Electrification and Maritime Shipping

Jake Russell, PhD

ARPA-E ESS-1K Workshop

5/11/23


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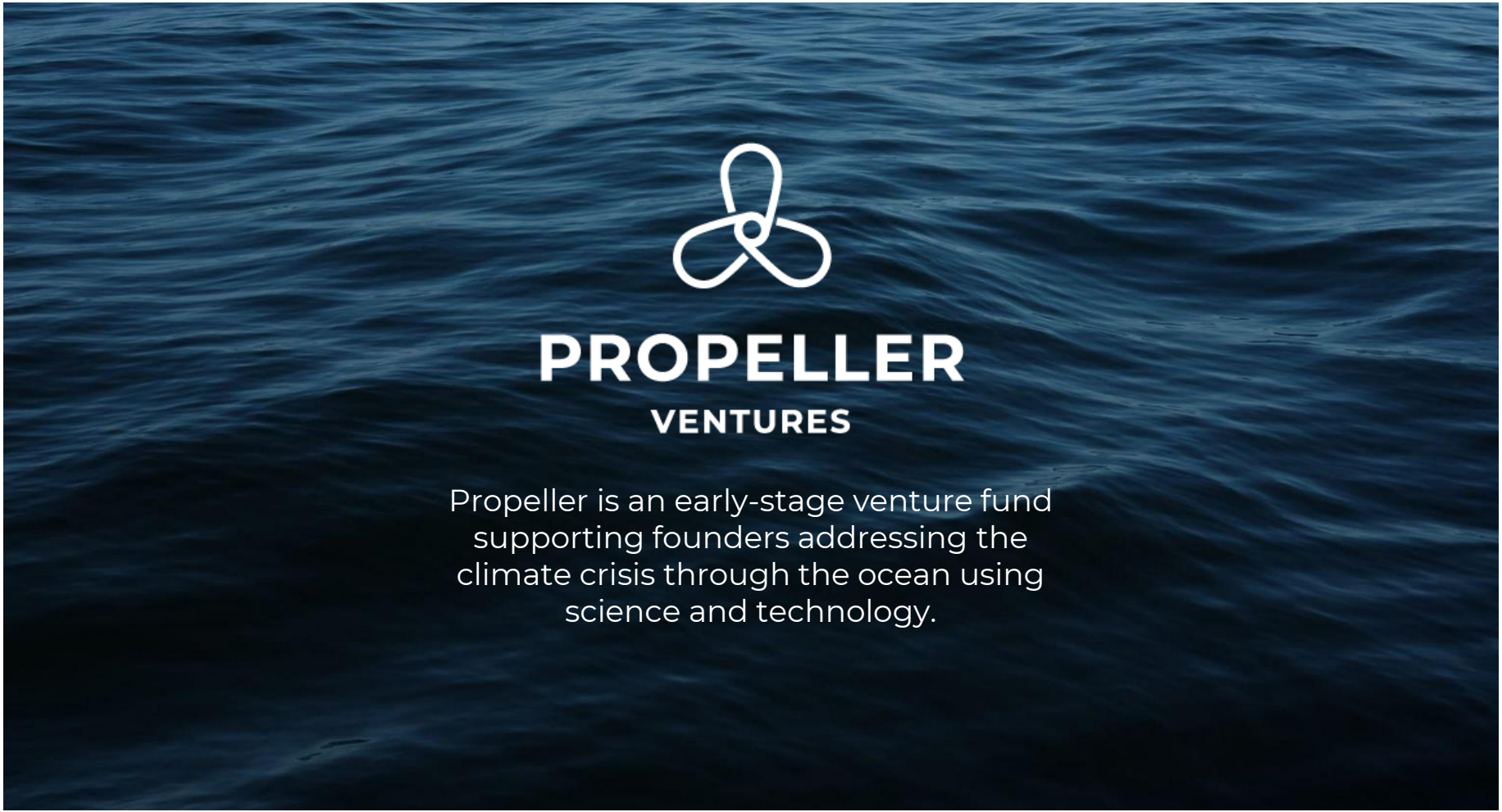
PROPELLER
VENTURES
Propeller is an early-stage venture fund supporting founders addressing the climate crisis through the ocean using science and technology.

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Acknowledgements

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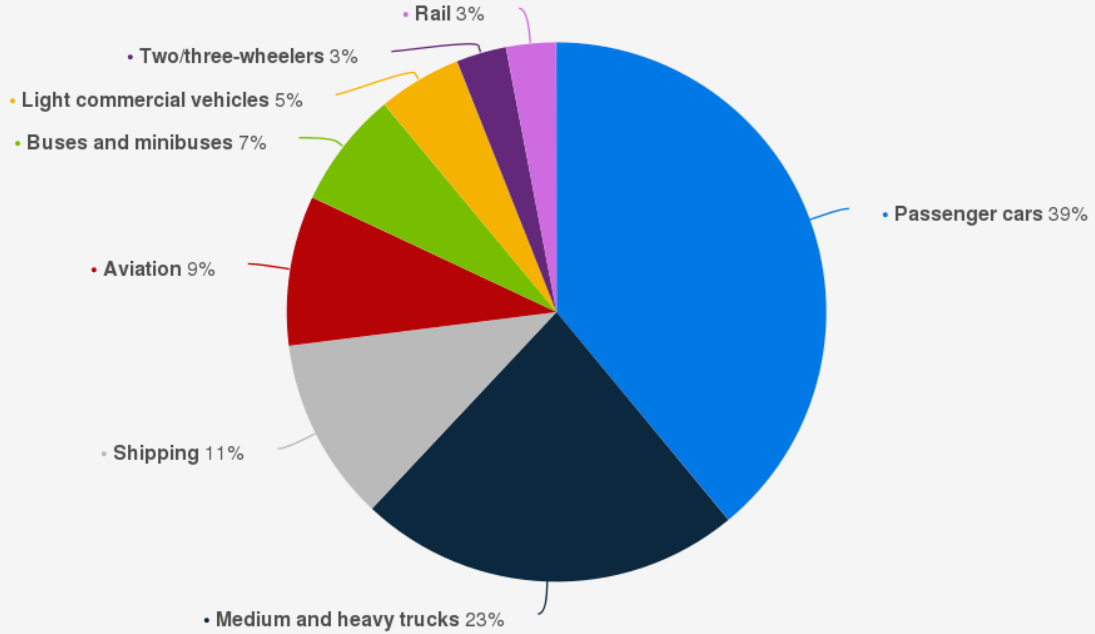
Lukas Kistner
(Leibniz Universität Hannover)

