NANYANG TECHNOLOGICAL UNIVERSITY SINGAPORE

A Study on the Future Energy Options of Singapore Harbour Craft

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Introduction

Background

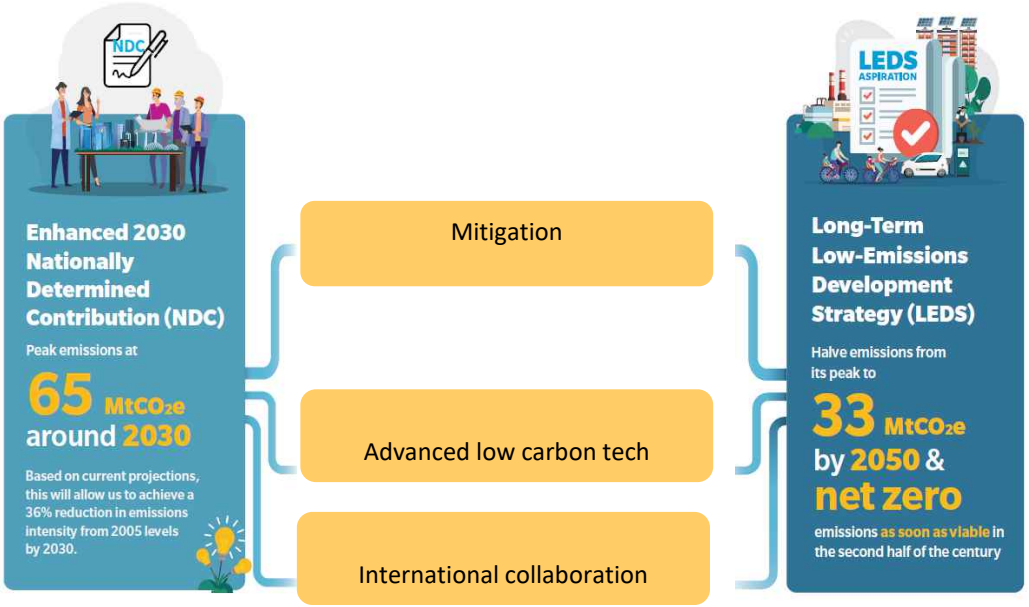
Charting Singapore's Low Carbon Future (NCCS,2020)

