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After 50 years of stability, companies face difficult decisions about running their existing fleet and new investment.

**Part 1**
Global energy & the development of green fuel

**Part 2**
The energy price issue – the cost of fuel and the consequences

**Part 3**
Ship propulsion – the systematic elimination of $CO_2$

**Part 4**
The timeline to zero carbon

After each webinar participants will be able to download a set of slides and a page bullet point notes of the material covered in the webinar.

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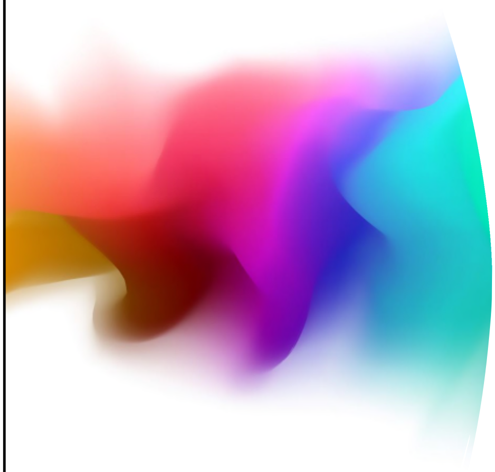

# 1. GLOBAL ENERGY & THE DEVELOPMENT OF GREEN FUEL

METHOD 1: **Sail, solar:** on board ships

METHOD 2: **Chemical energy:** HFO (with CCS), Biofuels, H2,methanol, Ammonia

METHOD 3: **Nuclear reactor;** stakeholders should prepare for it!

METHOD 4: **Secondary energy:** recovering energy from transport systems.

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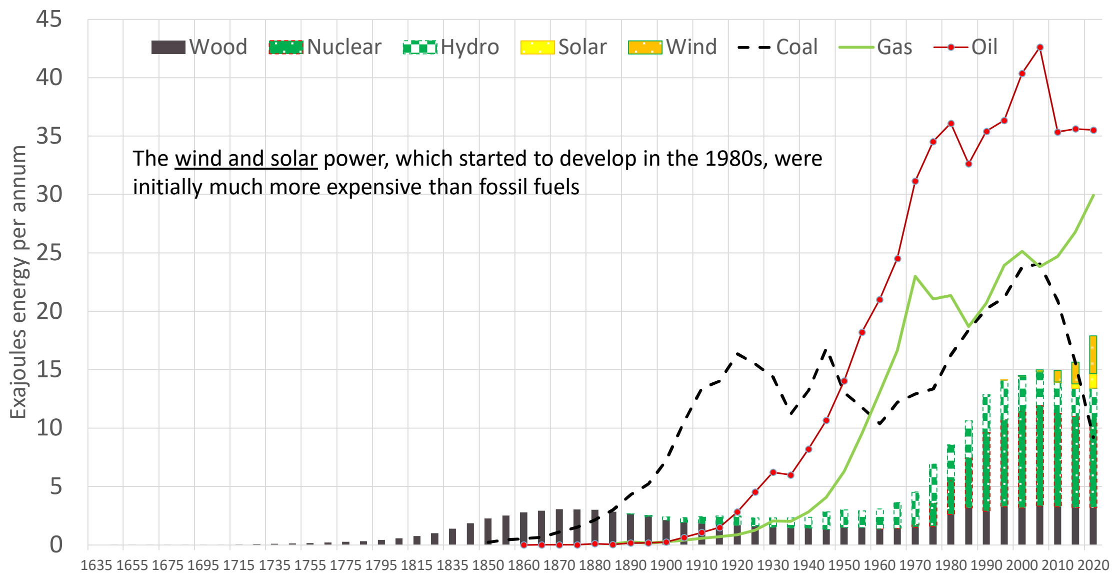
## S 2.1 USA energy consumption 1635-2020 – solar & wind in 2000s

