Development of efficient and reliable large scale CO_2 shipment with associated emissions management

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Introduction

Carbon Capture and Storage has been identified to be a necessary measure to comply with the targeted reductions of CO_2 emissions throughout the next decades and captured carbon dioxide is currently commercially transported through pipeline.

Furthermore, a complementary option is available to decarbonize smaller and more flexible industries: shipping of carbon dioxide. CO_2 shipment enables to transport liquid carbon dioxide upon liquefaction and it is already in use for food-grade purposes and other applications; however in order to make it feasible for large quantities, carbon dioxide needs to be transported as close to its triple point as possible (0.51 MPa, -56.6ºC).

Emissions generated by the ship's engine should be minimal for optimizing the process for net zero emissions. Energy Efficiency Design index (EEDI) and Ship Energy Efficiency Management plan (SEEMP) are measures proposed by IMO for emission reduction. Another option, post combustion capture by absorption is one alternative that efficiently reduces emissions.

Project Overview

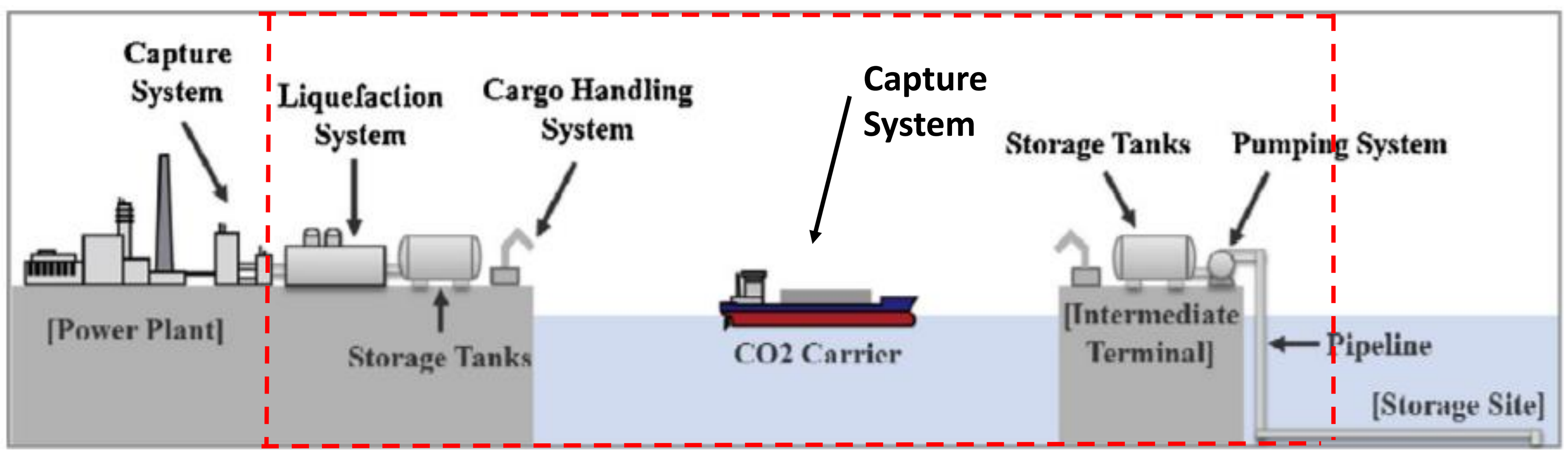

Figure 1: System boundary of the project

Methodology

Aim: To develop an efficient and reliable method for large scale transportation of CO_2 and mitigate losses from boil-off and flue emissions for optimization for net zero emissions.