Year 2017

Singapore's GHG emissions

52 megatons

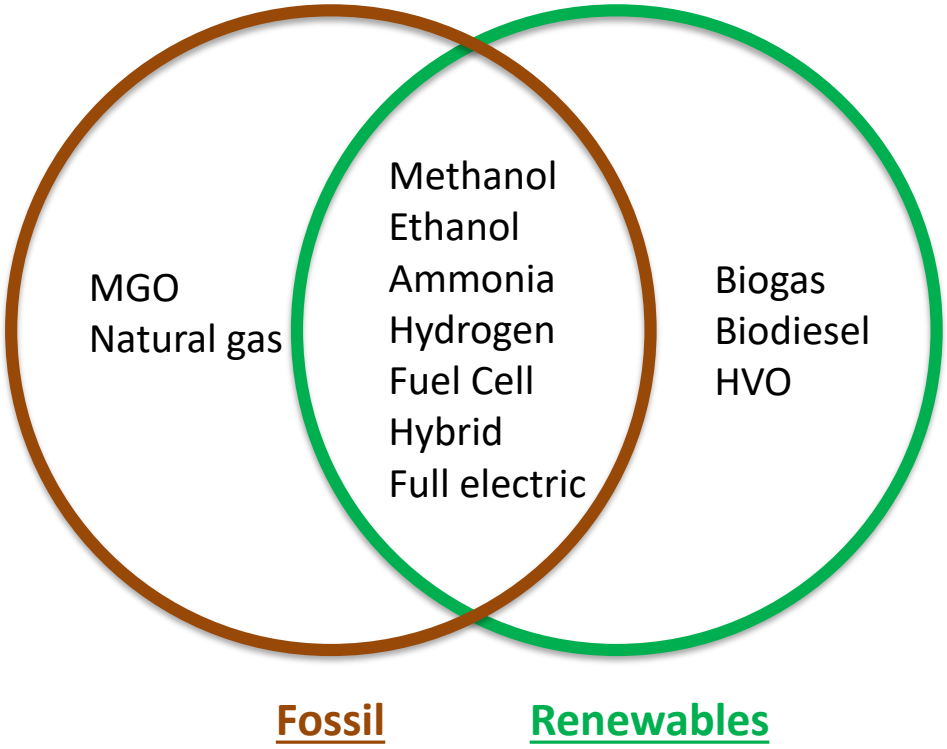
CO_2-equivalent



Objective

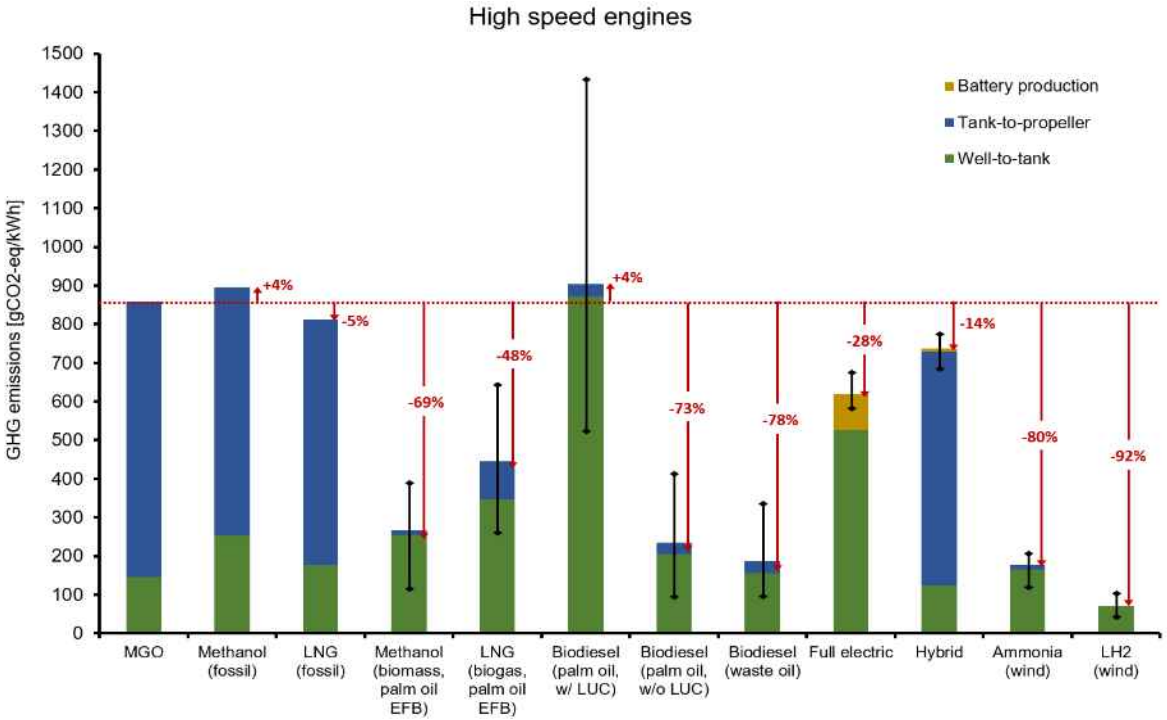
- ✓ Work out the profiling of Singapore harbour craft
- ✓ Assess the available and emerging green solutions for various harbour craft
- ✓ Provide projections for each specific category of harbour craft

Overview



- The studied energy options relate to fossil or renewable origin or both
- Fossil based options will gradually decline in future energy mix
- Feedstock availability is critical to biomass derived fuels
- Renewable electrons generation holds the key for renewable hydrogen and ammonia
- Options with significant electric component rely on the advancement of battery technology

LCA of GHG Emission of Energy Options

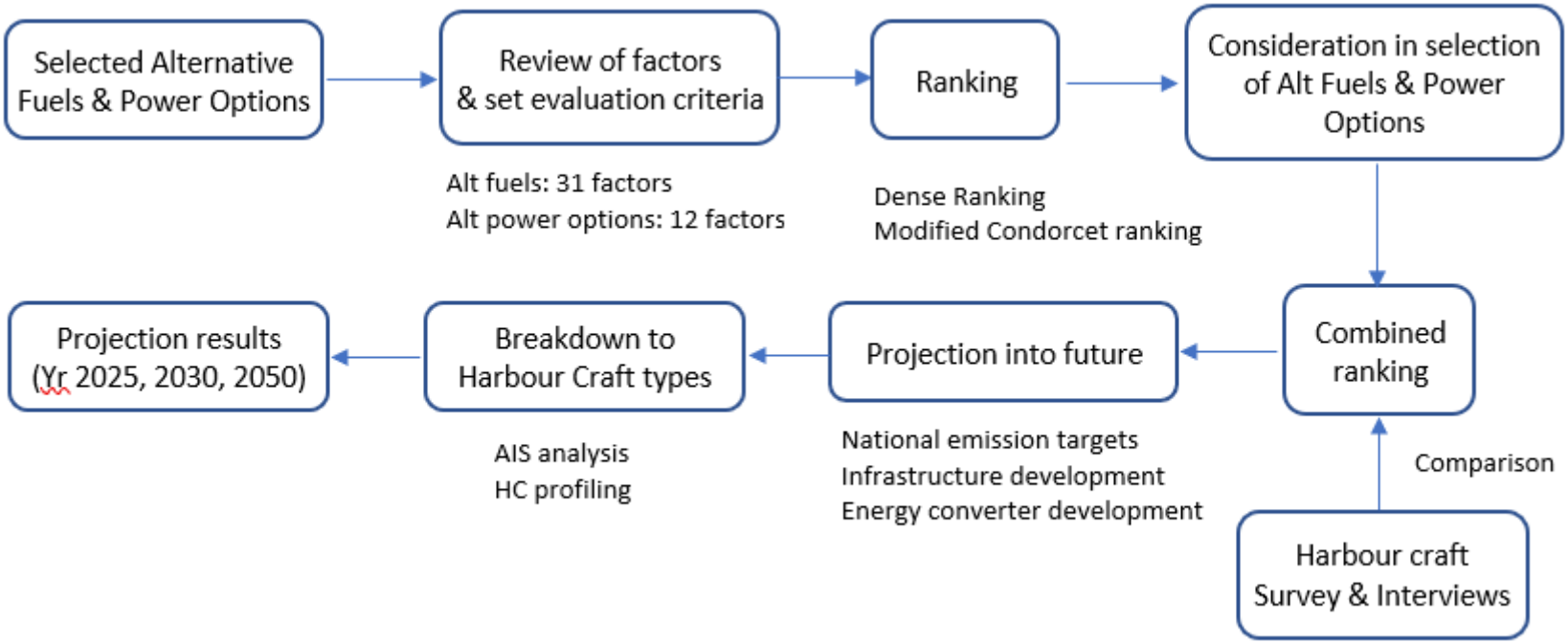


Well-to-propeller GHG emission of studied energy options

- Fossil based options can not achieve significant GHG reduction
- All energy options derived from biomass, wastes and renewable energy can achieve significant GHG reduction.
- Land Use Change (LUC) deserves special attention due to the huge carbon penalty associated