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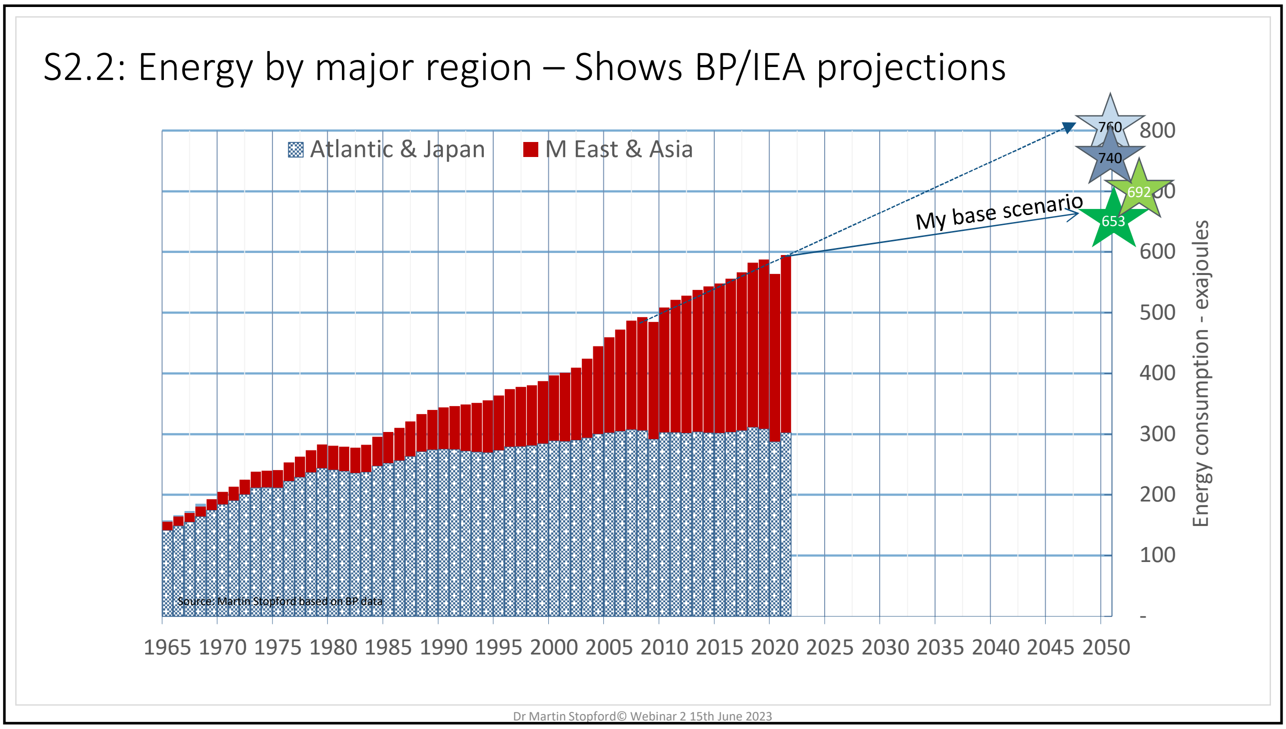
S2.2: Energy by major region – Shows BP/IEA projections
Atlantic & Japan
M East & Asia
My base scenario
760
740
692
653
800
600
500
400
300
200
100
-
Energy consumption - exajoules
Source: Martin Stopford based on BP data
1965 1970 1975 1980 1985 1990 1995 2000 2005 2010 2015 2020 2025 2030 2035 2040 2045 2050
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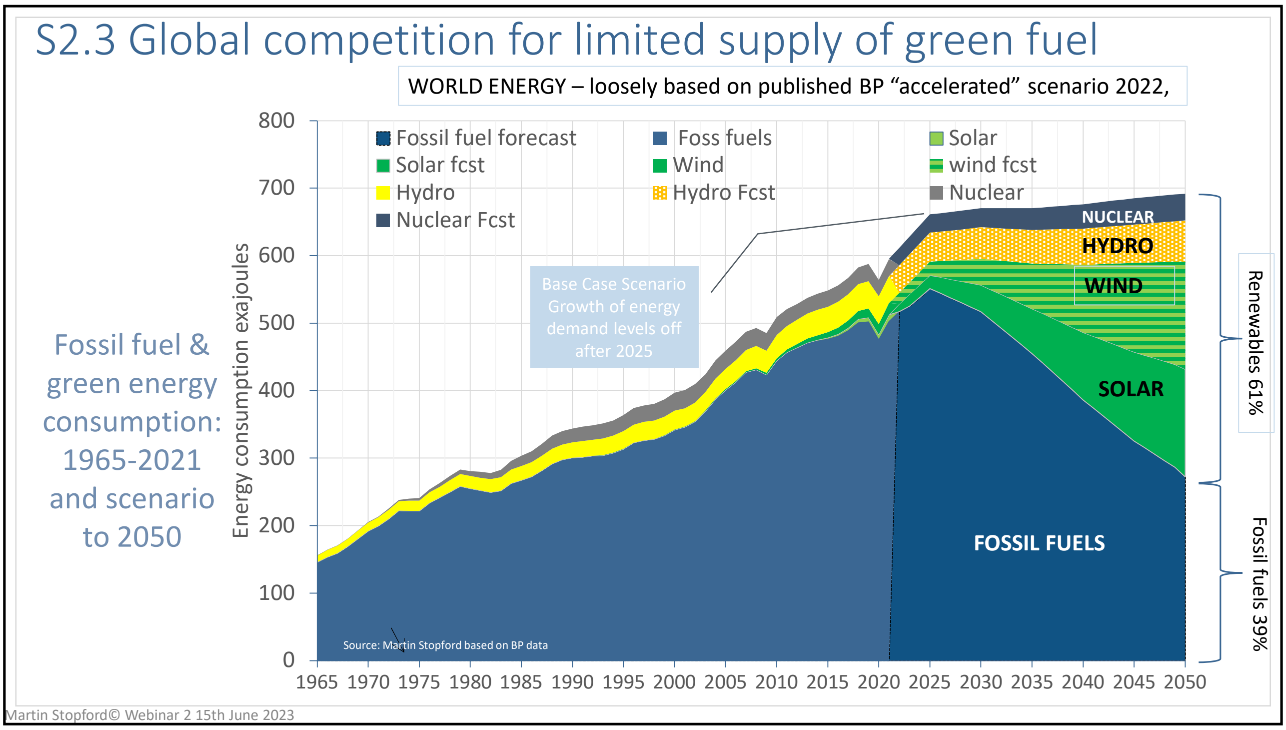
S2.3 Global competition for limited supply of green fuel
WORLD ENERGY – loosely based on published BP "accelerated" scenario 2022,
Fossil fuel forecast
Solar fcst
Hydro
Nuclear Fcst
Foss fuels
Wind
Hydro Fcst
Solar
wind fcst
Nuclear
Base Case Scenario Growth of energy demand levels off after 2025
NUCLEAR
HYDRO
WIND
SOLAR
FOSSIL FUELS
Renewables 61%
Fossil fuels 39%
Fossil fuel & green energy consumption: 1965-2021 and scenario to 2050
Energy consumption exajoules
800
700
600
500
400
300
200
100
0
Source: Martin Stopford based on BP data
1965 1970 1975 1980 1985 1990 1995 2000 2005 2010 2015 2020 2025 2030 2035 2040 2045 2050
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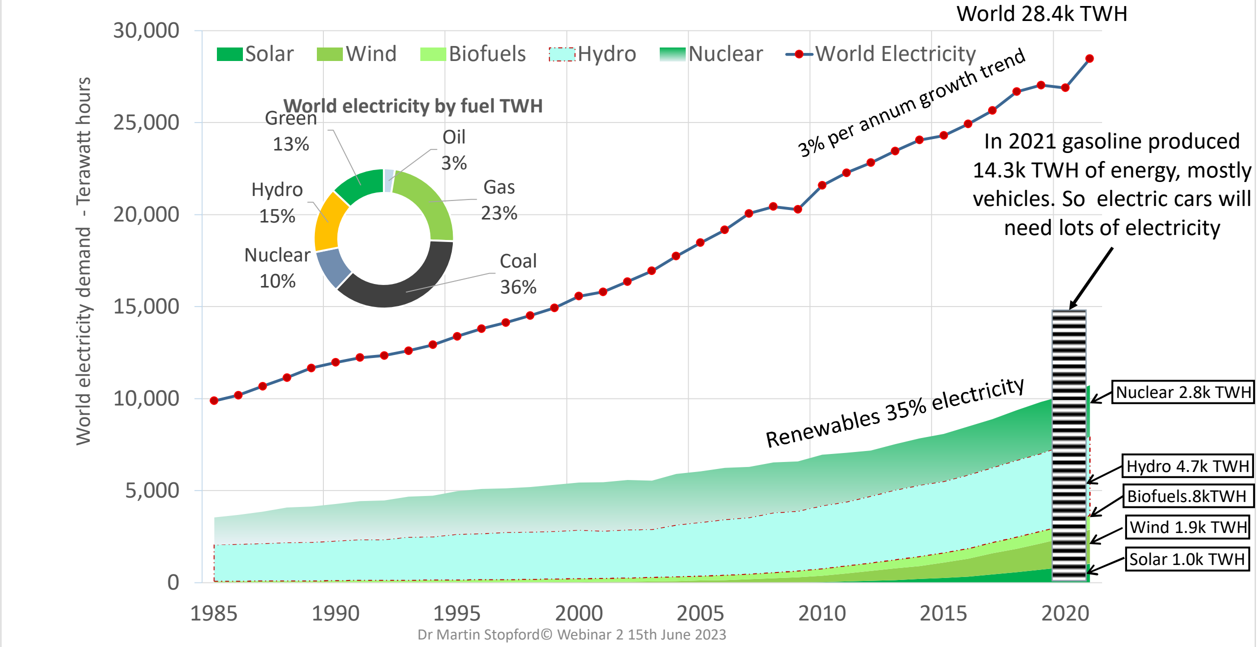
## S2.4: Green electricity limited but growing fast

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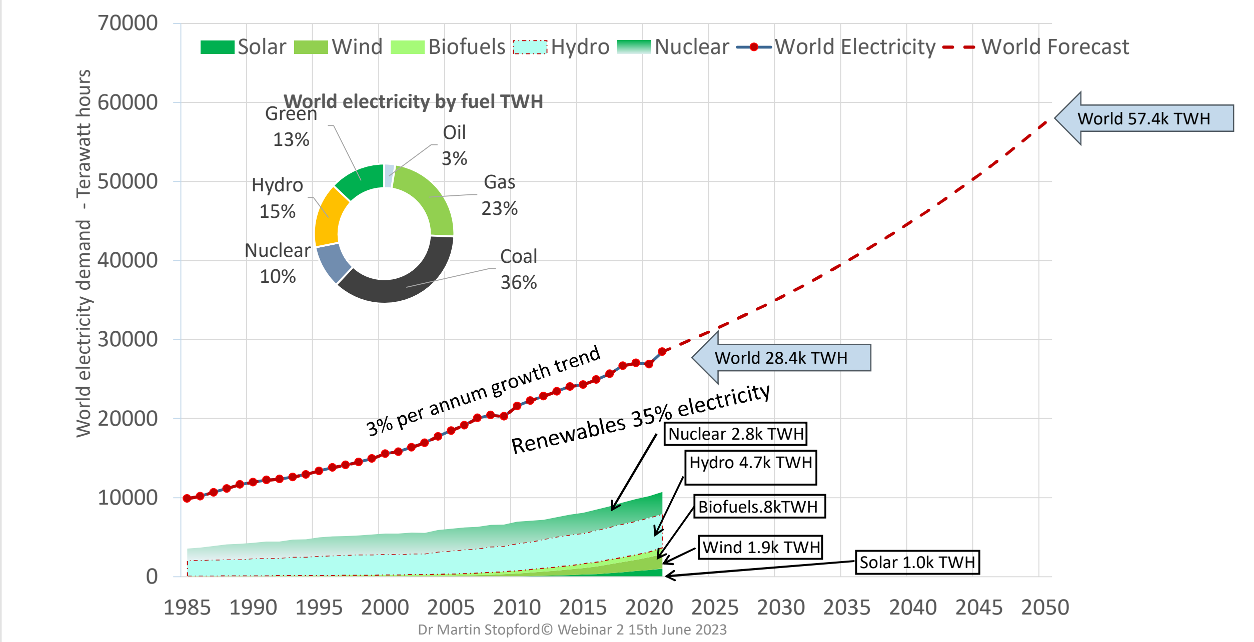
## S2.5 Electricity demand scenario to 2050 about 2% pa growth?