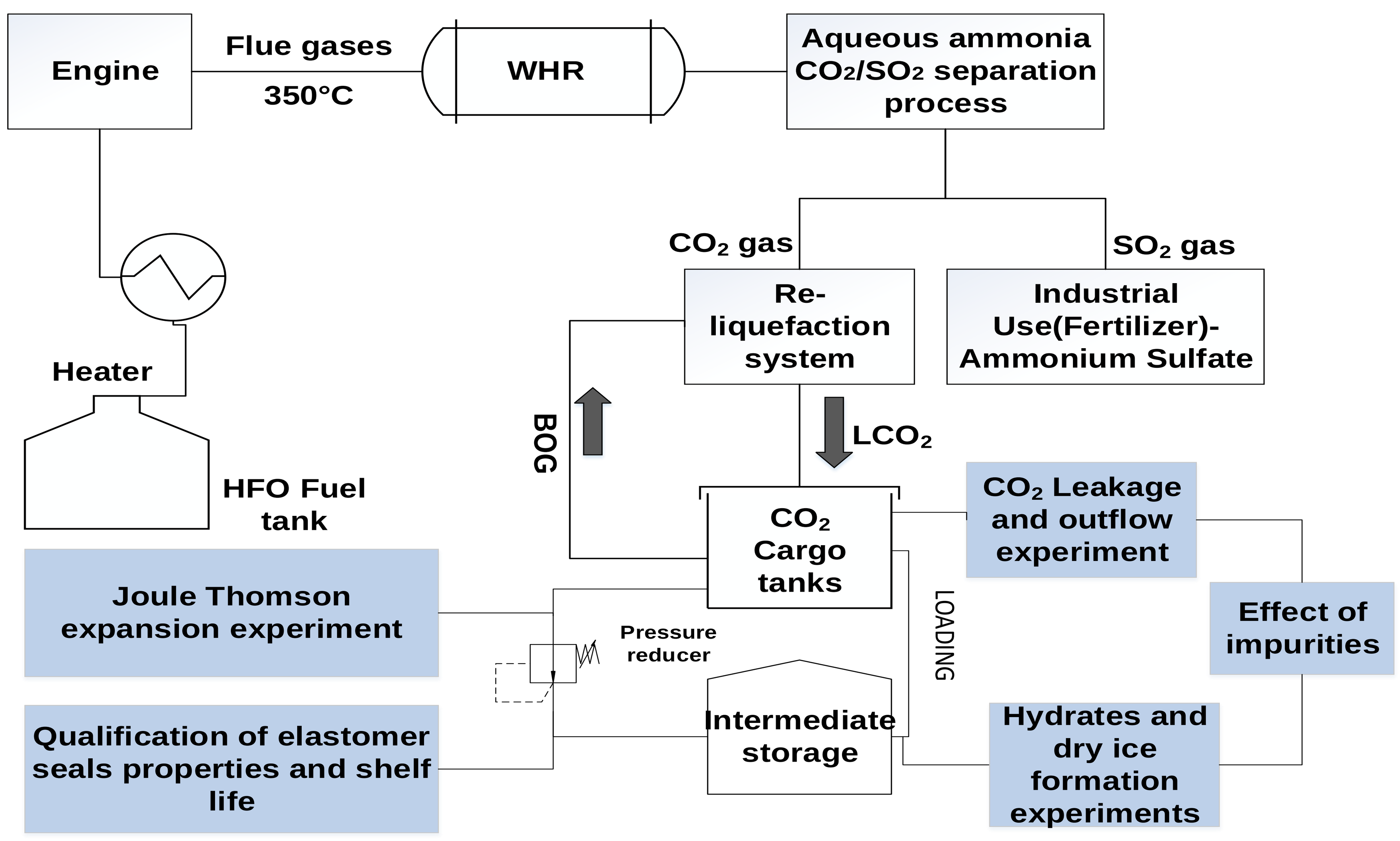

Figure 2: Proposed methodology for the project

Future work

The current PACT facility at Cranfield will be further upgraded to operate at CO_2 shipment conditions. The developed capture model will look into aqueous ammonia as a capture solvent for simultaneous SO_2/CO_2 removal on-board as compared to MEA, will be applied to achieve net-zero emissions for this infrastructure

Preliminary model for liquefaction and emissions with validations

Assumptions:

Wartilsa 9L76 diesel engine; Fuel type: HFO; Ship size: 20,000m^3; Length of voyage: 21 d; BOG: 0.15%