* For hybrid option, based on literature review of average fuel savings

Methodology



Projection process flow

Singapore Harbour Craft Profiling

Types of Singapore Harbour Craft

SP, Launch craft <= 12 pax

SP, Passenger ferry > 12 pax

SC, Ro-Ro vessel

SC, Cargo launch

Singapore harbour craft prefix

Prefix	Definition
SP	Used for the carriage of passengers
SC	Used for the carriage of dry or packaged goods
SB	Used for the carriage in bulk of petroleum, liquefied gases, liquid chemicals, vegetable or animal oils
ST	Used as a tug
SR	Used for any other purpose

SB, Bunker tanker

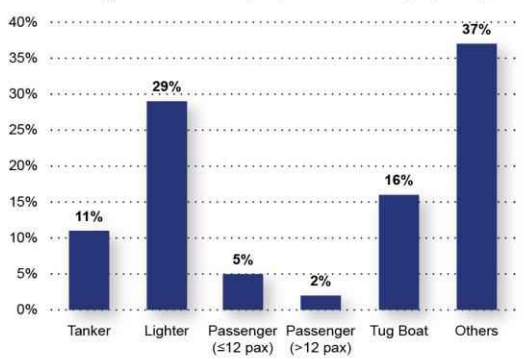
ST, Harbour tugboat

SR, Research vessel

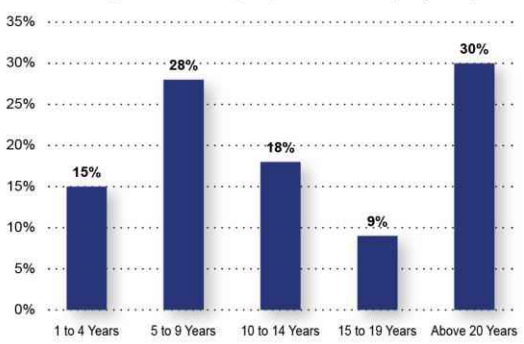
SR, Environmental Craft

Singapore Harbour Craft Overall Profiling (2017)*

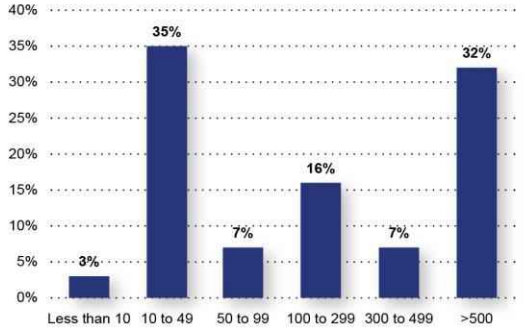
Vessel Types



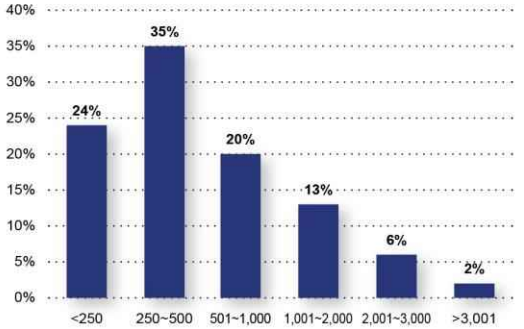
Vessel Age



Gross Tonnage



Engine Shaft Power (kW)

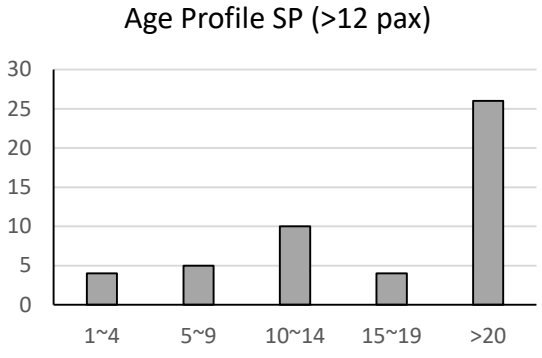


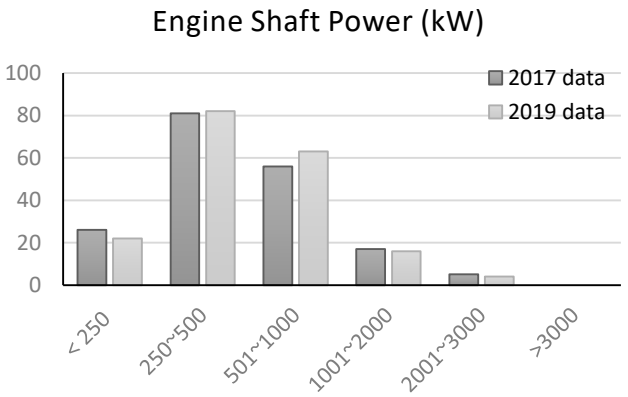
- SR and SC prefix are the two main types of vessels, followed by tugs, tankers and passenger crafts
- Up to 30% of vessels served for more than 20 years
- Two dominating GT: 10~49 and > 500
- Small to medium sized engines dominate

