Investigating potential installation of CCS on CO_2 carriers

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Motivation & Goal

Motivation: The shipping industry is currently under increasing pressure to act upon the IMO target of reducing GHG emissions to 50% of 2008 levels by 2050 (IMO, 2018a). The IMO has also placed a global limit on the sulphur content on bunker fuels of 0.5% (from 3.5%) as shown in **Fig 1**. One vital step to meeting the target is to consider alternative fuel source or expanding the potential for carbon/sulphur reduction while using fossil fuels (IEA, 2012).

Goal: To explore the use of a solvent-based post-combustion carbon capture process using aqueous ammonia to reduce CO_2 and SO_2 emissions from a typical CO_2 carrier.

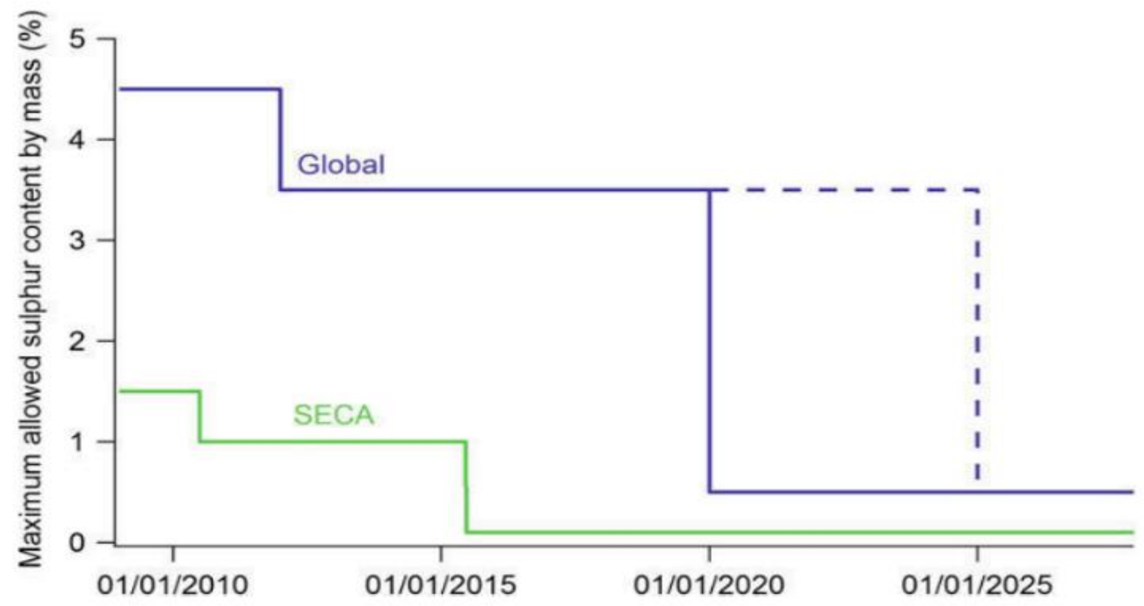


Fig 1: Sulphur Content limits in bunker fuels (Global and Sulphur Emission Control Areas) (Andersson *et al.*, 2016; IMO, 2018b)

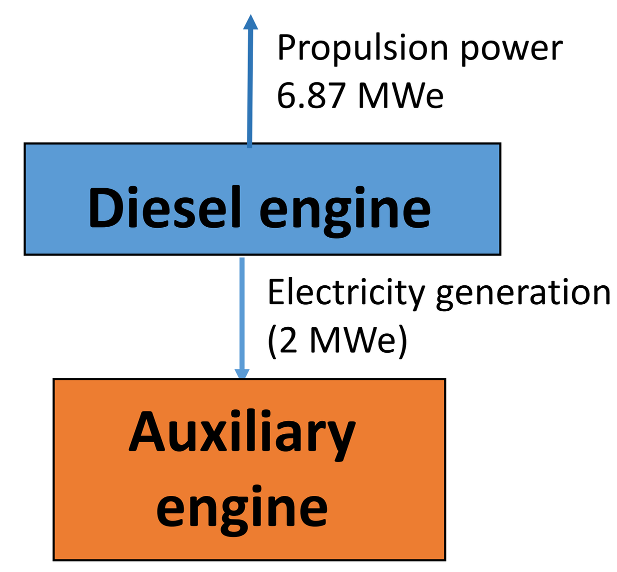


Fig 2: Ship reference case @ 85% engine load

Methodology

Sailing route: Mawei Port (China) to Port of Aardalstangen (Norway)
Average distance: 12223 nm (22636 km)
Crossing time: 40 days