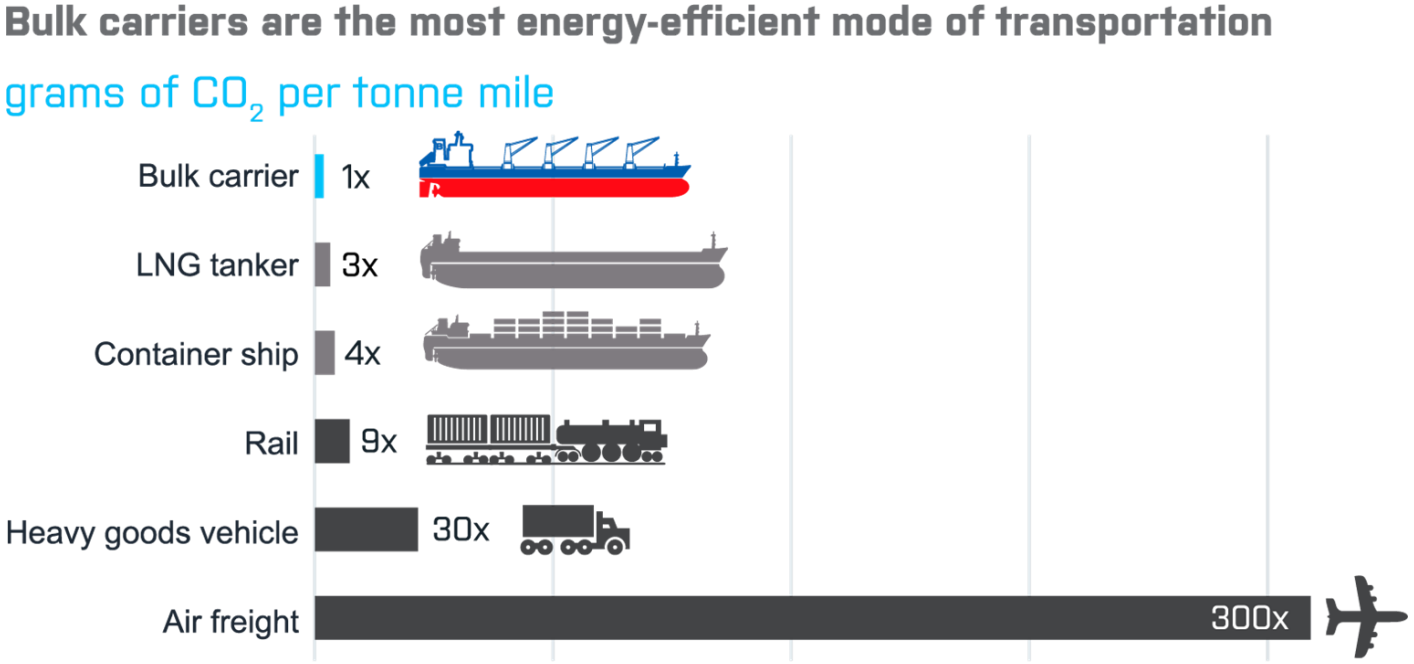
Distribution of carbon dioxide emissions produced by the transportation sector worldwide in 2021, by subsector



