



Zero-Emission energy revolution for ocean transportation

NAMEPA briefing - February 2021



Greatest challenge, **ever**

- IMO mandate from 174 nations to halve 2008 emission by 2050 = appr. 0.4 Gigaton emission reduction.
- Global fleet now 100,000 ships over 100grt, with appr 17,000 'large' ships responsible for 80% of all emissions.
- 7,000 ships trade on long-haul sea passages; unsuited to low carbon fuels; perfect for the m-MSR.
- 10,000 ships trade on limited duration voyages suited to low carbon fuels; produced by m-MSRs.

'Model fleet'	Tankers	Dry cargo	Container	Cruise	Total
# large ships	4,721	7,938	4,312	167	17,138
Installed power	66 GW	116 GW	123 GW	12GW	318 GW
FO cons p/a	56 mill MT	96 mill MT	107 mill MT	4.5 mill MT	263 mill MT
Est CO2	174 mill MT	287 mill MT	322 mill MT	14 mill MT	790 mill MT

- 'Model Fleet' = 17,138 vessels referenced.
- All figures assume full design service speed, no eco- or slow steaming and use of VLSFO as marine fuel.
- CO2 emissions estimated basis speed assumptions.
- Fleet as per 2020 - sources: Clarksons, SSY, Bancosta and Drewrys, CORE POWER.

Compliance, or **disruption**?

Which way should we go?

The marine Molten Salt Reactor;

- Fuel is 2 million times more **energy dense** than diesel.
- m-MSR is **95 x more efficient** than conventional LWR = minimal waste.
- Power **15 - 50MWe** average for lifecycle in 'modular configuration'.
- **Lifetime fuel cycle** of 6 -30 years.
- **Few moving parts**, minimal maintenance.
- Low-cost **mass manufacturing**.
- **Running cost below diesel / LNG.**
- Built from the MCFR for a **dynamic environment**; pitching, rolling and vibrating.

The world's leading MSR consortium

- CORE-POWER, TerraPower, Southern Company and Orano.
- Molten Chloride Fast Reactor (MCFR) is the power-core designed by TerraPower, the world's leading atomic innovation company.
- US DoE award of \$90.4 mill to consortium under 'ARDP' Risk Reduction in Dec 2020 to demonstrate the MCFR (MCRE) by 2024.
- CORE-POWER responsible for maritime readiness and regulatory approvals.

Making synthetic fuels

- **m-MSR technology** powering floating 'yellow H₂' + 'green MEHO' and 'NH₃' production (FPSO) for shipping, harbour craft and urban transportation.
- Raw materials input is: Water (H₂), Air (N), and electric power or process heat (m-MSR).
- Operating in **domestic waters or in ports** – US, UK/EU and Japan first.
- \$ Multi-billion market in multiple locations.
- Estimated build cost: \$1.0-1.2 billion + Power leasing and OPEX.
- Model demand for 'Green NH₃' is 250 mill MT p/a.
- 100-150kdwt sized FPSO = 2.5-3.0 million MT p/a
- H₂ at \$3.5 p/kg = NH₃ at \$660 p/MT (Current H₂ price = \$8-10 p/kg)

Powering large ships

A Capesize carrying 180,000 tons of iron ore from Brazil to N. Asia (C3) on a 60 day round voyage; fuel consumption price and emissions:

Fuel type	Total Fuel	Cost base	Waste, CO2 and GHG Emissions
380CST	3,700 MT	\$350-\$500 p/MT + Carbon	11,200 MT
Green NH3	8,800 MT	Est. 2.35 x 380 price	90 MT
m-MSR	1.1 kgs	Leasing equiv. <\$300 p/MT	1.1 kgs

✓ Zero vol. in propulsion cost = Fixed-margin long term COAs or Period TC.

Solving the big riddle

- Appr 20,000 m-MSRs (15-50 MWe) can create a new economic advantage for shipping, and:
 - Reduce CO2 emissions by 60% from operations;
 - Reduce 42% of all emissions from Total Life Cycle (well-to-wake).

<i>'Model fleet'</i>	Tankers	Dry cargo	Container	Cruise	Total
m-MSRs for e-Fuels	2,729	2,298	3,498	130	8,655
m-MSRs for propulsion	1,513	4,594	4,291	360	10,758
MTs LEU fuel cons p/a in fast spectrum m-MSR	723	1,175	1,328	84	3,310
GHG reduced from Ops	- 89 mill MT	-185 mill MT	- 194 mill MT	- 8 mill MT	- 476 mill MT

- Example: m-MSRs for e-fuels production at 50 MWe at 95% capacity.
- Example: m-MSRs for propulsion at 15 MWe at 65% capacity.
- Fuel efficiency based on MCFR / m-MSR running HALEU.

The **path** ahead





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