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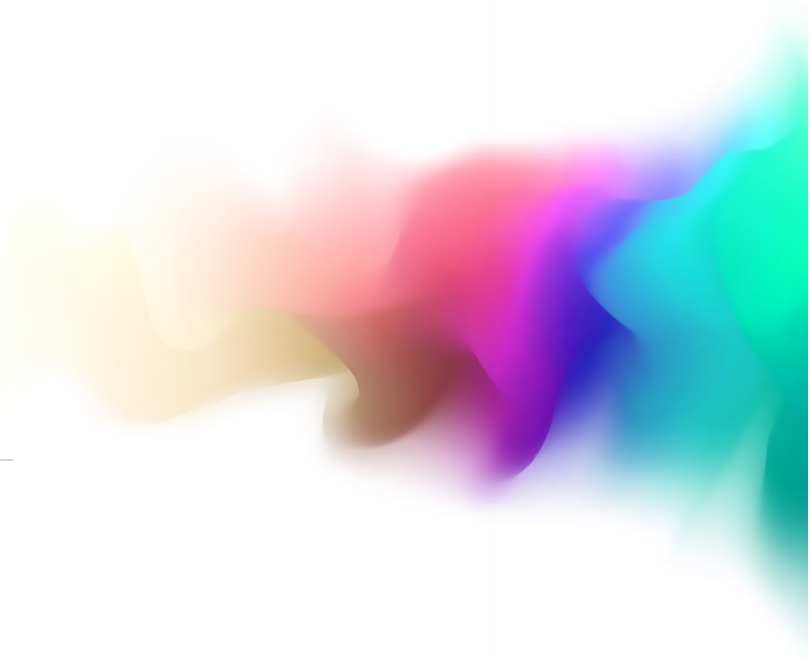
# 2. THE ENERGY PRICE ISSUE – FUEL COSTS WILL DRIVE CHANGE

Market based fuel prices likely to be much higher, driving be companies to change what they do and how they do it

If green fuel costs are not high, it will be business as usual. That would be the easy outcome!



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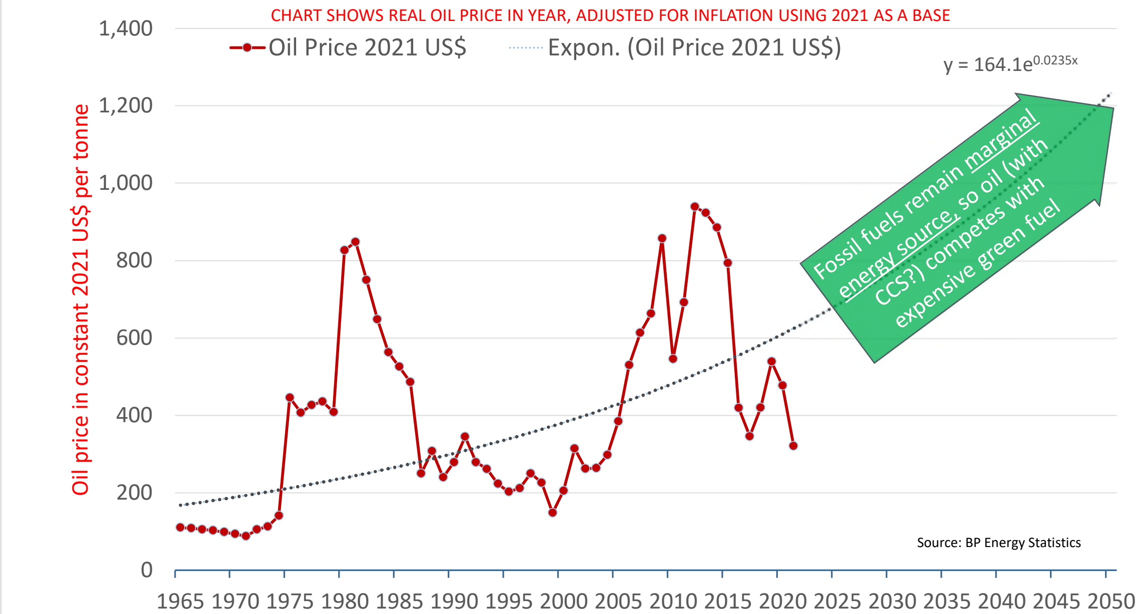
## S2.6: Oil prices – the trend suggests 2.3% pa real increase?

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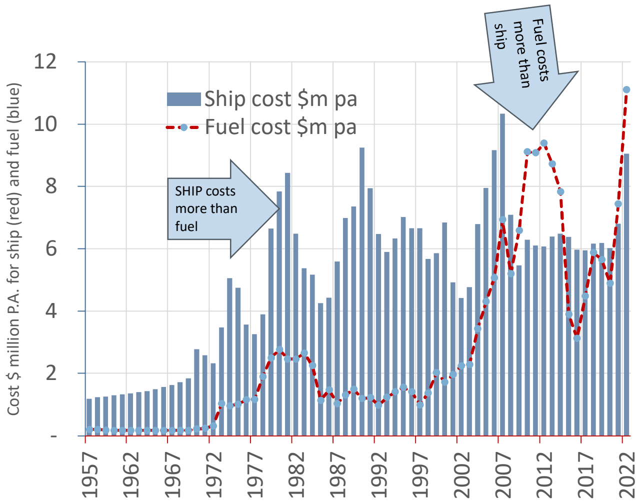
## S2.7: In 8 years since 2010 fuel cost more than the ship

1. **THIS HAS A MAJOR IMPACT ON THE SEA TRANSPORT COST MODEL**
2. 1957: the ship cost $1.2 million pa and bunkers cost $0.2 million pa - ship cost six times more than fuel.
3. 2022: at 14 knots the fuel cost 40% more than the ship - $11 million for fuel and the ship $8 million pa,
4. With today's bunker prices $5-700/tonne, the optimum speed is closer to 11 knots.
5. Assumptions: Aframax tanker – estimated cost of ship & fuel, on an annual basis, 49 TPD bunkers at 14 knots, Rotterdam bunker prices and OPEX adjusted to US$ inflation.




Source: Martin Stopford Maritime Economics



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## S2.8:The Green Energy Options: chemical and nuclear energy

### Liquid fuels which are, or could be, used to power merchant ships

| Ref | *all numbers relate to liquid product* | | CHEMICAL ENERGY (i.e. from chemical reaction) – PRODUCES ENERGY+CARBON EMISSIONS: HFO | LNG | LPG | LEG | NO CARBON: Green Methanol | Hydro-gen | Amm-onia | FISSION (1) – CHAIN REACTION: Uranium oxide |
|---|---|---|---|---|---|---|---|---|---|---|
| | *memo: Chemical composition* | | Composit | $CH_4C_2H_6$, | $C_3H_8$ | $C_2H_6$ | CH3OH | H2 | NH3 | U235 |
| 1 | Boiling point | ˚C at 1 bar pressure | 150 | -166 | -26.2 | -89 | 65 | -253 | -33 | 4131 |
| 2 | Energy density by volume (per litre) | MJ/litre | 41.0 | 21.6 | 24.9 | 53.2 | 15.7 | 9.2 | 15.7 | 67,443,012 |
| 3 | Cost (just an order of magnitude) | $/tonne | 750.0 | | | | 1,200 | 7,000 | 1,200 | |
| 4 | Cost (adjusted to HFO energy density) | $/tonne/VLSO equivalent | 750.0 | | | | 2,400 | 2,434 | 2,229 | |
| 5 | Energy density by weight (per kilogram) | MJ/kilogram | 41.8 | 48.0 | 46.1 | 51.9 | 19.7 | 120.2 | 22.5 | 3,898,440 |
| 6 | $CO_2$ emissions/kg when burnt | Kg $CO_2$ per Kg fuel burnt | 3.11 | 2.75 | 2.99 | | 1.37 | 0 | 0 | 0 |
| 7 | Auto Ignition | Temp ˚C to ignite | 398 | 650 | 428 | 472 | 450 | 535 | 630 | NA |
| 8 | Ratio of liquid volume to HFO* | based on $m^3$ per kg | 1 | 1.85 | 1.6208 | | 2.54 | 4.33 | 2.55 | 0.05 |
| 9 | Flammable range | % vol in air to burn | | 5-15% | 8.9-18.8% | | 5.5-26% | 4-74% | 15-28% | N/A |
| 10 | Carbon content per kg | % | **85%** | **75%** | **82%** | | **38%** | **0%** | **0%** | **0%** |
| 11 | *$CO_2$ emissions/kg % reduction* | *Compared to HFO* | - | *12%* | *3%* | | *56%* | *100%* | *100%* | *100%* |
| 12 | $CO_2$ emissions per kWh output | kg $CO_2$ kWh | 0.27 | 0.21 | 0.24 | | 0.25 | 0 | 0 | 0 |
| 13 | *$CO_2$ emissions reduction/ kWh* | *kg $CO_2$/kWh less than HFO* | - | *24%* | *15.60%* | | *11%* | *100%* | *100%* | |
| 14 | Low flashpoint fuel | | Yes | Yes | Yes | | Yes | Yes | No | N/A |

(1) NUCLEAR FISSION: nuclear reaction in which a heavy nucleus splits spontaneously or on impact with another particle, releasing energy

* HFO 996.6 kg/m3 @15degrees C.