Sources
IEA; Statista

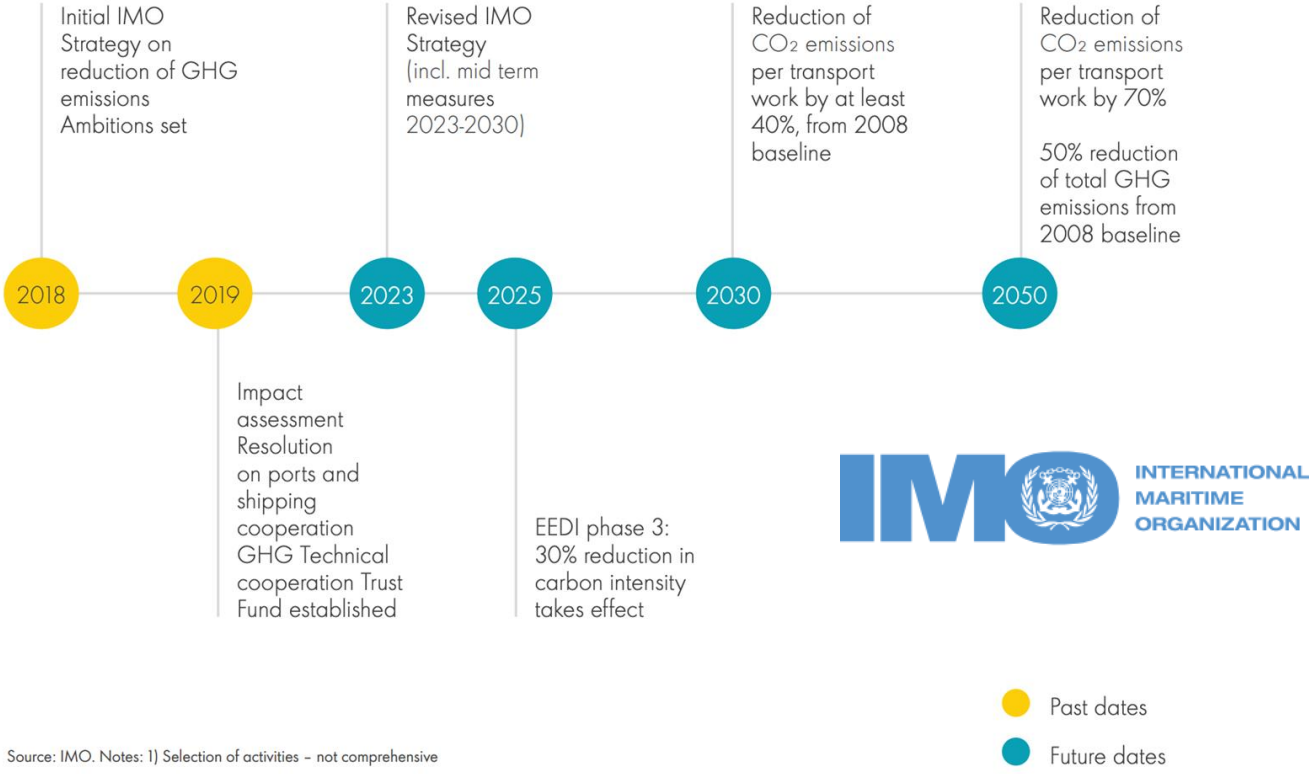
Additional Information:
Worldwide; 2021

Ships are the most efficient way to move goods



Source: Pacific Basin, comparisons are approximate and based on data from the UK Government's Greenhouse gas reporting: conversion factors 2019

04 **IMO Timetable to Reduce GHG Emissions**[1]



Source: IMO. Notes: 1) Selection of activities – not comprehensive

Source: World Economic Forum

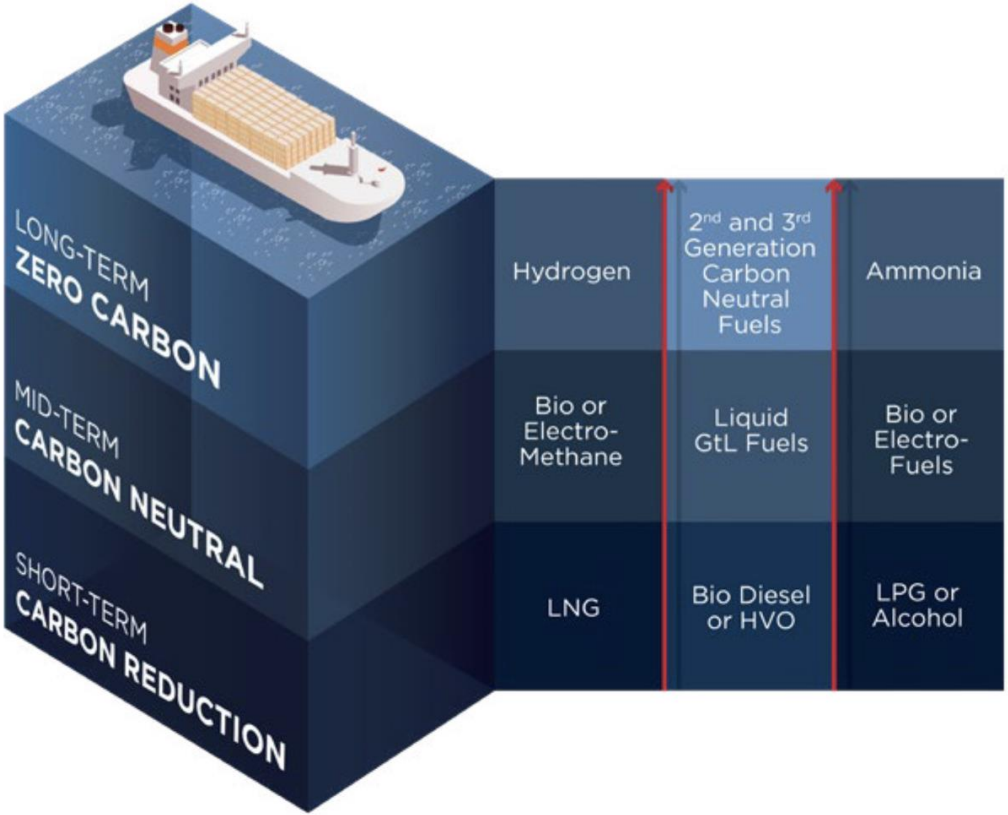


Figure 1: The three fuel pathways to carbon-neutral and zero-carbon shipping.