Modes of shipping	Engine load (%)	Crossing time
Sailing	Main/Aux - 85	37
Manoeuvring	Main/Aux -75	2
Hoteling	Main - 0, Aux - 50	1

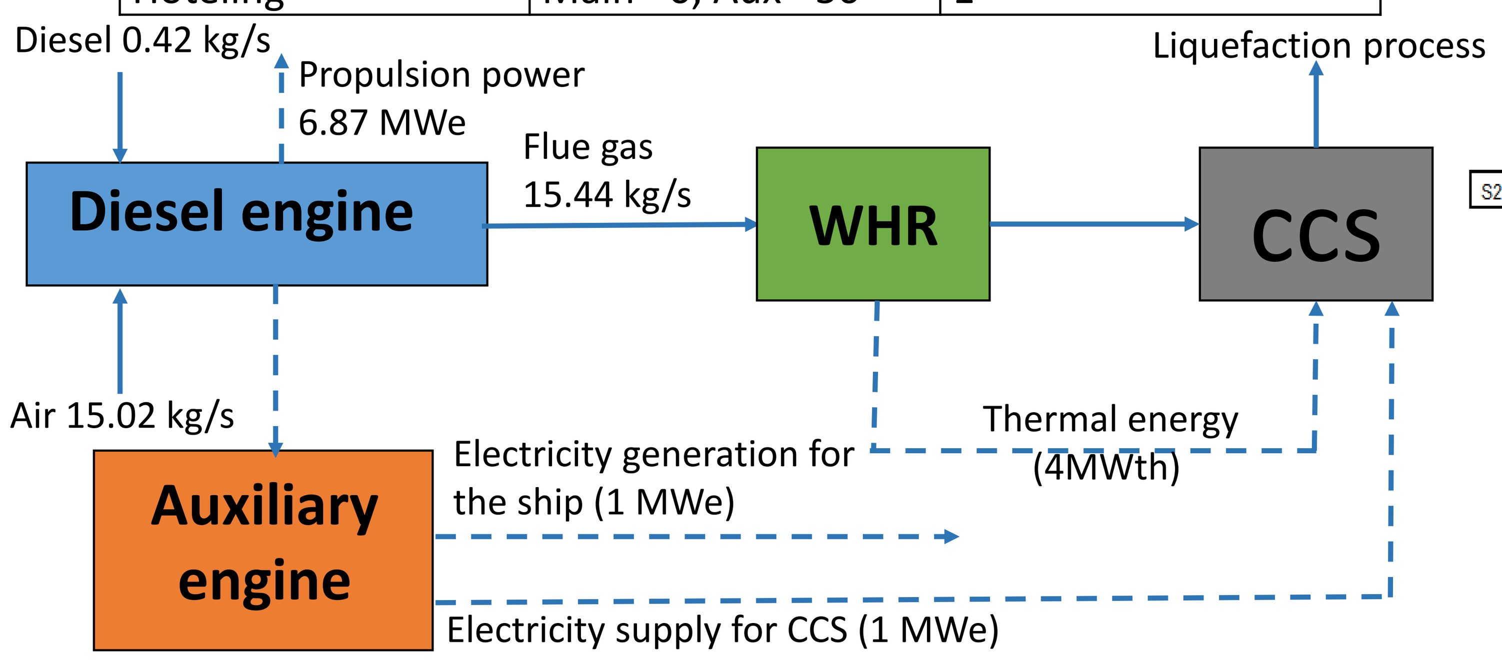


Fig 3: Ship reference case with CCS @ 85% engine load

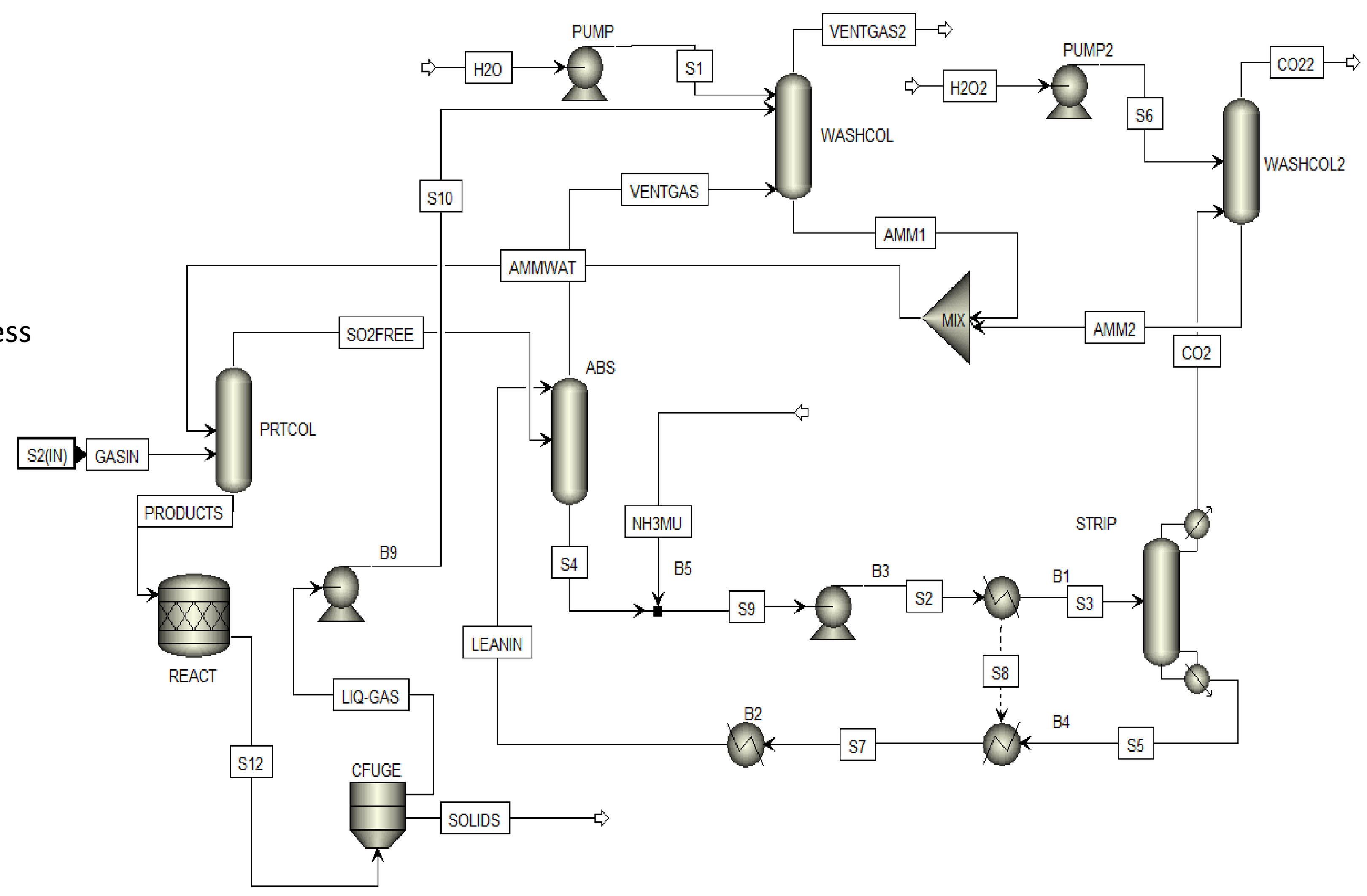


Fig 4: Aqueous Ammonia capture system

The rate based aqueous ammonia capture process was modelled and validated in ASPEN PLUS ™ using the electrolyte non-random two-liquid (ELECNRTL) thermodynamics method applied for the liquid phase and Redlich-Kwong equation of state for the vapour phase, with data available from the Munmorah pilot plant (Yu et al., 2012, 2011). After wards, scaled up to the required capacity of the flue gas with further modification to accommodate the SO_2 capture resulting in the formation of ammonia sulphate.

