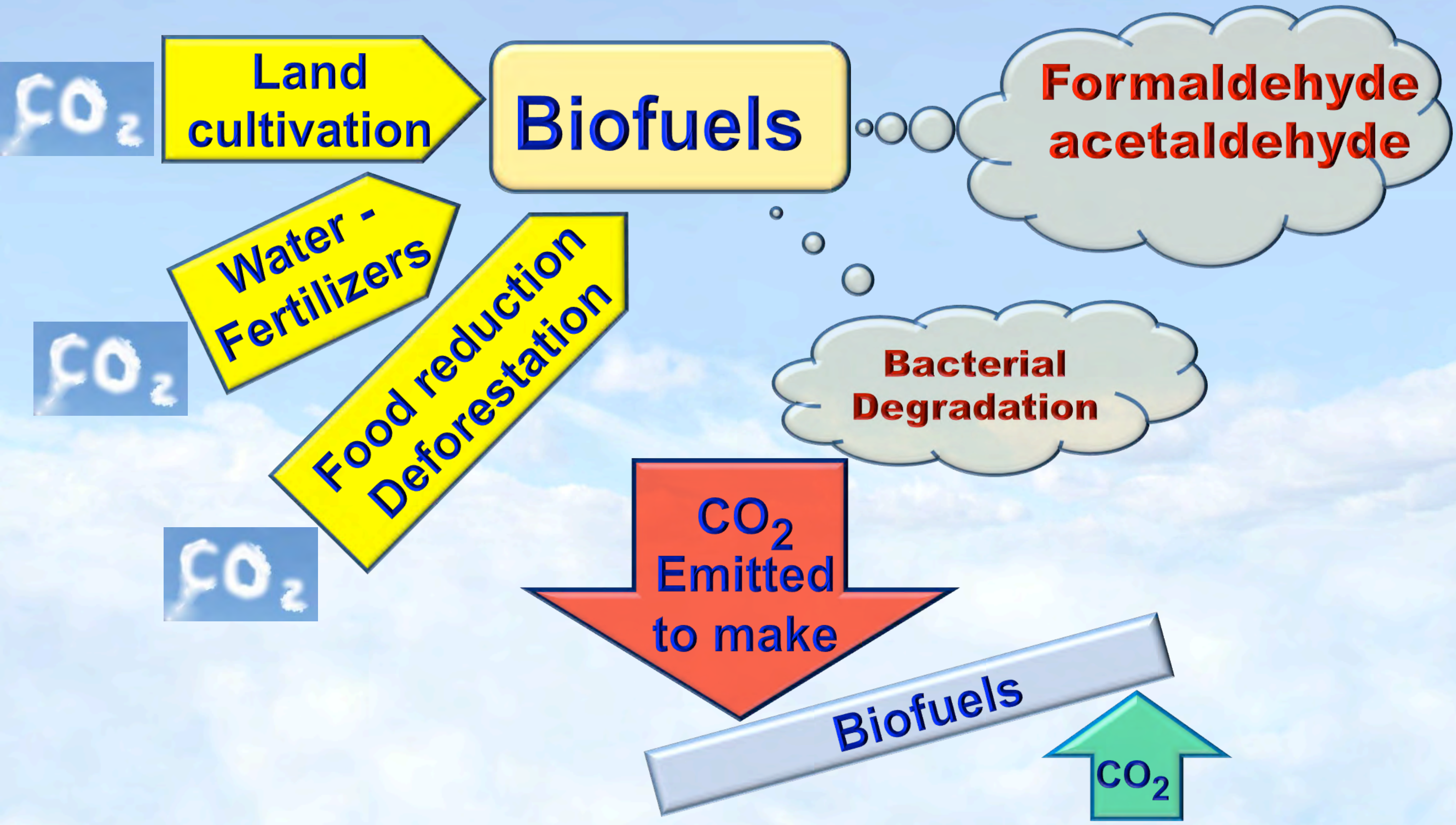


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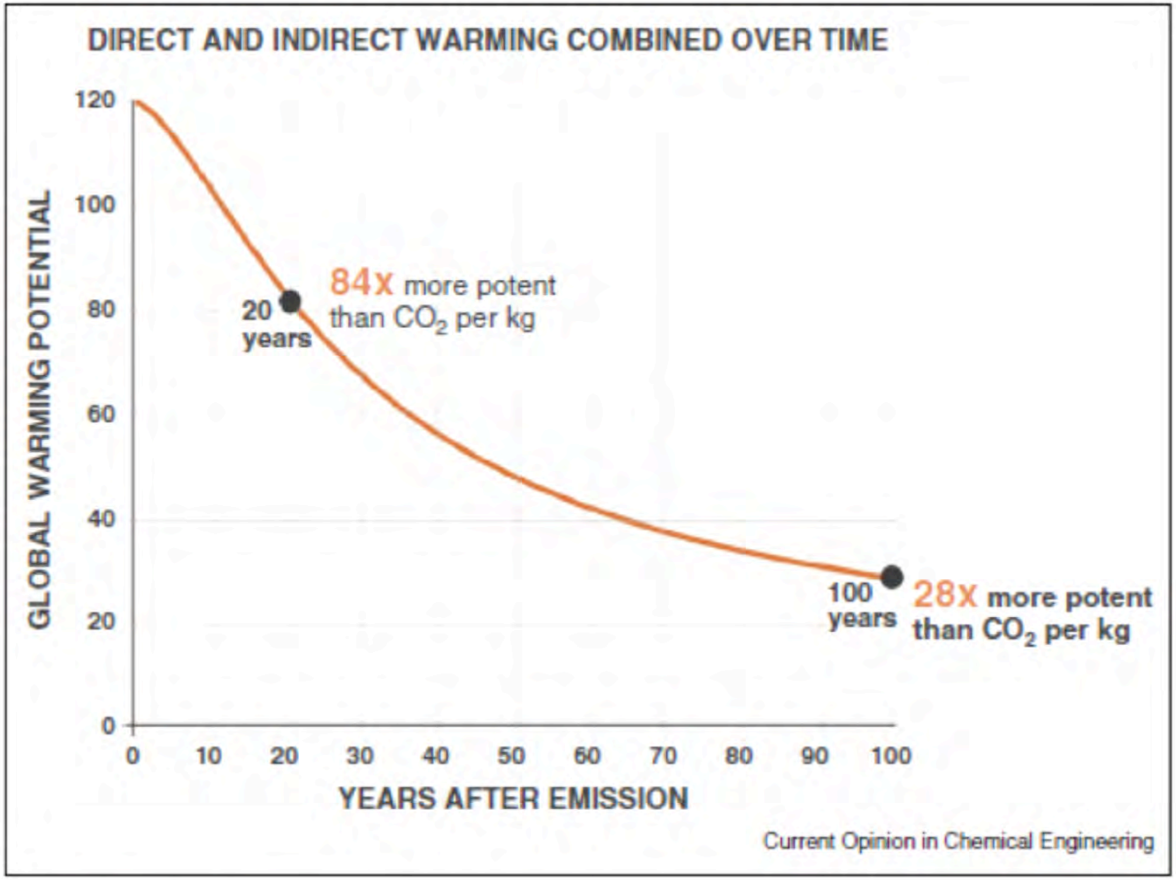
Figure 2



Global warming potentials for methane (kg CO_2 emissions equivalent to a kg of methane emissions), as a function of the time horizon used in the GWP calculationAdapted from [22**] with updated estimates from [21].

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NG production is abt. 3,700 billion m3 / year = abt. 3.1 billion tons (bt).

World avg escape (most at production) is 5 – 6% with shale gas more.

Manmade CO2 is abt. 36 bt (shipping 0.8 billion)

Say only 4% NG escape = 0.12 bt LNG x 86 = 10.7 bt CO2e

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Methane Emissions from Natural Gas Bunkering Operations in the Marine Sector:
A Total Fuel Cycle Approach

Prepared for
U.S. Department of Transportation
Maritime Administration

21 November 2015

Table 11 Total fuel cycle greenhouse gas emissions results of each scenario as compared to low sulfur diesel fuel.