Source: [American Bureau of Shipping]

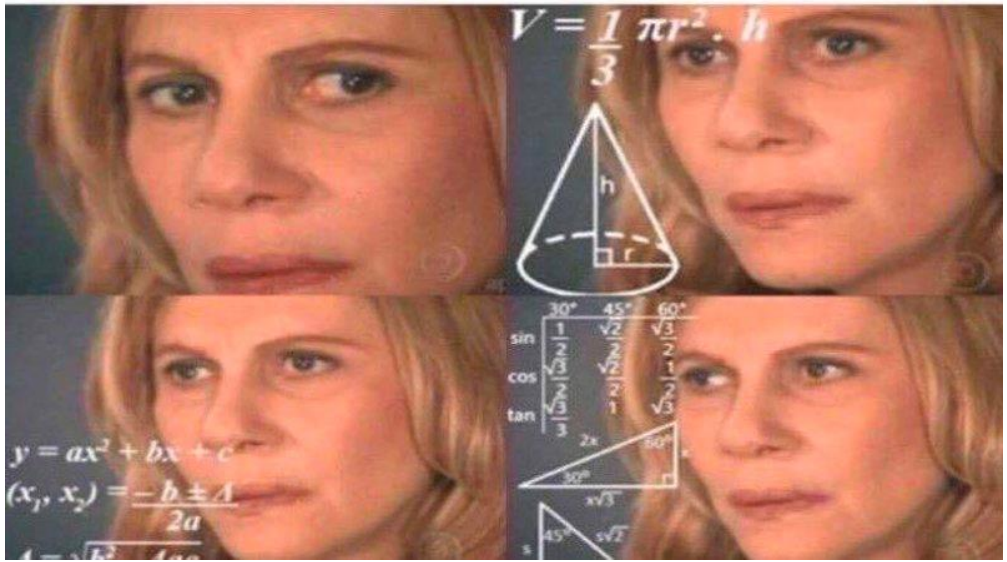
Fuel choices: no clear winner

Shipping Industry

Ammonia ICE

Ammonia fuel cell

Liquid H2



bio-Methanol

LNG

bio-diesel

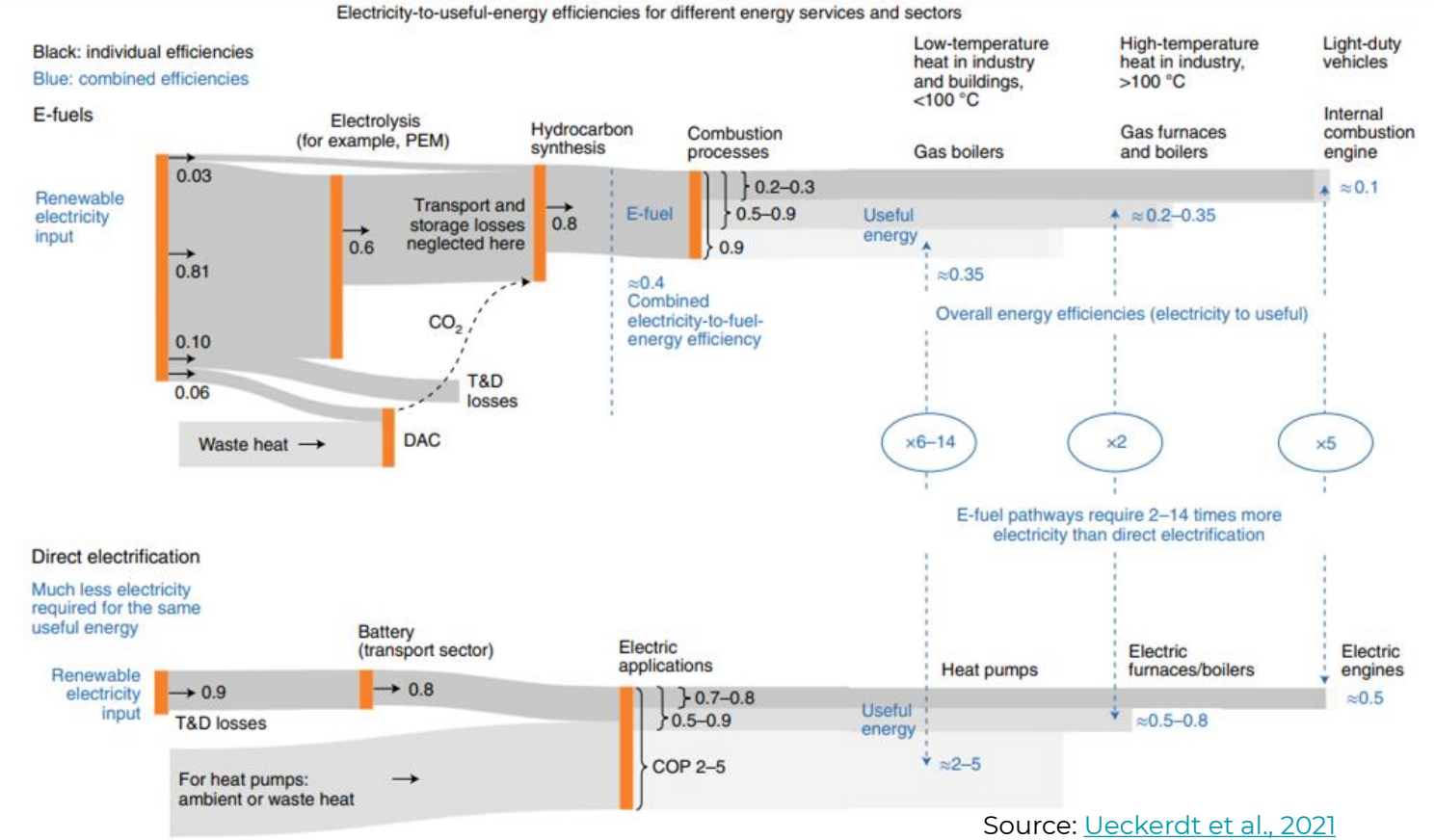
Compressed H2

e-Methanol

DME


So why is battery electrification left out of the discussion?