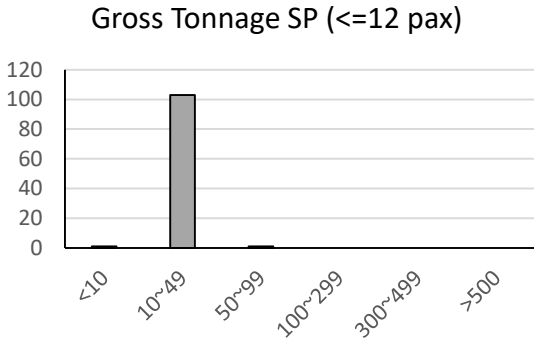
* Propelled and Non-propelled

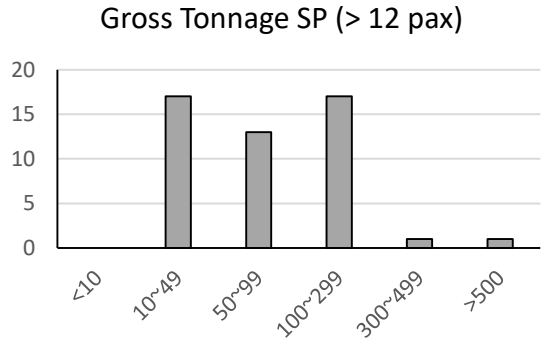
Source: MPA

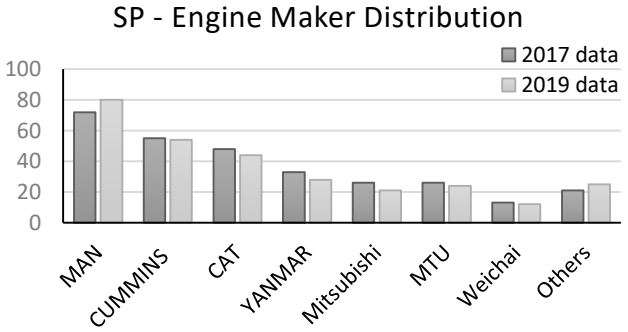
SP Prefix





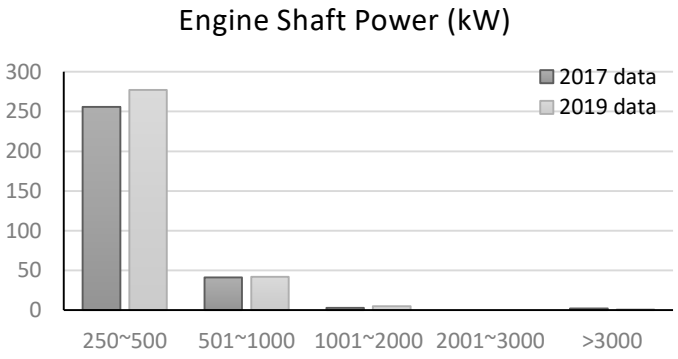


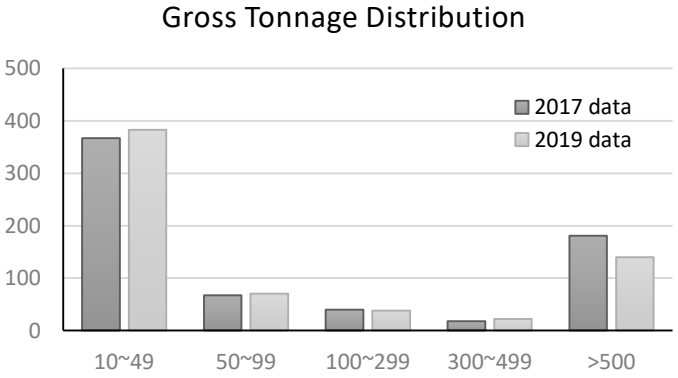


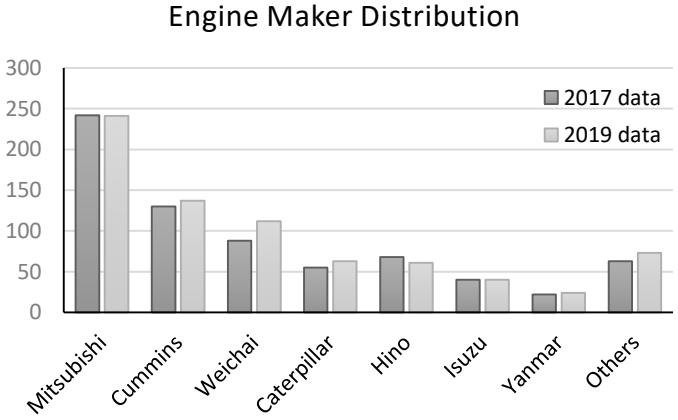


Source: MPA

SC Prefix

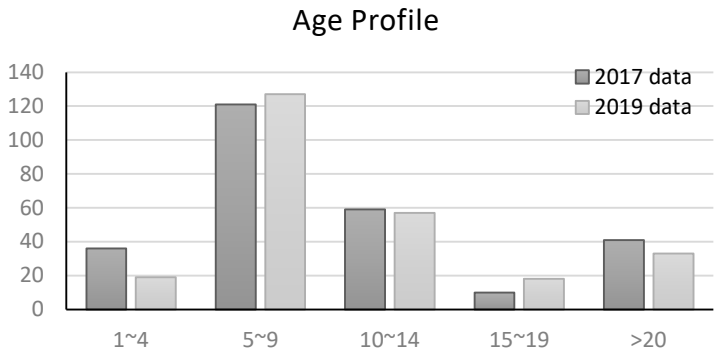


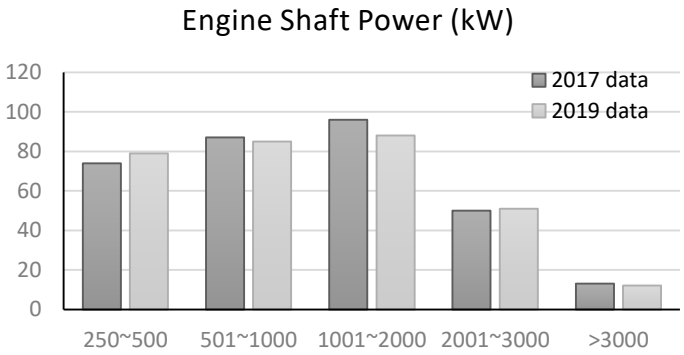