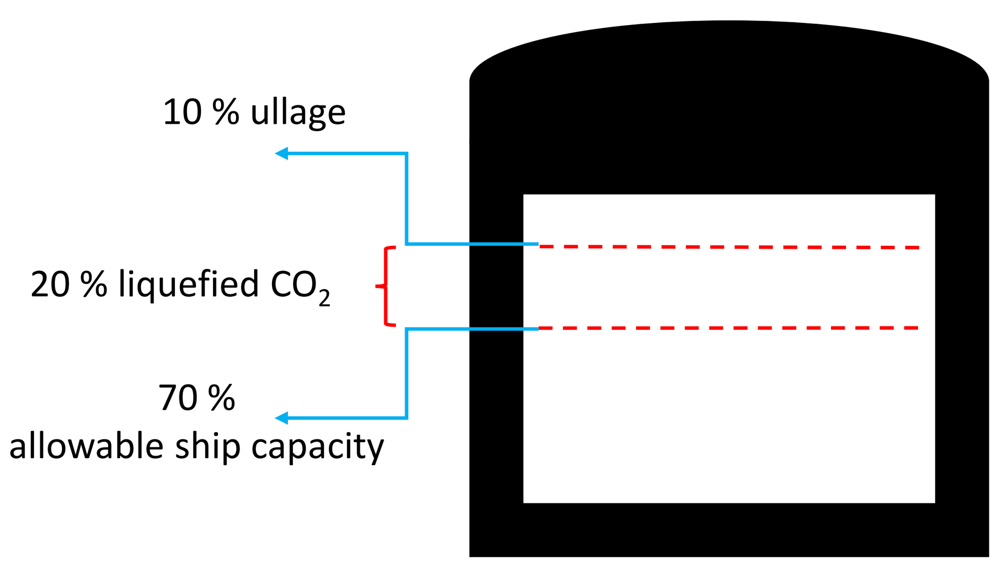
Results

Thermal performance with/without CCS

Description	Reference case (Fig1)	Reference case + CCS (Fig2)
Diesel consumption (kg/s)	0.42	0.42
Ship propulsion output (MWe)	6.86	6.86
Ship electric power output (MWe)	2	1.2
WHR Thermal energy (MWth)	-	4
Electric power consumption of auxiliary in capture process (MWe)	-	0.2
Electric power consumption of auxiliary in liquefaction (MWe)	-	0.8
Stripper reboiler duty (MWth)	-	3760.11
Fuel consumption per trip (tons)	1343	1343
CO_2 emitted/trip (tons)	4181.676	1209 - Before wash column 796 - After wash column
Capture level (%)	-	71 - Before wash column 80 - After wash column

Studies on cargo capacity

- Ship size - 20,000 m^3
- 10 % ullage
- BOG - 0.2%/day
- Liquid flowrate (BOG and captured CO_2) – 4721 kg/hr
- Volume – 3900 m^3
- Space occupied -20 %
- Allowable ship capacity - 70 %



Cargo tank

Results

Performance of the ammonia capture process (Fig 4)

Description	Reference case + CCS (Fig2)
Flue gas flowrate (kg/s)	15.44
CO_2 content in the flue gas (mol%)	5.57
Capture level (%)	71
Lean loading/ Rich loading (mol CO_2/mol NH_3)	0.24/0.34
Reboiler duty (MWth)	3760.11
Absorber diameter (m)	5
Absorber height (m)	10
Stripper diameter (m)	2
Stripper height (m)	6
Ammonia sulphate /trip (tons)	160

Future work

1. Cost analysis of integrating CCS to ships
2. Investigate the impact of impurities on the liquefaction process.
3. Explore the use of integrating CCS to non-CO_2 carriers.

References

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