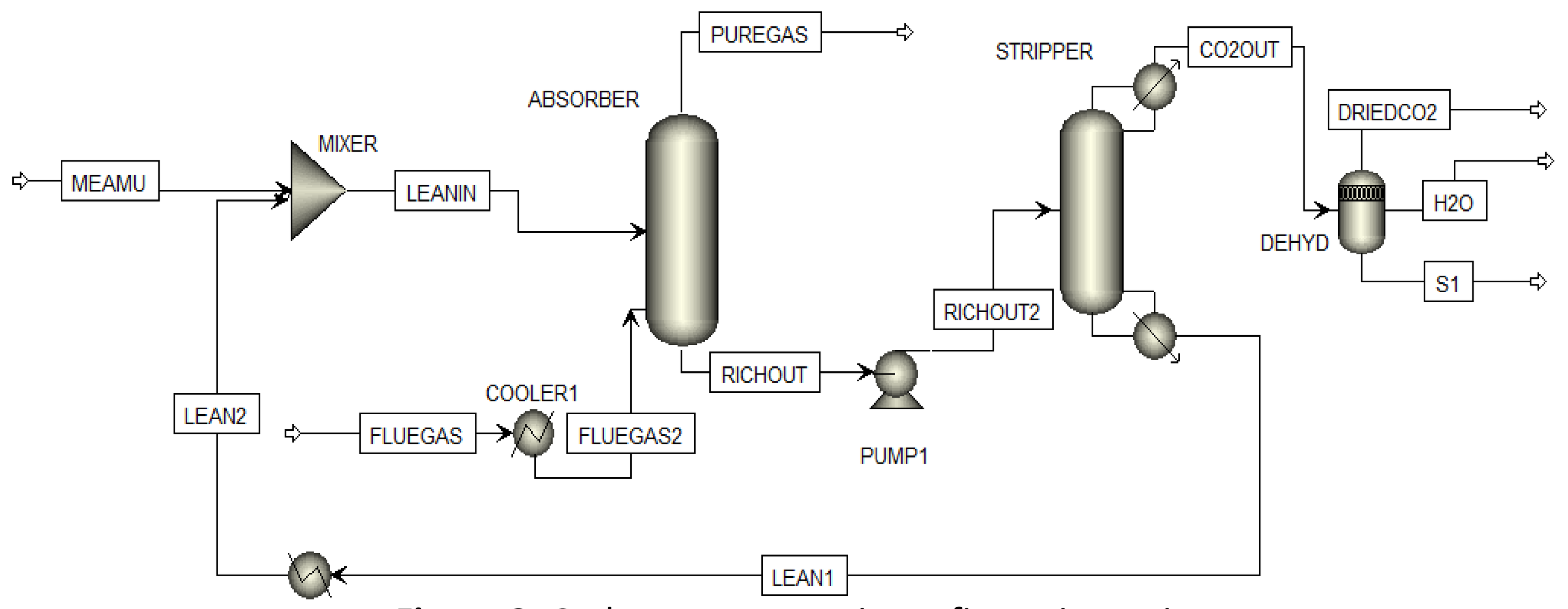

Figure 3: Carbon capture unit configuration unit

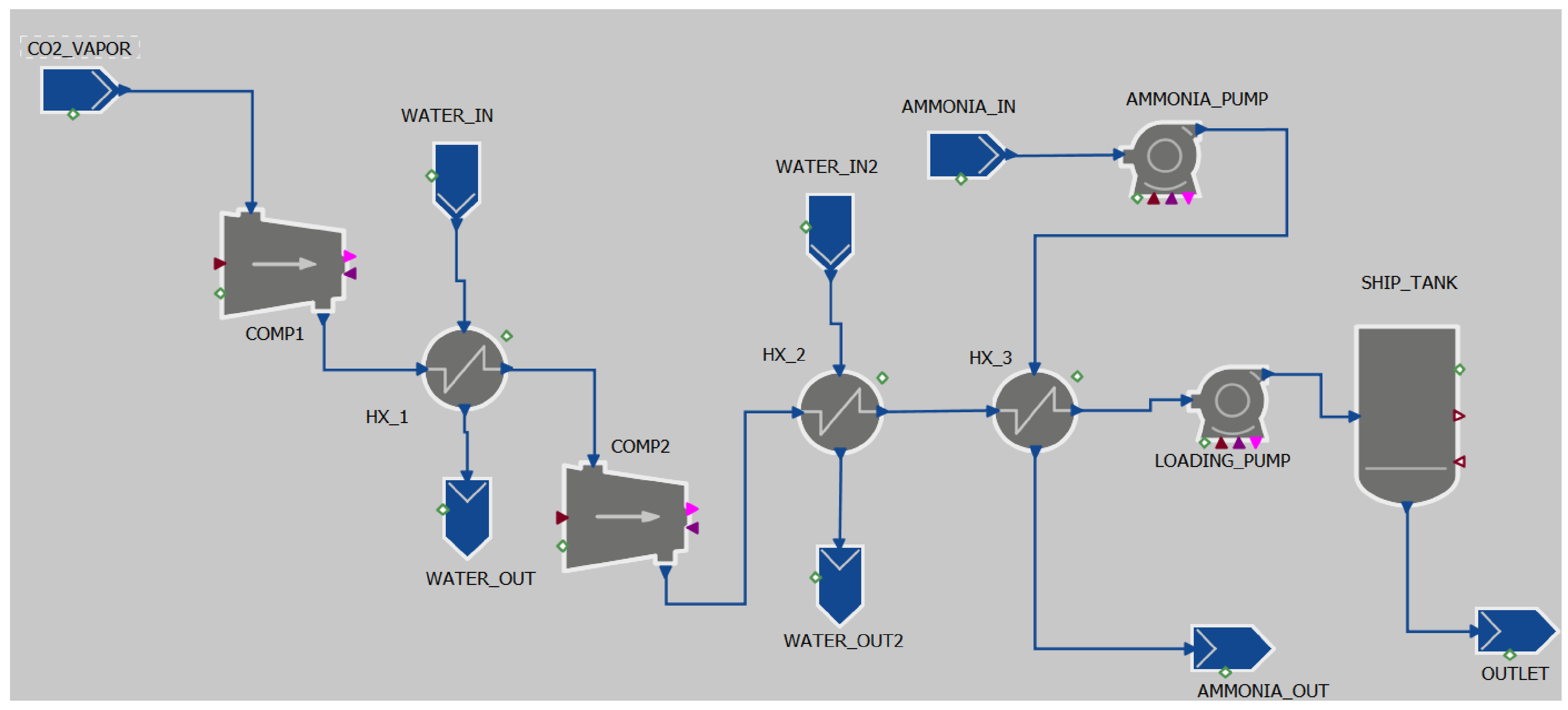

Figure 4 :Multi-stage liquefaction and compression unit for the open cycle water/ammonia system for the ship transport of CO_2 to achieve the required condition

Table 1: Capture and liquefaction conditions for the preliminary capture design

Capture Conditions	(Luo and Wang, 2017)	This work
Flue gas flowrate (kg/s)	32.84	12.97
Flue gas CO_2 content (%mol)	5	14
Solvent MEA content (%wt)	35	35
L/G ratio (kg/kg)	1.73	1.73
Lean loading (molCO_2/mol MEA)	0.308	0.308
CO_2 capture level (%)	73	73
CO_2 amount captured (kg/s)	2.07	2.066

Liquefaction Conditions	(Seo et al.,2016)	This work
Inlet/ Outlet Pressure (bar)	1.8/6	1/7.5
Inlet/ Outlet Temperature (°C)	40/-52.3	20/-53.9
Density (kg/m^3)	1159	1222
LCO_2 purity (mol%)	95.87	97.62

The flue gas composition used for this work was gotten by combustion calculations from a heavy fuel oil sample.

Conclusions

- The preliminary models designed were in agreement with the analyzed literature.
- Efficient CO_2 (73%) capture level can be achieved using MEA
- A liquefied stream of temperature -54°C is attained by ammonia and cooling water use.

References

1. Luo, X. and Wang, M. (2017) 'Study of solvent-based carbon capture for cargo ships through process modelling and simulation', Applied Energy, 195 Elsevier Ltd, pp. 402–413.
2. Seo, Y. et al. (2016) 'International Journal of Greenhouse Gas Control Comparison of CO_2 liquefaction pressures for ship-based carbon capture and storage (CCS) chain', *International Journal of Greenhouse Gas Control*, 52 Elsevier Ltd, pp. 1–1

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