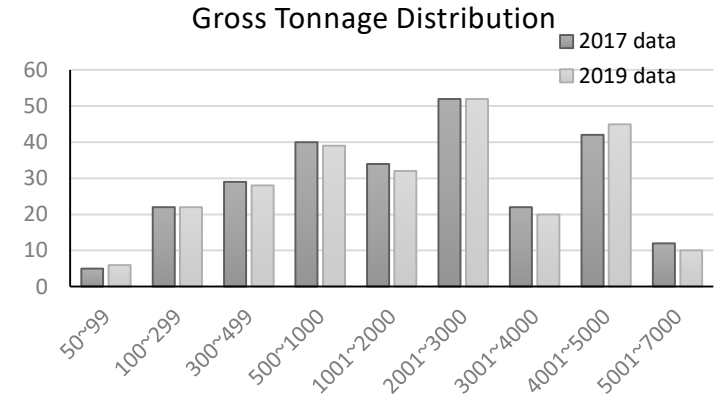


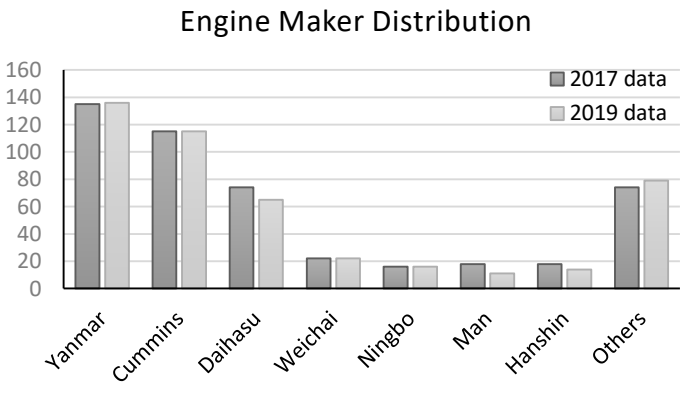
Source: MPA

SB Prefix



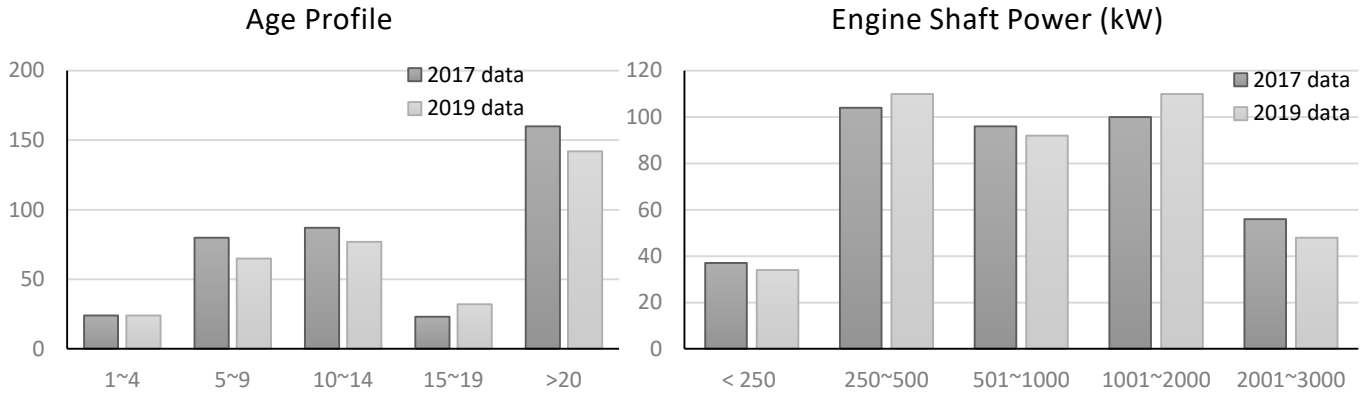


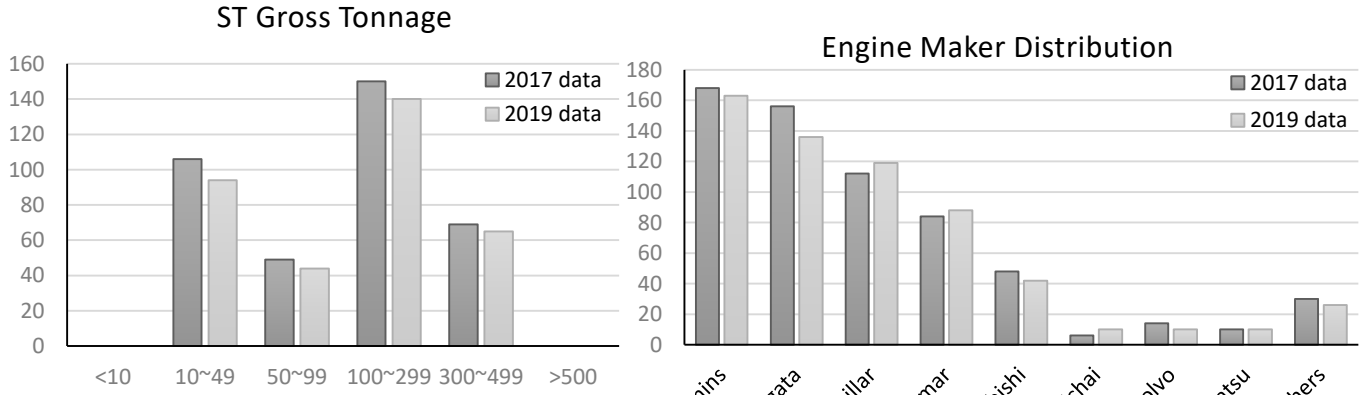




Source: MPA

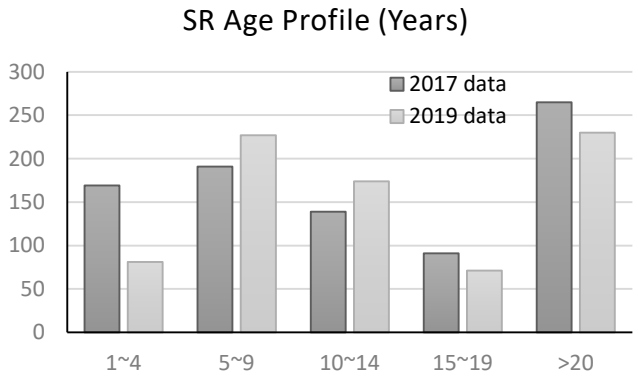
ST Prefix

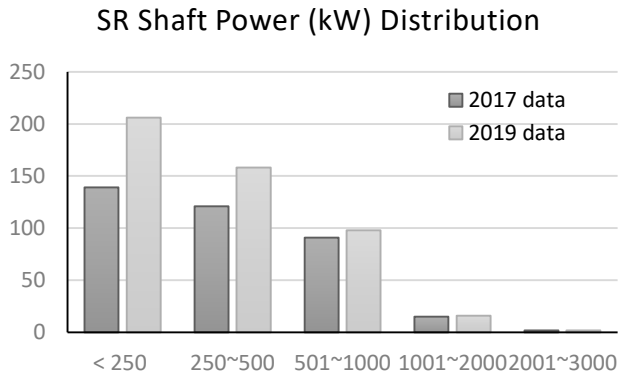


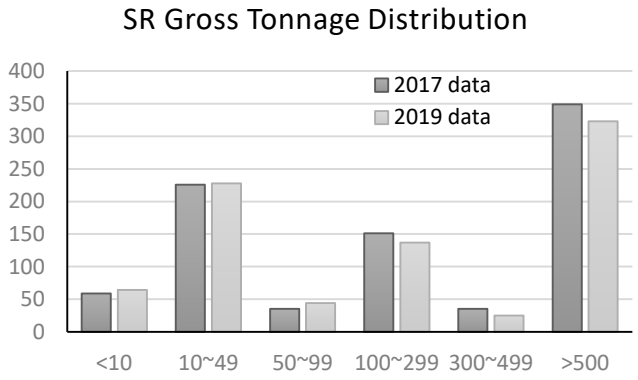


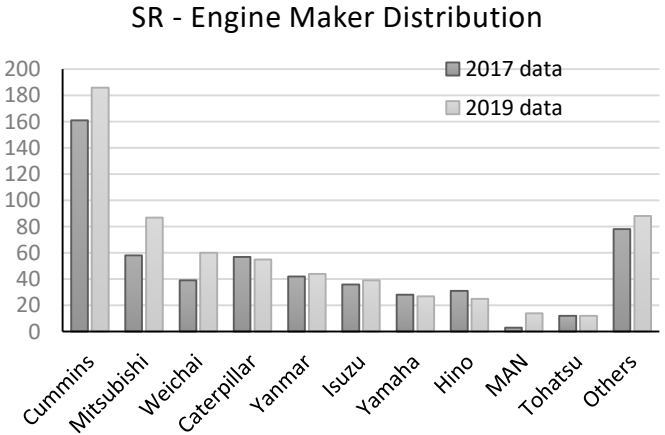
Source: MPA

SR Prefix









Source: MPA

Observation

- Fleet with old ships: higher chances of new builds or retrofits join the fleet in near to mid-term due to replenishment
- Larger gross tonnage: more potential space (as well as flexibility) onboard to accommodates the lower energy density of alternative fuels and energy storage systems
- Smaller engine capacity: a smaller engine requires less energy storage (fuel and battery) or shorter refueling/charging time