	LNG w/ Compression Ignition Engine	LNG w/ Spark Ignition Engine	Low Sulfur Diesel	Residual Fuel Oil
LNG No Bunkering	-14.9%	+5.4%	-	+1.4%
LNG Bunkering (0.065%)	-14.3%	+6.0%	-	+1.4%
LNG Bunkering (0.24%)	-12.9%	+7.4%	-	+1.4%
LNG Bunkering (1.0%)	-6.7%	+13.6%	-	+1.4%

If proper factor of 86 applied, even these engines become worse than diesel

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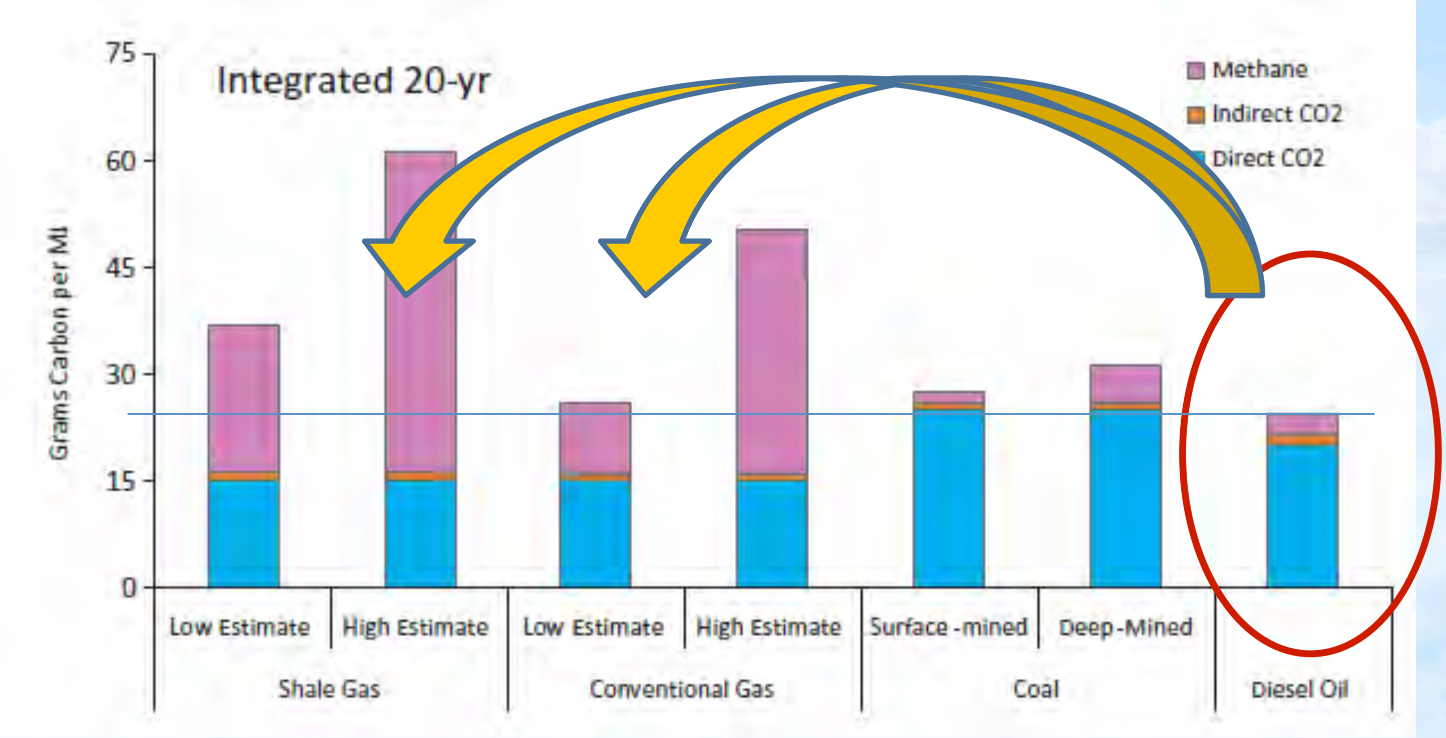
Considering the whole Lifecycle