Source: Martin Stopford, ABS, Core Power, various



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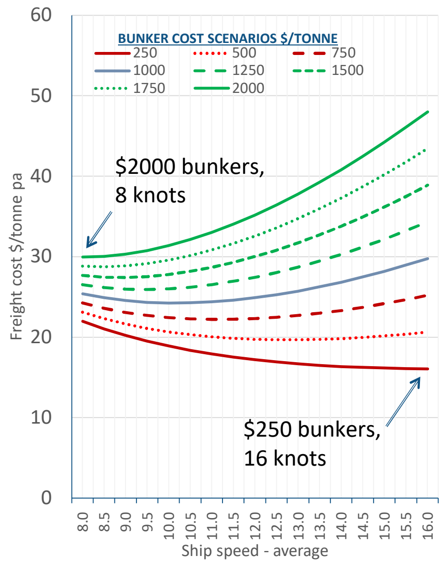
## S2.9: The easy way to halve carbon emissions…

This chart shows how freight cost (& carbon) could respond to bunker costs of $2,000/tonne. At 8 knots carbon emissions are halved compared with 11 knots. It needs 30% more ships…*to be continued in Webinar 3*

Table 1: Freight cost, bunker cost & speed (red shows cheapest freigh

| Speed knots | 250 $/tonne | 500 $/tonne | 750 $/tonne | 1000 $/tonne | 1250 $/tonne | 1500 $/tonne | 1750 $/tonne | 2000 $/tonne |
|---|---|---|---|---|---|---|---|---|
| | Bunker cost in $ per tonne HFO equivalent | | | | | | | |
| **8.0** | 22.0 | 23.1 | 24.3 | 25.4 | 26.5 | 27.7 | 28.8 | **30.0** |
| **8.5** | 21.0 | 22.3 | 23.6 | 24.9 | 26.2 | 27.5 | **28.8** | 30.0 |
| **9.0** | 20.2 | 21.7 | 23.1 | 24.5 | 26.0 | **27.4** | 28.9 | 30.3 |
| **9.5** | 19.5 | 21.1 | 22.7 | 24.3 | **25.9** | 27.5 | 29.2 | 30.8 |
| **10.0** | 18.9 | 20.7 | 22.5 | **24.2** | 26.0 | 27.8 | 29.6 | 31.4 |
| **10.5** | 18.4 | 20.3 | 22.3 | 24.3 | 26.2 | 28.2 | 30.2 | 32.1 |
| **11.0** | 17.9 | 20.1 | **22.2** | 24.4 | 26.5 | 28.7 | 30.9 | 33.0 |
| **11.5** | 17.5 | 19.9 | 22.2 | 24.6 | 27.0 | 29.3 | 31.7 | 34.0 |
| **12.0** | 17.2 | 19.8 | 22.3 | 24.9 | 27.5 | 30.0 | 32.6 | 35.2 |
| **12.5** | 16.9 | **19.7** | 22.5 | 25.3 | 28.1 | 30.8 | 33.6 | 36.4 |
| **13.0** | 16.7 | 19.7 | 22.7 | 25.7 | 28.7 | 31.7 | 34.8 | 37.8 |
| **13.5** | 16.5 | 19.7 | 23.0 | 26.2 | 29.5 | 32.7 | 36.0 | 39.2 |
| **14.0** | 16.3 | 19.8 | 23.3 | 26.8 | 30.3 | 33.8 | 37.3 | 40.8 |
| **14.5** | 16.2 | 20.0 | 23.7 | 27.5 | 31.2 | 35.0 | 38.7 | 42.5 |
| **15.0** | 16.2 | 20.2 | 24.2 | 28.2 | 32.2 | 36.2 | 40.2 | 44.2 |
| **15.5** | **16.1** | 20.4 | 24.7 | 29.0 | 33.2 | 37.5 | 41.8 | 46.1 |
| **16.0** | 16.1 | 20.6 | 25.2 | 29.8 | 34.3 | 38.9 | 43.5 | 48.0 |

Source: rough calculations by Martin Stopford with speed simulation model (SSM)



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## S2.10: 100 years ago, 10.5 knots was state of the art!

- These state-of-the-art designs advertised in 1920 by Doxford shipbuilders are based on 10.5 knots.
- The advert shows that this is not the first time shipowners have had to make difficult design choices.
- What a helpful summary this advert, by the shipbuilder and engine manufacturer Doxford, provides!
- This is the sort of design information investors a century later need.




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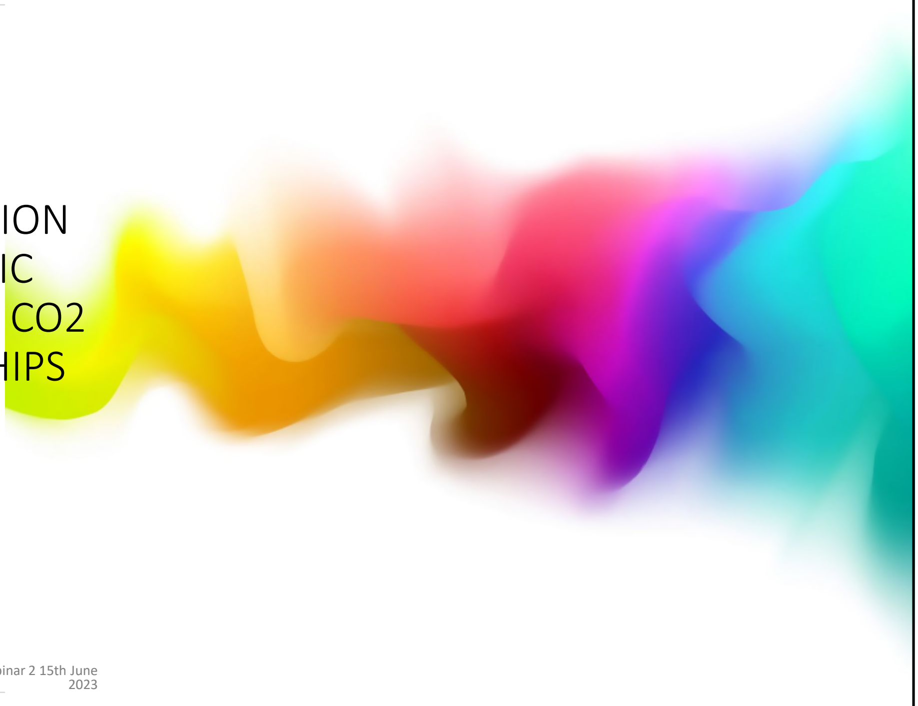
## 3. SHIP PROPULSION – THE SYSTEMATIC ELIMINATION OF $CO_2$ EMISSIONS BY SHIPS



Summary



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## S2.11: The ship propulsion systems in use today

Table 15.3 World merchant fleet May 2019 by main propulsion type

| Engine Type | Number | Mill Dwt | Av dwt | % Number |
|---|---|---|---|---|
| Diesel 2-Stroke | 25,109 | 1,783 | 71,009 | 78% |
| Diesel 4-Stroke | 5,385 | 55 | 10,289 | 17% |
| Diesel Electric | 1,198 | 33 | 27,812 | 4% |
| Steam Turbine | 306 | 26 | 84,005 | 1% |
| Non Propelled | 170 | 23 | 132,374 | 1% |
| Hybrid Mech./Elec. | 105 | 8 | 72,962 | 0% |
| Combined | 13 | 1 | 99,505 | 0% |
| Gas Turbine | 14 | 0 | 14,217 | 0% |
| Batteries & Diesel | 18 | 0 | 3,932 | 0% |
| Nuclear | 7 | 0 | 7,547 | 0% |
| Steam Reciprocating | 2 | 0 | 2,686 | 0% |
| Grand Total | 32,341 | 1,929 | 59,656 | 100% |

From file in market data fleet (owner)