Direct electrification is 2-14x more efficient than e-fuels.



Source: [Ueckerdt et al., 2021]

Answer: it's really expensive upfront

18,000 TEU ship, 16 day voyage ~ 15 GWh energy @$100/kWh

→ Would need $1.5B of batteries

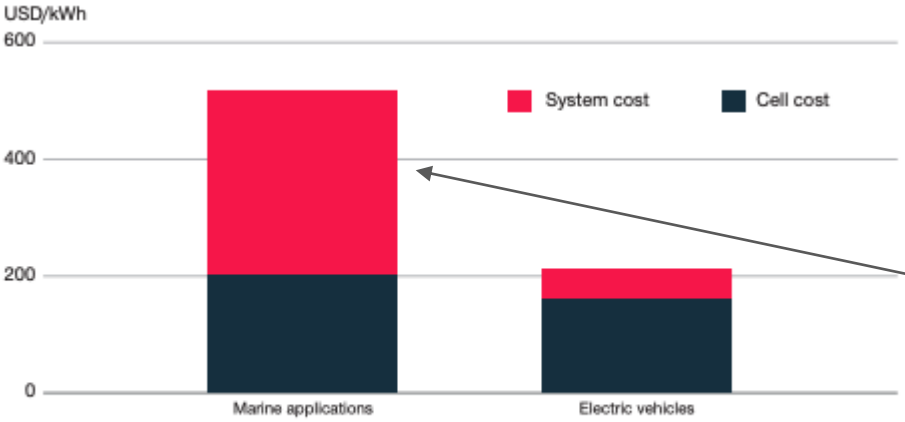
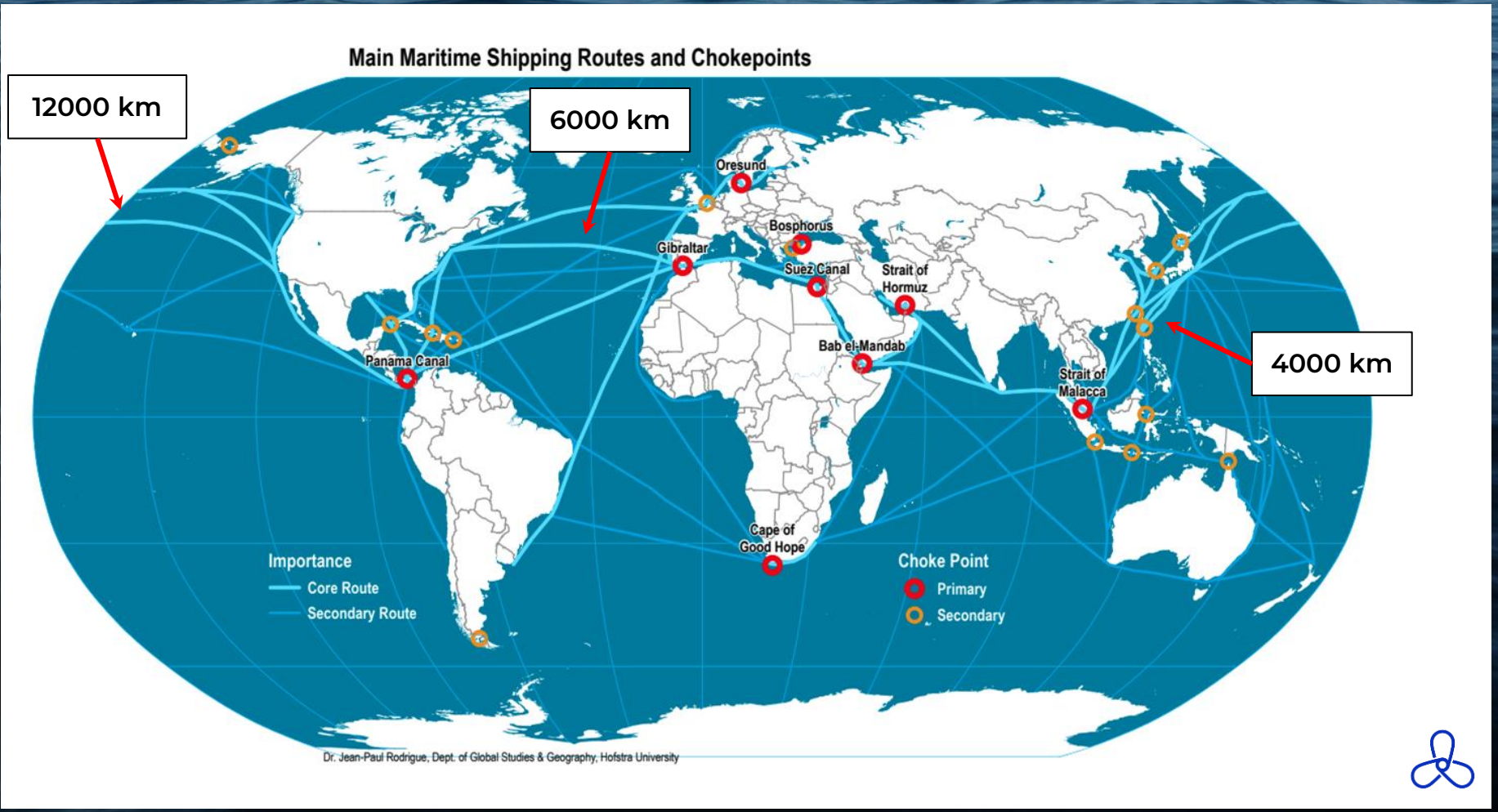