A bridge to nowhere: methane emissions and the greenhouse gas footprint of natural gas

Robert W. Howarth

Department of Ecology & Evolutionary Biology, Cornell University, Ithaca, New York 14853



SCIENTIFIC AMERICAN

SUSTAINABILITY

Climate Benefits of Natural Gas May Be Overstated

Policymakers and the energy industry have been looking to natural gas in recent years as a more climate friendly fuel with half the greenhouse gas emissions of coal, but EPA research is casting doubt on that plan

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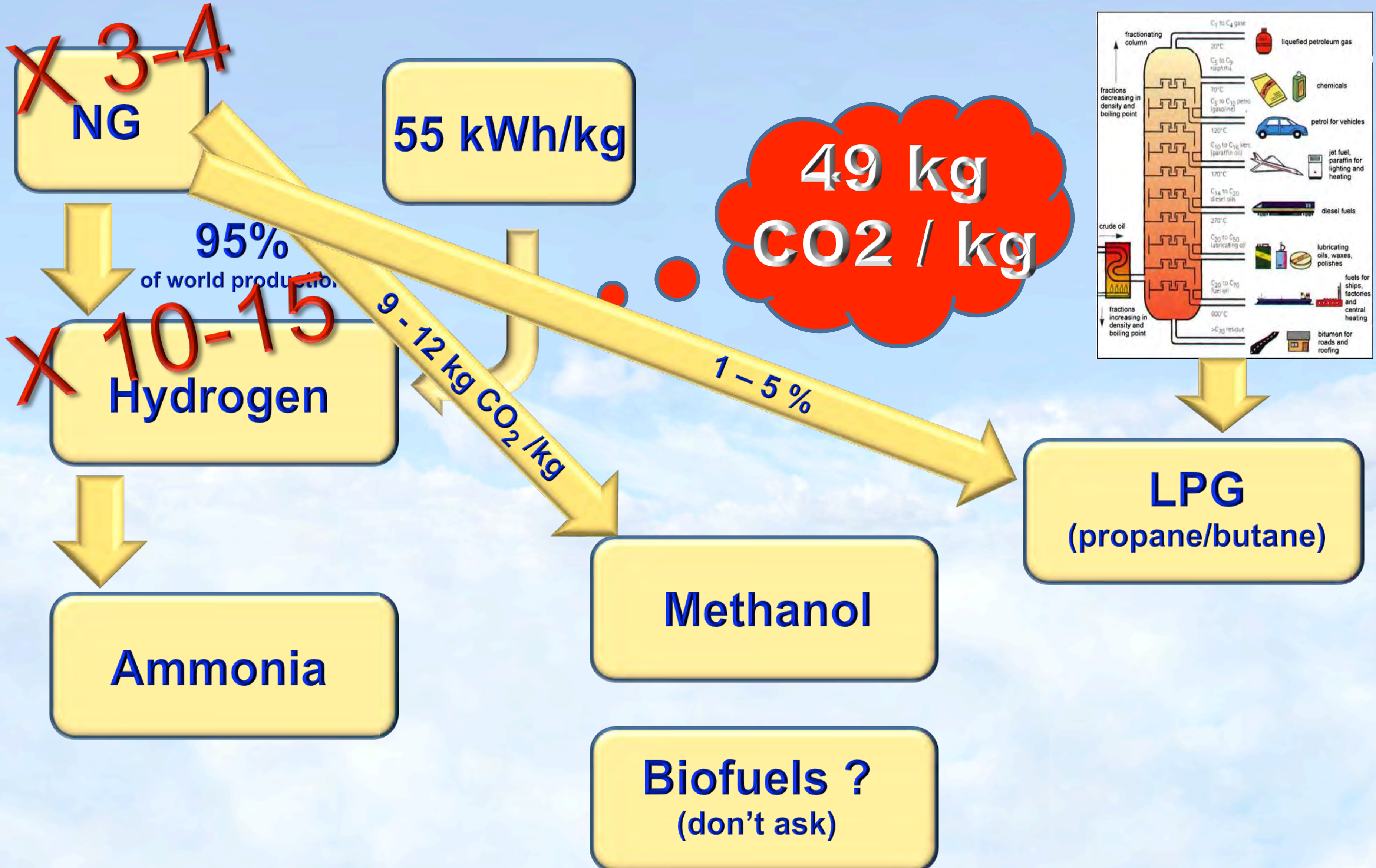
European Commission