Engine Makers' Development in Alternative Fuel

Engine makers' development in alternative fuel

Engine maker	Alternative fuel	Pollutant reduction	Improved fuel economy
MAN	Biodiesel Methanol Ammonia (developing)	SCR	-
Yanmar	Biodiesel (B20) Natural Gas	-	-
Cummins	Biodiesel (B20)	-	-
Daihatsu	Natural Gas	SCR	-
Mitsubishi	Natural Gas	-	Waste heat recovery
Weichai	Natural Gas Methanol (trial)	-	-
Niigata	Natural Gas	SCR	Hybrid (for tugboat)
Caterpillar	Biodiesel (B30) Biodiesel (B100, developing)	SCR EGR	-

- SO_x and NO_x emissions are addressed by sulphur-free fuel or post-combustion treatment.
- CO_2 emission reduction by gradual approaches
  - ✓ fuel economy enhancement (hybrid, waste heat recovery)
  - ✓ Lower carbon fossil fuel (natural gas)
  - ✓ Lower carbon renewable fuel (biodiesel blends)
- Renewable alcohols (methanol, ethanol), hydrogen, ammonia, advanced batteries and fuel cells are still awaiting further development.

Infrastructure and Operating Profile

Bunkering

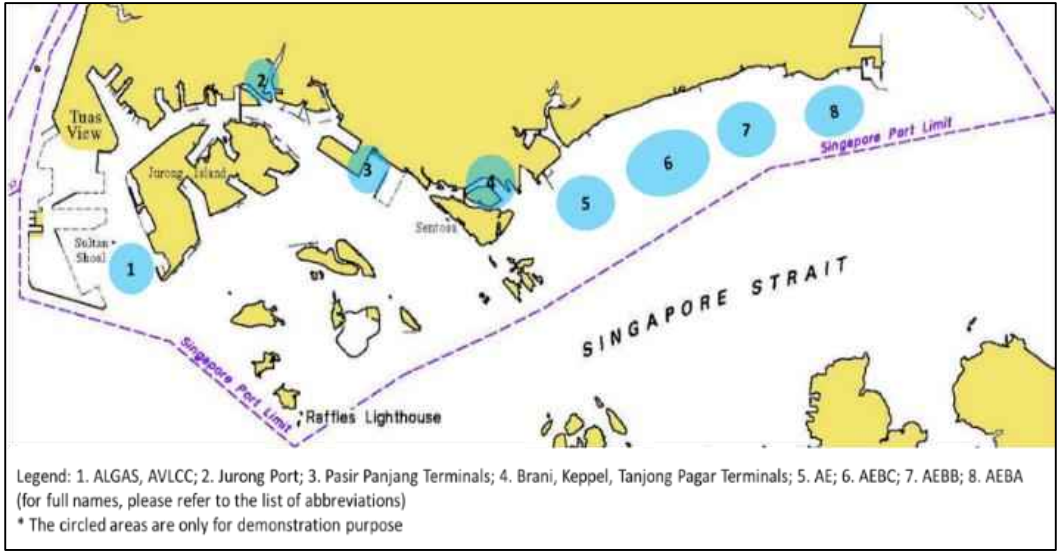


Illustration of Singapore offshore and marine infrastructure (Source: MPA)

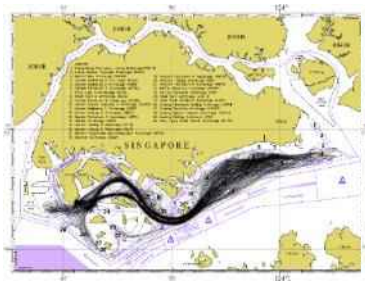
Bunkering operation conducted at sea (ship to ship)

Bunkering operation (shore to ship)

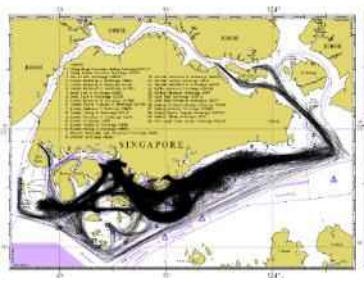
Land based fuel storage tank

- Storage and terminals of petroleum products are located at Southwestern region of Singapore
- Bunker fuels are delivered through various type of bunkering operation to Singapore harbour craft

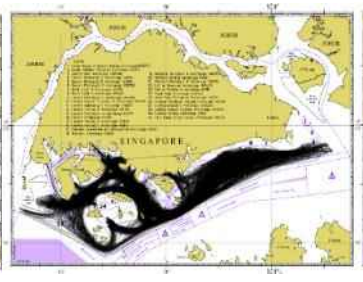
Operating Profile



SP (7/154)



SC (21/677)



SB (6/267)

ST (67/374)

SR (15/855)

AIS location graphs of randomly selected harbour crafts*

- Frequently found from western to eastern routes serving as connections between ferry terminals.

- Cover almost all fairways
- The meetings of launches with the international vessels happen at either Western or Eastern anchorages with an equal number of jobs.
- The busiest anchorages on the Western are ALGAS and AVLCC
- The busiest anchorage on the Eastern is AEBC

- Operates exclusively at all anchorages
- Bunker fuel is picked up in the West, and most deliveries are made in the East anchorages and terminals
- All chemical tankers' activities are located in the Western anchorages, including LPG.
- Bulk liquid cargoes are mostly delivered in the Eastern anchorages.