Fig. 8: The cell cost share of the total system cost shown for marine application and electric vehicles as of 2019

(Ship itself costs $190M)

Insulation, cooling, fire prevention, fire fighting equipment

Source: MAN, Vaclav Smil (IEEE)


Main Maritime Shipping Routes and Chokepoints
12000 km
6000 km
4000 km
Oresund
Bosphorus
Gibraltar
Suez Canal
Strait of Hormuz
Bab el-Mandab
Panama Canal
Strait of Malacca
Cape of Good Hope
Importance
Core Route
Secondary Route
Choke Point
Primary
Secondary
Dr. Jean-Paul Rodrigue, Dept. of Global Studies & Geography, Hofstra University

ARTICLES
https://doi.org/10.1038/s41560-022-01065-y
nature energy

Check for updates

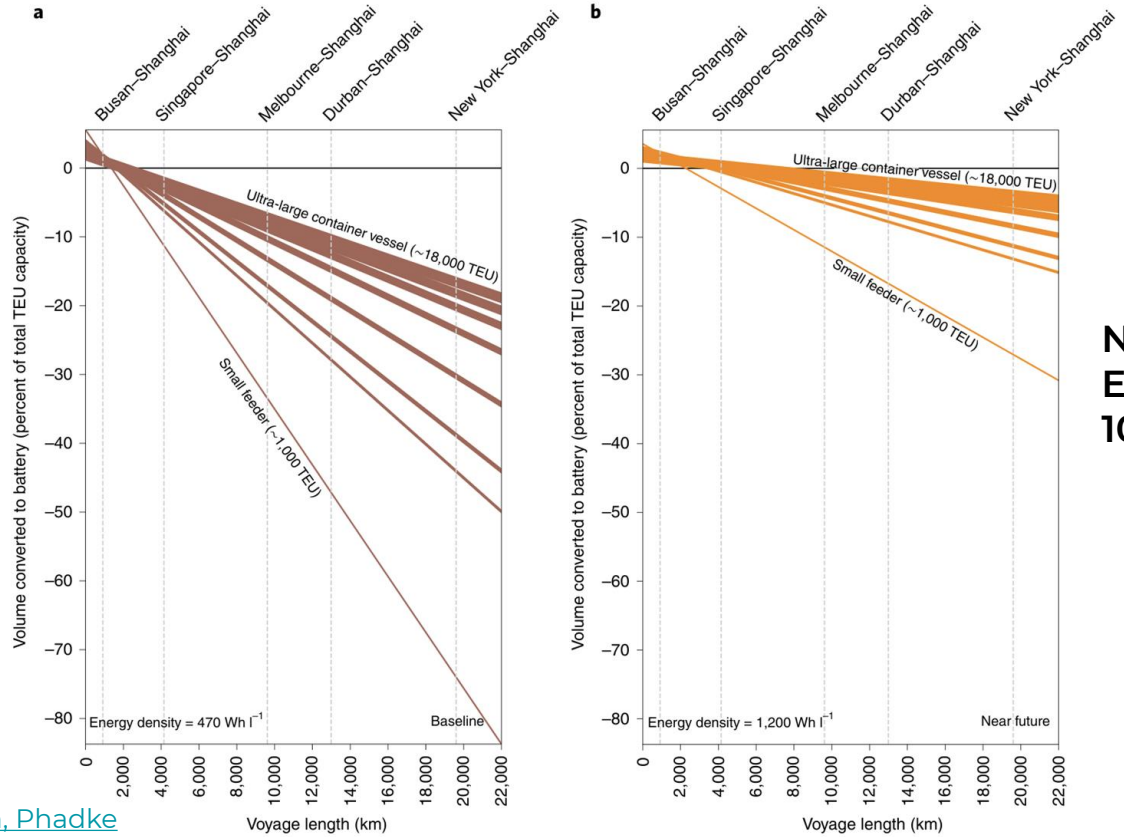
OPEN

Rapid battery cost declines accelerate the prospects of all-electric interregional container shipping