Science for Environment Policy

Methane emissions from LNG-powered ships higher than current marine fuel oils

Due to regulation on sulphur emissions, liquefied natural gas (LNG) has increased in use as a maritime fuel. This study measured exhaust gases from a ship with dual-fuel engines running on LNG and marine gas oil (MGO). Although NO_X and CO_2 emissions were lower for LNG compared to MGO, hydrocarbon and carbon monoxide emissions were higher. The authors say future work should reconsider the climate impact of LNG.

What About other Alternative fuels ?



Liquid Biofuel

Ethanol

Biodiesel

USA, Brazil

Europe

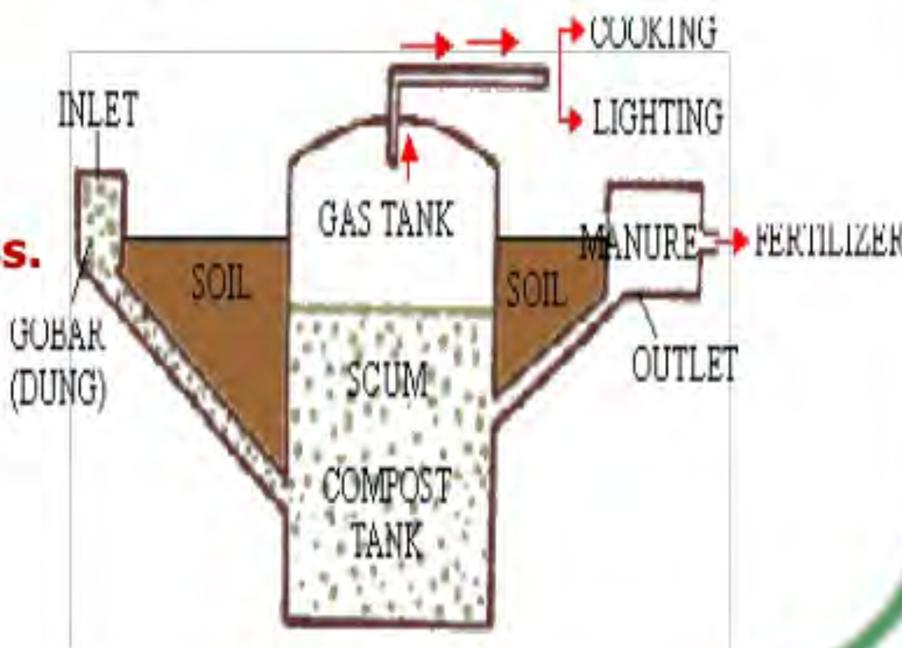
New or Used fats and oils

Bio GAS

BIO-GAS

- **Methane** is the primary biogas.
- Landfill gas is primarily methane but contains CO_2 and other gases from plastics, etc.
- **Gobar Gas :-**

  Gobar gas production is an anaerobic process.