Source: world fleet over 5000GT



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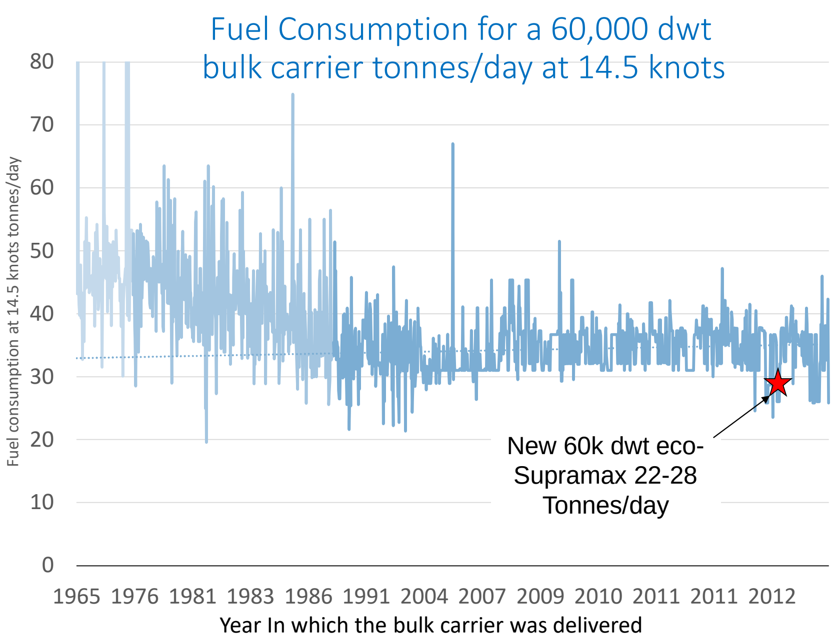
## S2.12: Fuel consumption improved until 1980s, then flat



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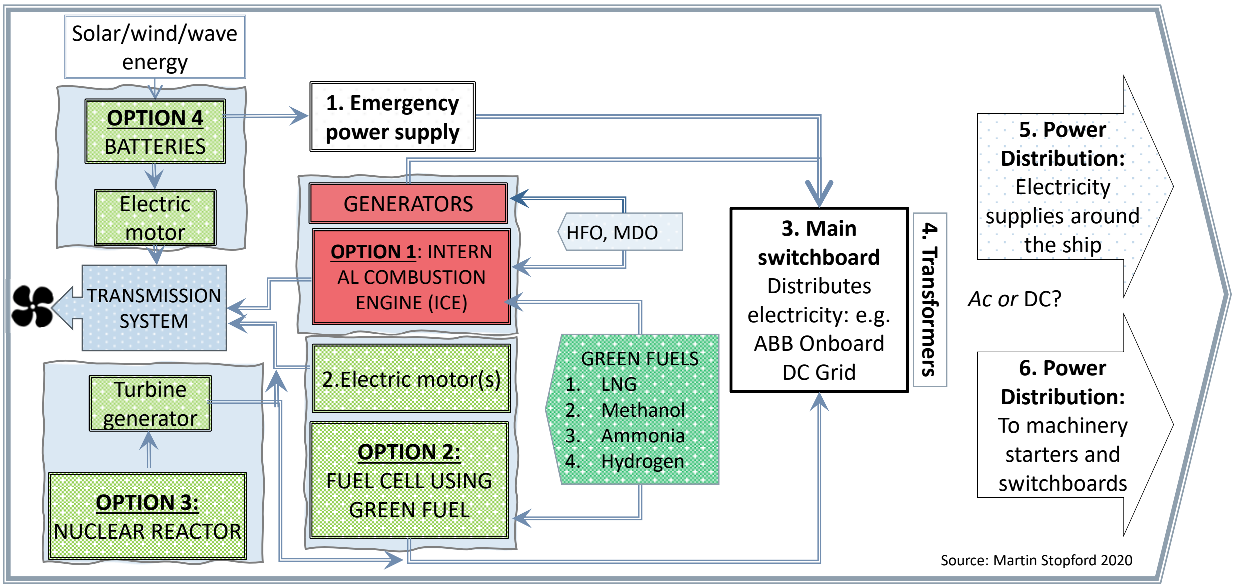
## S2.13 Developing low/zero emission fuel & propulsion – four options



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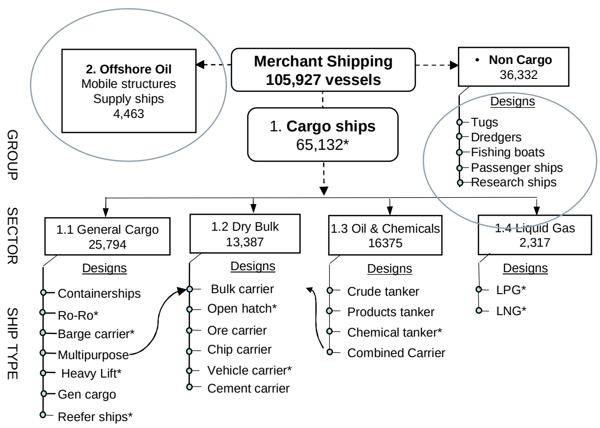
## S2.14: Ship design innovation model - different for each market segment

| | Variable | Goal |
|---|---|---|
| 1 | Fuel | Zero carbon |
| 2 | Speed | Just in time |
| 3 | Propulsion system | Energy efficiency |
| 4 | Ship Size | Economies of scale |
| 5 | Logistics system | integration |
| 6 | Information system | coordination |
| 7 | Automation | optimisation |




* Indicates 7,259 vessels not included in breakdown below

Figure 14.1 The commercial shipping fleet classified by group, sector and ship type
Source: Ship numbers from Clarkson Research SIW at 19th May 2023



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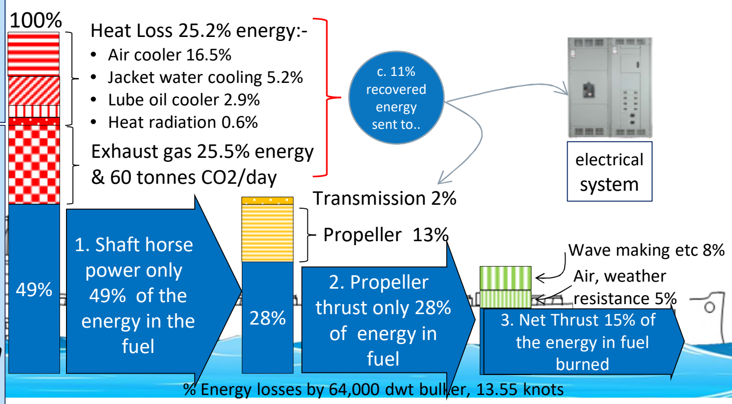
## S2.15 Propulsion options, Fuel options A-E and 6 methods of emission management:

**PROPULSION OPTIONS**

- I. Internal Combustion engine with shaft drive
- II. Electric motor/s with: -
  - Diesel-generators
  - Battery, fuel cell

**GREEN FUELS**

- **A. "Cleaner" fossil fuels**: - for example LNG, LPG
- **B. Biofuels** *(organic)*
- **C. Electricity:** from: -
  - *A. Solar panels*
  - *B. Wind turbines*
  - *C. Nuclear boilers*
- **D. 4. Green fuels** *made with green electricity: -*
  - *A. Hydrogen*
  - *B. Methanol*
  - *C. Ammonia*
  - *D. Hydrogen*
- **E. 5. Carbon capture** *(CCS):*




6 Operations
- a) Cargo size
- b) Voyage plan: -
  - I. Just in time
  - II. Ballast
  - III. Trim
  - IV. Dead freight
  - V. Port operations
  - VI. Off hire plan

5. Speed in service & ballast

$$E6(4)\ \ F = F^* \left(\frac{S}{S^*}\right)^a$$

where:
F = actual fuel (tons/day)
S= actual speed
F*= design fuel (tons/day)
S*= design speed

Summary of incremental energy loss & list of ways to reduce loss at each stage

| 1. Fuel "combustion" loss 51% | 2. Transmission loss 21 % Fuel | 3. Wind/wave loss 13% | 4. Net Thrust15% |
|---|---|---|---|
| a) Waste heat recovery | a) Propeller speed & size | a) Speed | a) Block coefficient, |
| b) Battery hybrid combi | b) Propeller design & condition | b) Hull dimensions | b) Hull condition |
| c) Power optimization | c) Wake equalizer | | c) Air lubrication |
| d) Advanced maintenance | d) Pre-swirl (e.g. Mewis duct) | | d) Ballast design |
| e) Tune management | e) New propulsor (e.g. flipper) | | e) Lighter structure |