Jessica Kersey[1], Natalie D. Popovich[2] and Amol A. Phadke[2]✉

Forfeited cargo capacity is minimal

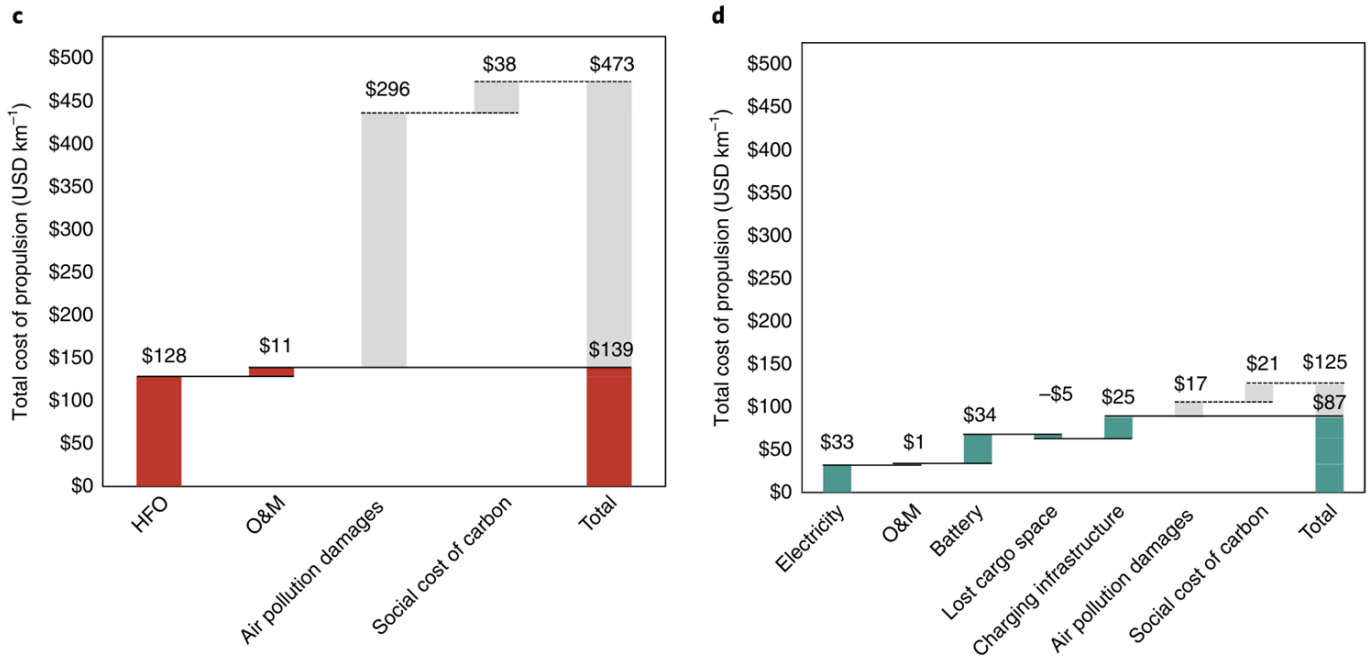
Baseline ESS: 470 Wh/L



Near future ESS: 1000 Wh/L

Source: [Kersey, Popovich, Phadke]

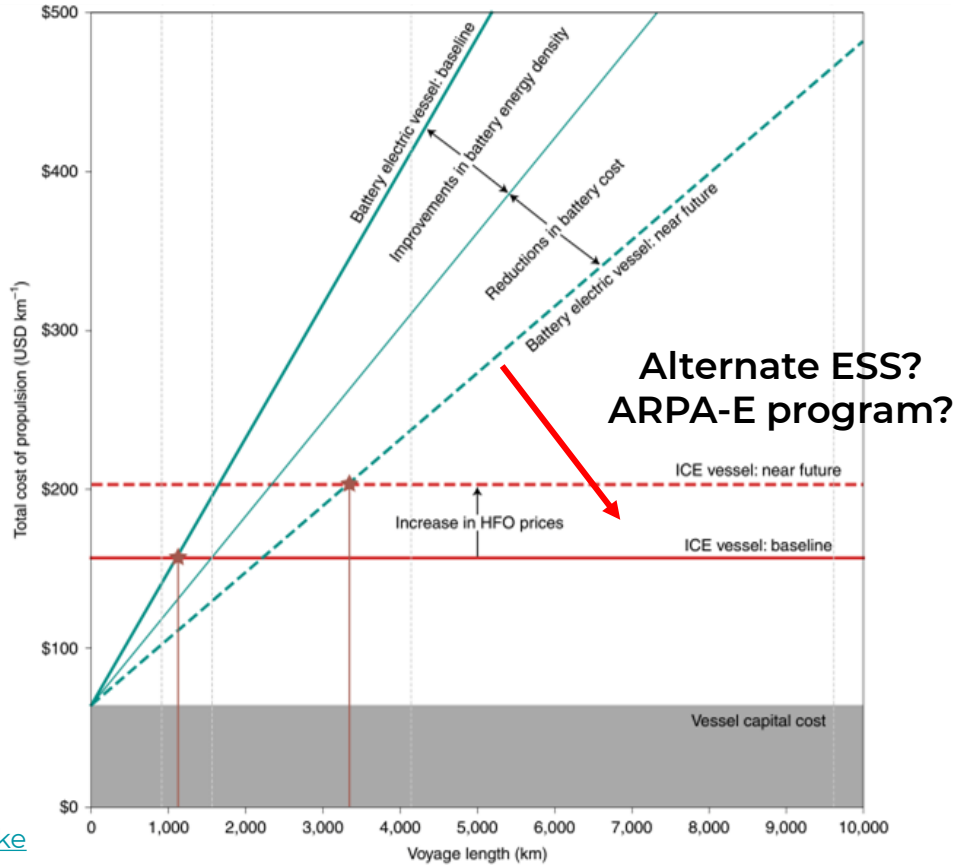
Total cost of propulsion could be lower for batteries



(Near future scenario)