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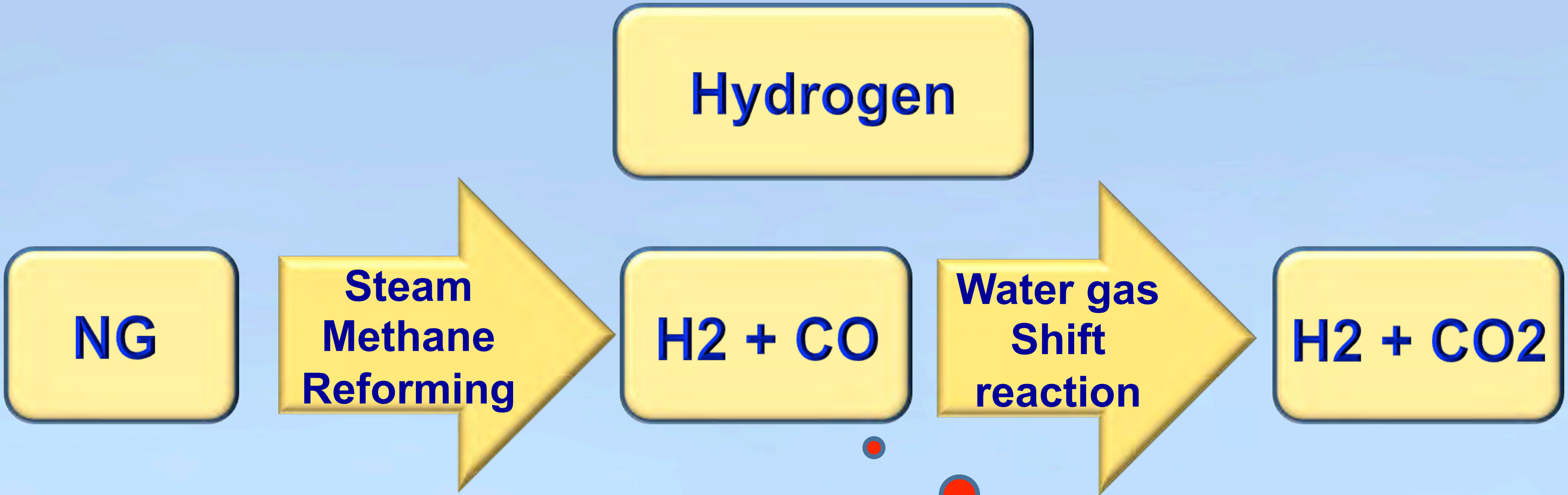
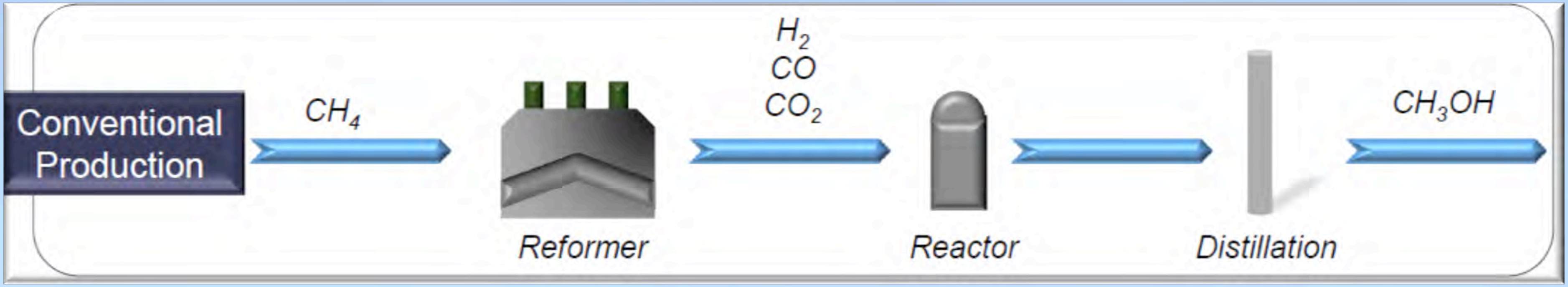


Partial oxidation of methane reaction
$CH_4 + \frac{1}{2}O_2 \rightarrow CO + 2H_2$ (+ heat)
Water-gas shift reaction
$CO + H_2O \rightarrow CO_2 + H_2$ (+ small amount of heat)

- **Combustion: No CO2, No SOx, low NOx**
- **Liquid at -253^{o} C**
- **Not easy to transport / store**
- **Safety issues**

Methanol



- Combustion: LNG CO2, low SOx, NOx not down to Tier III
- Liquid at atmospheric pressure, so
- Easy to transport / store
- Safety issues, low flash point 12^{o} C
- Health issues, Toxic