*Source:* Compiled by Martin Stopford in 1979 from various sources, updated 2021 Dr Martin Stopford© Webinar 2 15th June 2023

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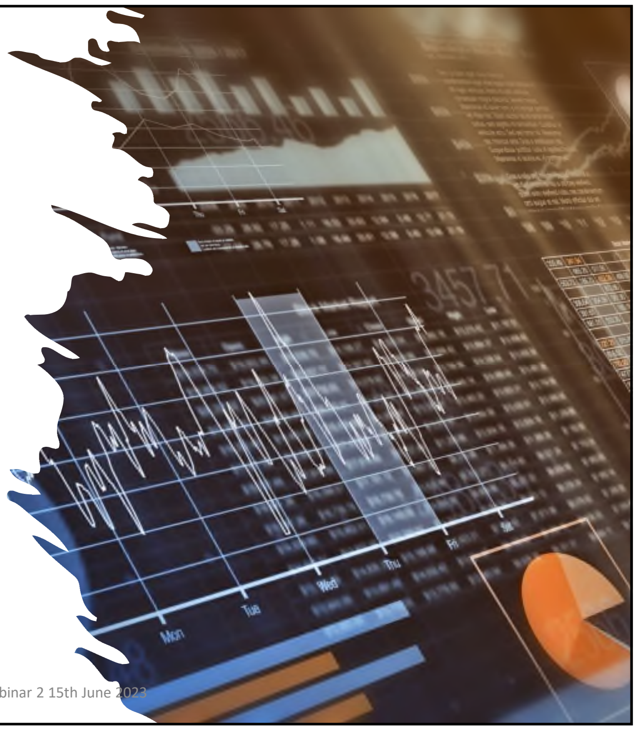
Nuclear & carbon capture have potential. But organisation, skill and resources needed to make it work



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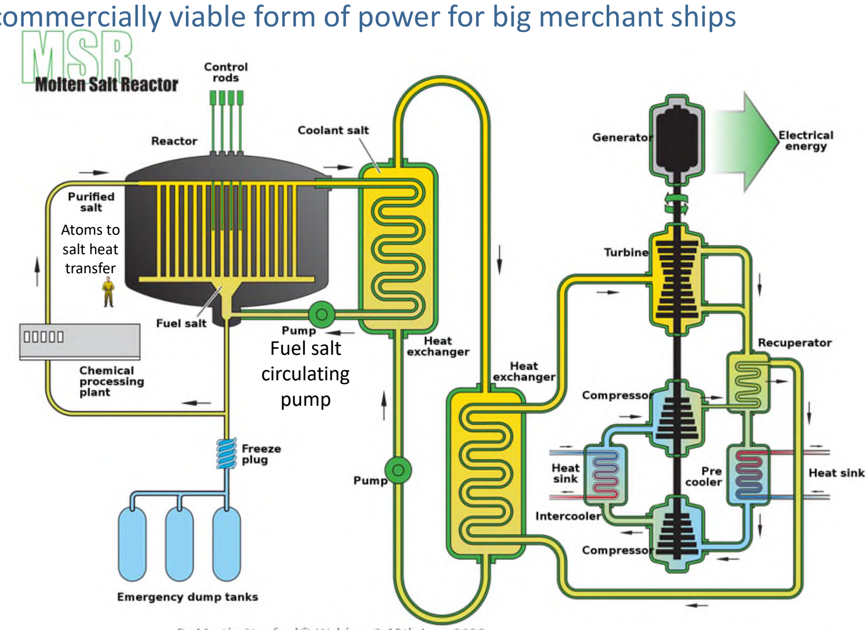
## S2.16: Nuclear reactor using molten salt as the heat exchanger fluid, and fabricated in a factory could prove to be a safe and commercially viable form of power for big merchant ships

- Molten salt reactors work at AMBIANT PRESSURE, so no radiation plume if reactor shell fractures* .
- Runs 30 years without refuelling & most fuel would be recovered at end of ship's life.
- Could be cheaper than green fuels and possible comparable life cost with HFO.
- TerraPower's test unit started trials last year.
- Commercially available early 2030s?
- A MSR 20-90 MW reactor is well sized for big merchant ship

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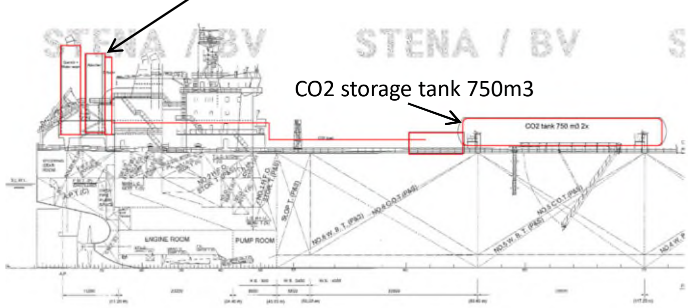
# S2.17 Carbon Capture feasible but costly – a valuable retrofit option if things get tough

CO2 collecting and stripping towers




- "Extending and adapting the technology to marine vessels poses unique challenges, but also represents a great opportunity to reduce emissions from a difficult to abate sector within transportation." Dr Michael Traver.
- "This study proves once again that there is no silver bullet solution to meet the IMO's climate targets, and that we must promote and adopt a wide variety of proven and commercially sensible solutions if we are to successfully decarbonize."
- Key technical requirements deck space; fuel use; availability of energy in the exhaust stream, CO2 disposal
- LNG the most straightforward with right mix of onboard infrastructure.

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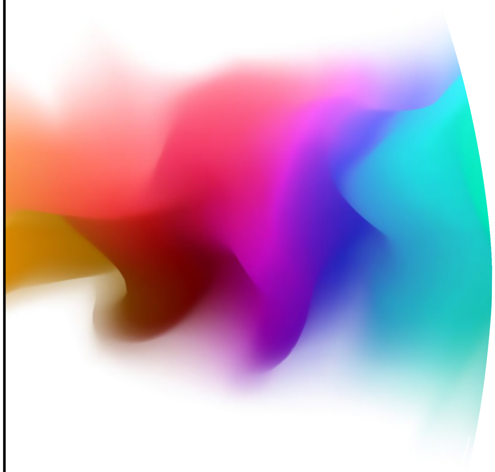

# 4. THE TIMELINE TO ZERO CARBON

1. This is difficult because new technology takes time to develop and test. Then it takes decades to build a fleet of ships with the new technical performance.
2. Will it be possible to retrofit the new technology, a practice very common during the steam era, but less so in the last fifty years.
3. The key issue is revolution versus evolution

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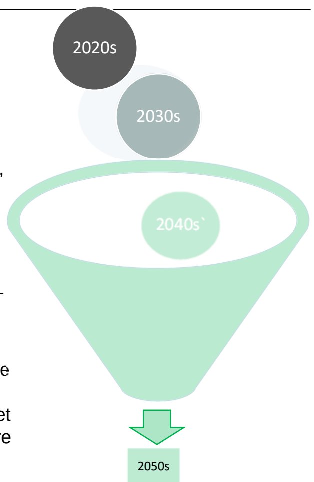
## Slide 2.18 : The Ship Propulsion Timeline – corrections will be needed!