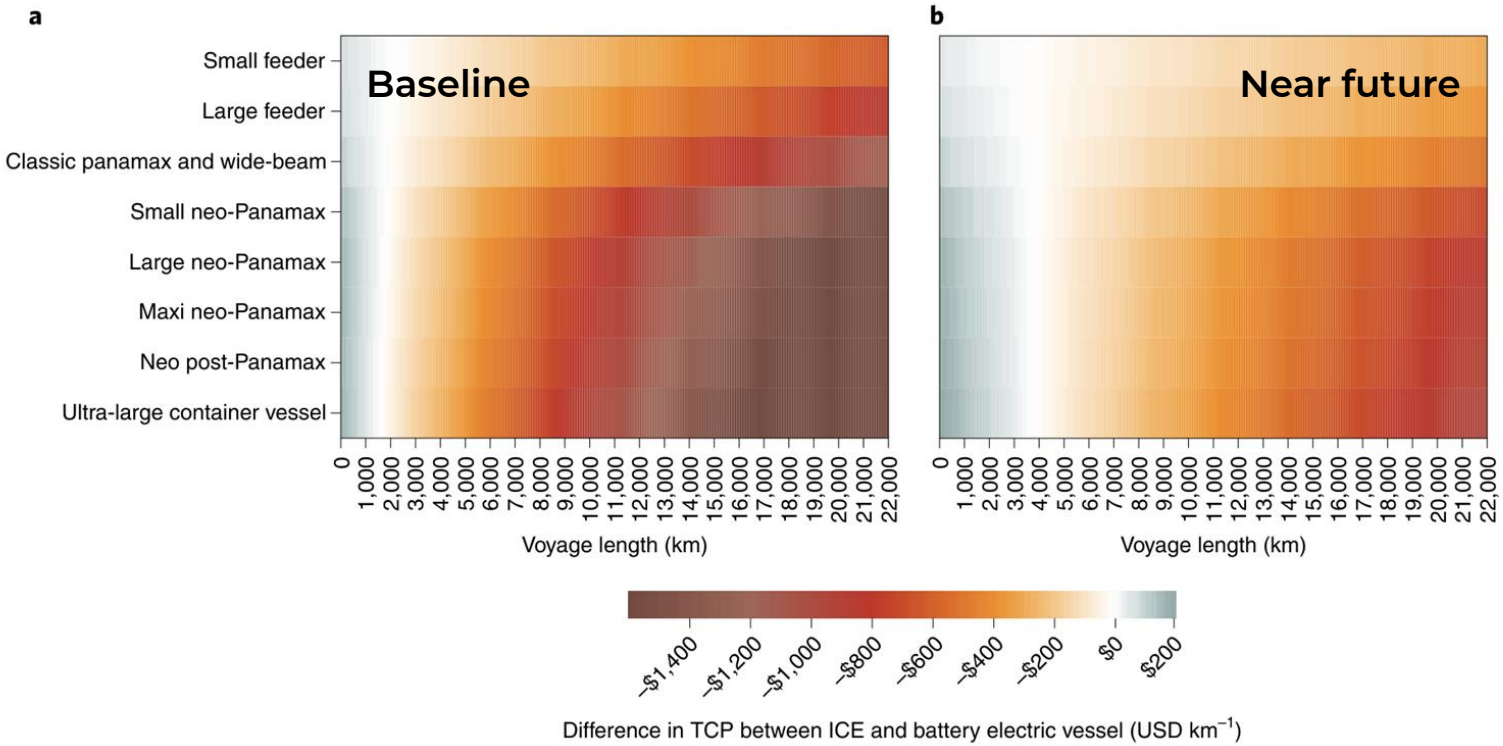
Source: [Kersey, Popovich, Phadke]

+Density and -Cost = longer ranges



Source: [Kersey, Popovich, Phadke]

Electrification could be competitive with near-future advances

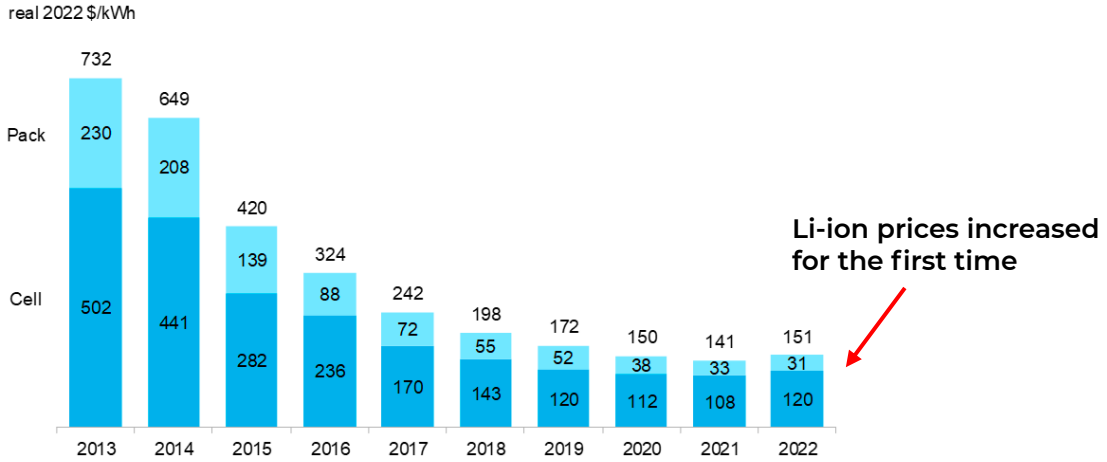


Source: [Kersey, Popovich, Phadke]

Remaining concerns…

- Doesn't account for degradation over time
- Doesn't account for charge cycling efficiency
- Price assumptions ($100/kWh) are optimistic

Figure 1: Volume-weighted average lithium-ion battery pack and cell price split, 2013-2022



Source: BloombergNEF. All values in real 2022 dollars. Weighted average survey value includes 178 data points from passenger cars, buses, commercial vehicles and stationary storage.

Focus areas for maritime energy storage:

1. **Decreased specific cost**
2. **Increased volumetric density**
3. **Safety at sea**

Leverage unique marine features:

- **Surrounded by electrolyte**
- **Already carrying swappable modular building blocks**
- **Dock near industrial centers**