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Ammonia

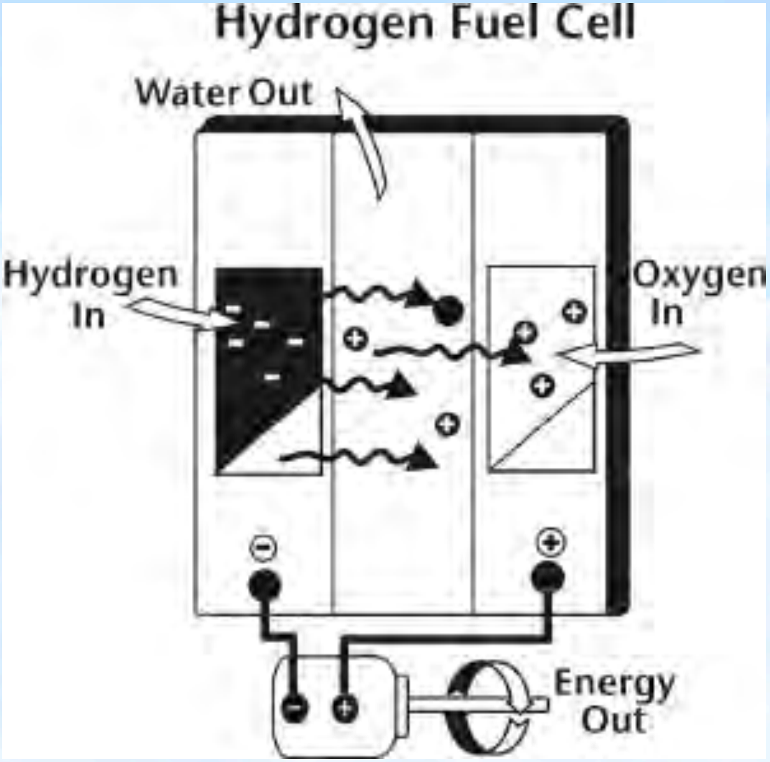
H2 → Add Nitrogen → $3H_2 + N_2 \rightarrow 2NH_3$

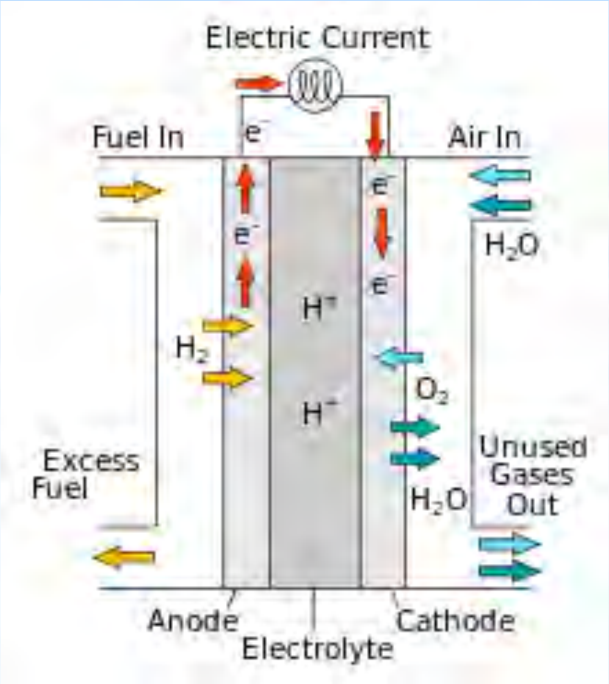
Very Carbon Intensive process since air is burned to get the Nitrogen

- **Combustion: H2 carrier**
- **Liquid at -34^{o} C --> much easier than H2**
- **Health issues, Toxic**

Fuel Cells

They convert the chemical energy of compounds, through electrochemical oxidation, to electric power, without combustion involved, releasing thermal energy in the process.
The most usual fuel used is hydrogen, the exhaust being water. LNG, methanol and ammonia could also be used.





- **Short lifetime**
- **Large size**