2023

Time horizon

| TIME HORIZON | TIMESCALE | ACTION POSSIBLE (NOT NECESSARILY IN THIS ORDER) |
|---|---|---|
| Now | Hours | Negotiate lower speed |
| Short Term | 36 months | 1. speed management<br>2. retrofitting plan for fleet<br>3. replacement investment plan |
| Medium Term | 4-10 years | 1. implement retrofitting plan<br>2. roll out digital systems<br>3. Find low carbon cargo projects,<br>4. Commission new ships<br>5. Some green fuel available,<br>6. Develop organisations<br>7. build skills & capability |
| Long Term | 10-27 years | 1. climate strategy waypoint (1)<br>2. ships built 2023/5 need upgrade<br>3. new ships can be zero carbon<br>4. Surge of investment in new fleet<br>5. Innovators gaining market share |

2050




Note: (1)A waypoint is a reference point that helps us know where we are and where we're going. It helps us find our way

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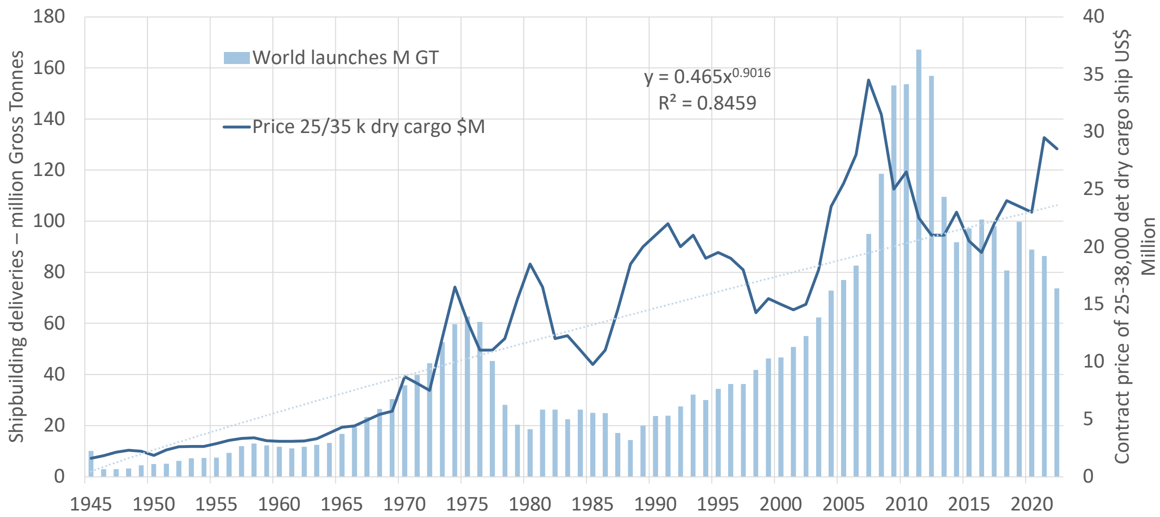
## S2.19: Shipbuilding output & prices 1945-2022

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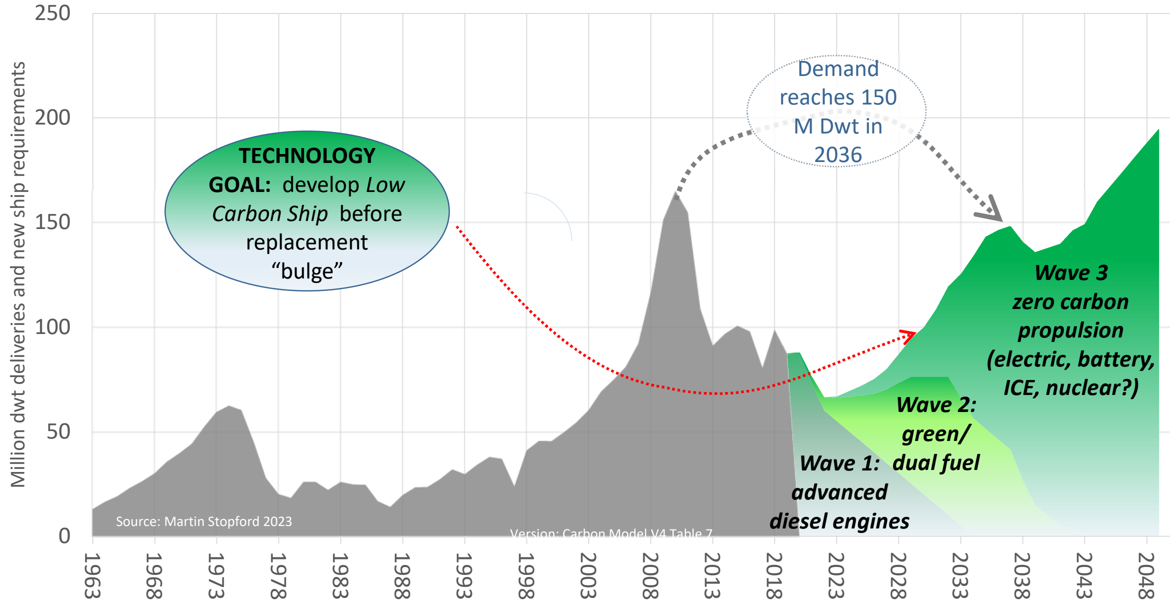
## S20: Shipbuilding "waves of innovation" scenario 2020-2050.




Shipbuilding (Scenario 2): Soft trade growth and 12 knots speed

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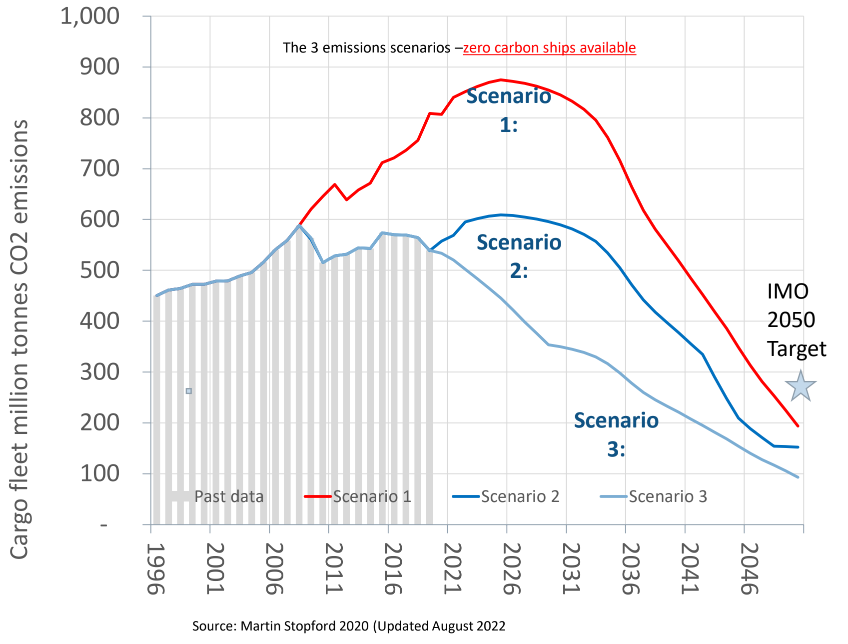
## S21: Three scenarios showing merchant fleet emissions (UPDATE JUNE 2023)

**Scenario 1:**
- 200 Mt Carbon;
- 14 knots;
- 2.0% trade growth;
- 3 wave technology roll out.

**Scenario 2:**
- 153 Mt Carbon
- 12 knots,
- 0.8% trade growth,
- 3 wave technology.

**Scenario 3:**
- 94 Mt Carbon
- 10 knots,
- -0.1% growth,
- 3 wave tech




Source: Martin Stopford 2020 (Updated August 2022

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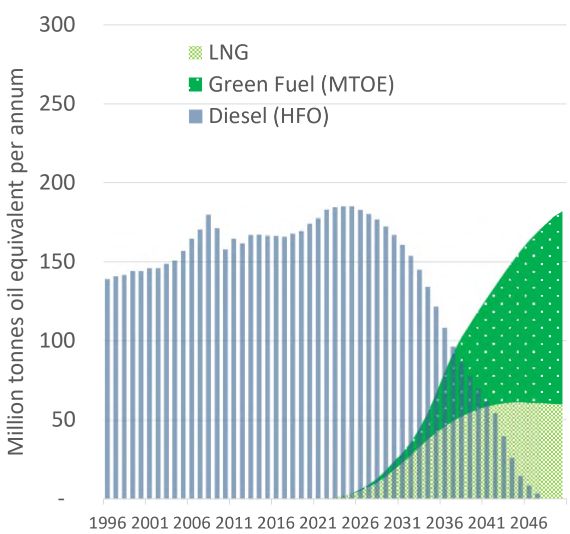
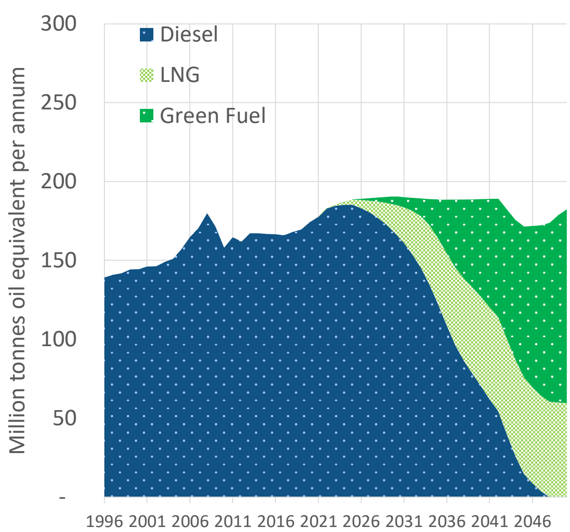
## S22: Development of green fuel use by cargo ships

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S23: CONCLUSIONS

1. Change will de driven by energy prices in the 2020s , but the real action will start in the 2030s.
2. Fossil fuels still have a long life in shipping , supported by CCS and lower operating speeds.
3. Expensive green fuels and the marginal supply position of oil and LNG will push up energy prices.
4. This will make innovative investment projects viable, as well as operation at speeds below 10 knots.
5. Each market segment will find its own solution - not "one size fits all".
6. Shipyards will play a major part in developing design options.
7. The 2020s is the time for companies to build the organisation and systems they will need to succeed in the 2030s when change starts to bite.