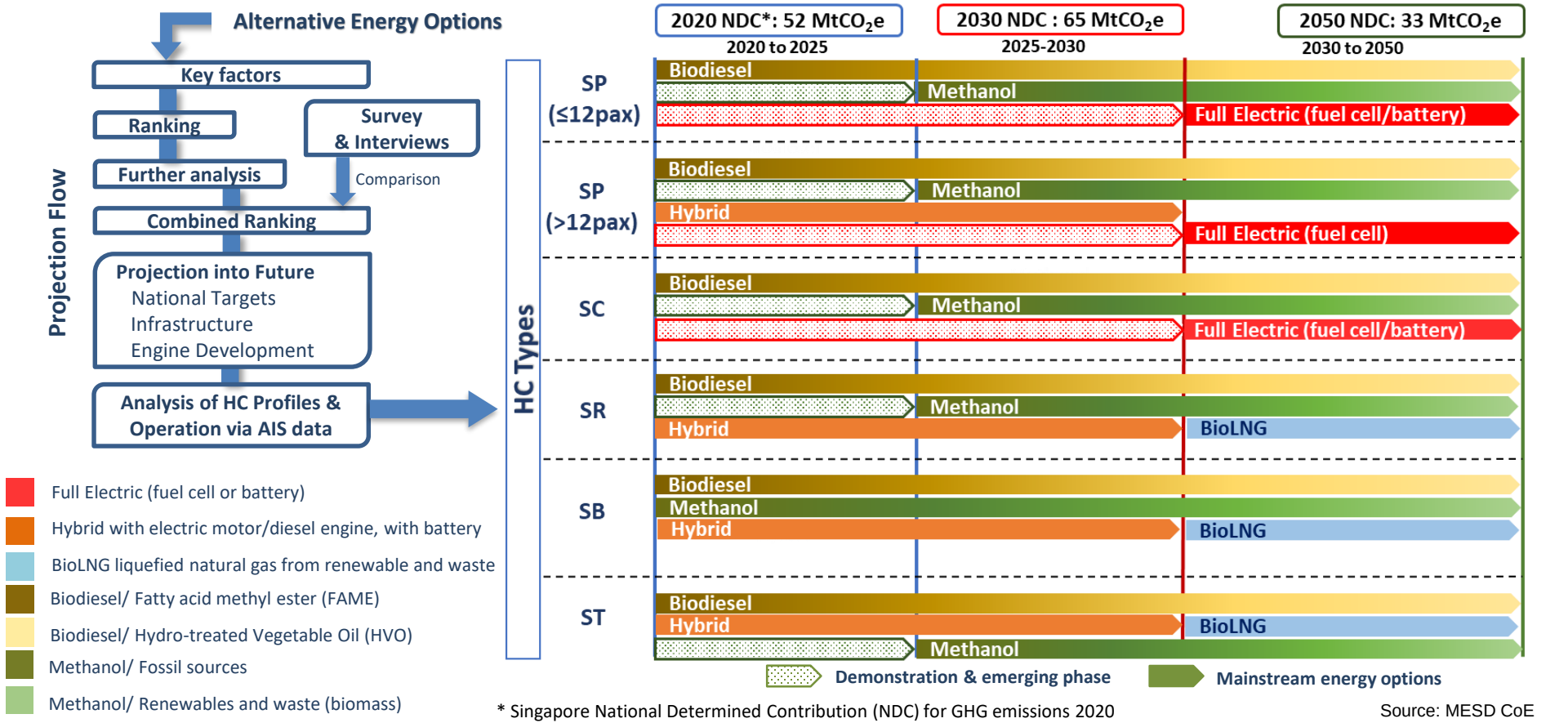
- Most of the towage activities are concentrated at the terminals, bunkering anchorage and shipyards.
- Vessel types requiring the majority of the towage services are mainly tankers
- Towage job typically takes less than 5 km an 20 minutes.

- Operate exclusively within fairways
- Operational routes extend to Pulau Tekong.

*Numerator: number of sample vessels
Denominator: total vessel number

Ranking and Projection Process

Ranking Energy Options for Harbour Craft



Full Electric (fuel cell or battery)

Hybrid with electric motor/diesel engine, with battery

BioLNG liquefied natural gas from renewable and waste

Biodiesel/ Fatty acid methyl ester (FAME)

Biodiesel/ Hydro-treated Vegetable Oil (HVO)

Methanol/ Fossil sources

Methanol/ Renewables and waste (biomass)

* Singapore National Determined Contribution (NDC) for GHG emissions 2020

Source: MESD CoE

Conclusion

Photo courtesy: Singapore Island Cruise and Ferry Services

The diverse requirements from Singapore harbour craft industry influence the decarbonisation pathway and complicate the selection of alternative fuels and associated power options.

Six alternative fuels and three power options emerging as the top energy options for harbour crafts.

More work will be needed in the following areas:

- ✓ A clear roadmap of GHG emission reduction for the sector
- ✓ Collaboration between all stakeholders to develop, trial and demonstrate the feasibilities
- ✓ Create a level playing field for adopters of green solutions
- ✓ Leverage R&D activities to reduce the risks of adoption and to provide confidence

Thank you

Contact MESD:
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For more information, please visit MESD website http://coe.ntu.edu.sg/MESD_CoE