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# THE END

Dr Martin Stopford,

President Clarkson Research

June 2021

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# MARITIME INNOVATION Webinar 2

WELCOME: we started from the conclusion of Webinar 1 that the challenge was not to lose the 95% efficiency gains made by shipping since fossil fuels were introduced 200 years ago. Many stakeholders are involved, but shipping investors and the cargo charterers are the key players. They must deal with the challenge developing green fuels and propulsion systems; commoditised markets which do not pay a premium for quality; investment "out of proportion to historic profits"; and the motivation to do something completely different.

## Part 1: Global energy and the development of green fuel.

Slide 2.1: The evolution of fossil fuels: in a series of waves, culminating in a wave of renewables based on wind and solar energy. The way this wave develops will determine the supply of zero carbon fuels to the shipping industry.

Slide 2.2: Energy by region: many industries and regions will be competing for scarce supplies of green fuel. The growth scenario in this chart suggests an increase in global energy consumption from 580 Ej in 2021 to 650-800 Ej in 2050. Most 2050 forecasts include several scenarios and scenarios by BP and EIA are shown in this slide. One issue is the slow growth of the mature economies, mainly in the Atlantic and the rapidly expanding Middle East and Asia consumption. Some countries in this region are less concerned with climate change than energy supplies.

Slide 2.3: Global competition for limited supply of green fuel: based on last year's BP energy Outlook scenario, this shows renewables expanding to around 61% of energy in 2050, with fossil fuels falling to 39%. So throughout this period, and especially in the coming decade, fossil fuels will remain the key "swing" source of energy.

Slide 2.4: green electricity limited but growing fast: This is important because many land-based businesses, particularly motor vehicles, steel, agriculture and cement need green energy. If the swing to electric cars is sustained, this will mean replacing gasoline, which in 2021 provided 14,300 TWH of energy, with green energy.

Slide 2.5: electricity demand scenario to 2050: consumption reaches 57,400 TWH in 2050. In the first two decades there will be competition for scarce green electricity, which must be taken into account when looking at future supplies of green bunkers for shipping.

## Part 2: The energy price issue – fuel costs will drive change.

Slide 2.6: Oil prices –trend suggests 2.3% pa real increase: in the global energy market oil and gas will continue as the marginal supply source for energy, and this will be reflected in the oil price. Historic prices, adjusted for inflation, shown in this slide indicate a long-term growth trend of 2.3% per annum. But in future the marginal supply price of oil could reflect rising green fuel prices.

Slide 2.7: Since 2010 fuel has cost more than the ship: This simulation analysis shows that until 2000 the ship cost five or six times as much as the fuel burned, so using more fuel and less ship (i.e. going faster) made economic sense. In the last 10 years fuel has been more expensive than the ship, and this has been reflected in a slowdown to 11 kn.

Slide 2.8: The Green Energy Options: chemical and nuclear energy: this chart compares the "black" and "green" fuels on offer, with a rough estimate of the cost of green fuels. The green fuels cost as much as $2000 a tonne, compared with current bunker costs of around $500-$750/tonne. This is not surprising, because the synthetic green fuels have to pay for the work done over millions of years by nature and geology.

Example the cost of electricity for green methanol: as a reality check, the next slide shows a rough example of the cost of producing green electricity to power a large container ship. The windfarm requires $790 million investment, and costs around $60,000 a day to run. There would be additional costs to transform the electricity into hydrogen by electrolysis, source green carbon dioxide, and synthesise methanol.

Slide 2.9: An easy way to halve carbon emissions. If fuel costs increase, this will affect the optimum speed. This slide analyses the optimum speed for a 10 year old Supramax trading at speeds between 8 kn and 16 kn (down the side of the table), at bunker costs ranging from $250 per tonne to $2000 per tonne (along the top). The red number identifies the cheapest freight rate – for example at $750 a tonne the cheapest freight rate of $22.2/tonne occurs at 10 kn. If bunkers cost $1750 per tonne, the optimum speed is 8.5 kn. There would be an inventory cost which varies with commodity. But there would also be a massive carbon saving at slow speeds – for example CO2 halves by slowing from 11 kn to 8 kn..

Slide 2.10: 100 years ago 10.5 kn was state-of-the-art! This advert placed by shipbuilder in 1920 shows that slow speed is not new. It also shows that today's shipowners are not the first ones to facedifficult technical choices!

## Part 3: Ship propulsion – systematic elimination of CO2 emissions

Slide 2.11: most ships today are powered by diesel engines.

Slide 2.12: Fuel consumption improved until 1980s, then flat: fuel consumption for 60,000 deadweight bulk carrier at 14.5 kn, 1965 to 2016. Shows fuel efficiency improved until 1990, but has been pretty stable since then.

Slide 2.13: developing low emission fuel and propulsion – four options. Option 1 internal combustion engines; Option 2 fuel cells; option 3 nuclear reactors; option 4 batteries (or hybrid). In the coming decade Option 1 looks the best bet, with the combination of slower operating speeds and carbon capture and storage (CCS) might be a simple solution, until something better comes along

Slide 2.14: ship design innovation model – different for each market segment. The shipping market has many segments. Each will develop its own design model. This is a challenge the shipyards will need to deal with, as Doxford did 100 years ago.

Slide 2.15: propulsion options – fuel options A-E & six areas which can contribute to emission management – there is great scope for fine tuning the ship and operations. We will pick this up in webinar 3 using digital systems, which are very relevant to measuring, monitoring and automating fine tuning.

Slide 2.16: nuclear reactors using molten salt as the heat exchanger fluid. This system is being developed by Terra power in the United States, with its marine associate Core Power. It avoids many of the risks associated with pressurised water reactors, and looks very promising as a propulsion system for merchant ships, available sometime in the 2030s.

 

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Slide 2.17: carbon capture feasible but costly. This technology is still clunky, the track record of water ballast management and sulphur scrubbers shows that given time on-board systems can be engineered to be cost-effective. Definitely worth taking seriously, perhaps in tandem with slower operating speeds which would reduce the amount of carbon.

### Part 4: The timeline to Zero carbon

Slide 2.18: the ship propulsion timeline: there are three phases – 1-3 years, 4-10 years; and 11-30 years. The first three years is time for careful planning and time sensitive investment. In the remainder of the decade, focus on the existing fleet and organisation building, digital technology and developing sophisticated skills needed when new technology arrives in the 2030s. The serious innovation starts in the 2030s.

Slide 2.19: shipbuilding capacity is a major issue for two reasons: Firstly there is a major cycle in the age profile of the fleet, following the deliveries boom in 2011, and this will create replacement demand in the 2030s. Secondly the shipbuilders must develop product offerings incorporating the new technology - fuel, propulsion and digital. Not easy!

Slide 2.20: The shipbuilding "waves of innovation" scenarios 2020 to 2050: But fairly conventional designs continue in the current decade, as the more sophisticated options are tried and tested.

Slide 2.21: Three scenarios for merchant fleet emissions 2020 to 2050: based on different assumptions about trade growth, speed and technology. All three bring the industry well below the IMO 2050 target.

Slide 2.22: development of green fuel use by cargo ships: this shows the same thing in a different way – the take-up of green fuels does not really happen until the mid-2030s. The impact of nuclear is not shown.

Slide 2.23: conclusions. the "compelling case for change" will be energy prices, as fossil fuels play tag with the high cost of green fuels. The two issues which emerged in preparing this webinar were, in the short to medium term, the design of slower ships with carbon capture and sequestration (CCS); and in the medium to long term nuclear propulsion.

1,500 words
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