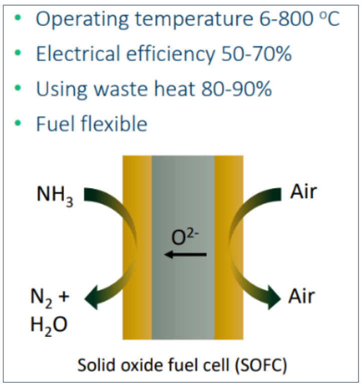
The research project *MaritimeNH3* is part of to the industry-led Green Platform project *Ammonia Fuel Bunkering Network*. In *MaritimeNH3,* SINTEF develop and disseminate new knowledge to facilitate the implementation of ammonia (NH_3) as a zero-carbon ship fuel.

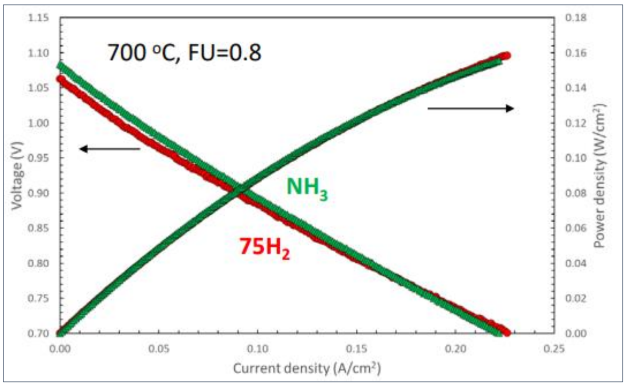
Webinar series

Below, you find some highlights from our three webinars. The webinar uptakes are available Events.

Webinar#1: Use of NH_3 for ship propulsion: crucial issues in engines and fuel cells

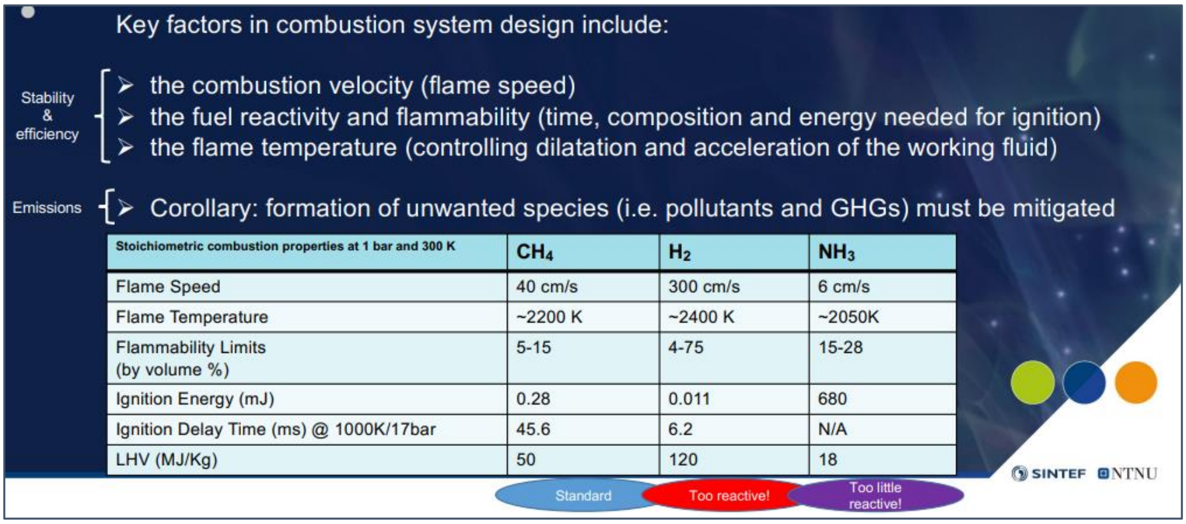
Part 1: Solid Oxide Fuel Cells (SOFSs) – presented by Vegard Øygarden.





- Direct operation of a SOFC with NH_3 shows equivalent electrochemical performance as for H_2.
- The preliminary short-term tests show no, or low, impact on cell durability due to degradation.
- Degradation of stack components will be further explored.
- A test rig for exploring nitridation and corrosion of metal parts are currently being built.

Part 2: Reciprocating engines – presented by Andrea Gruber

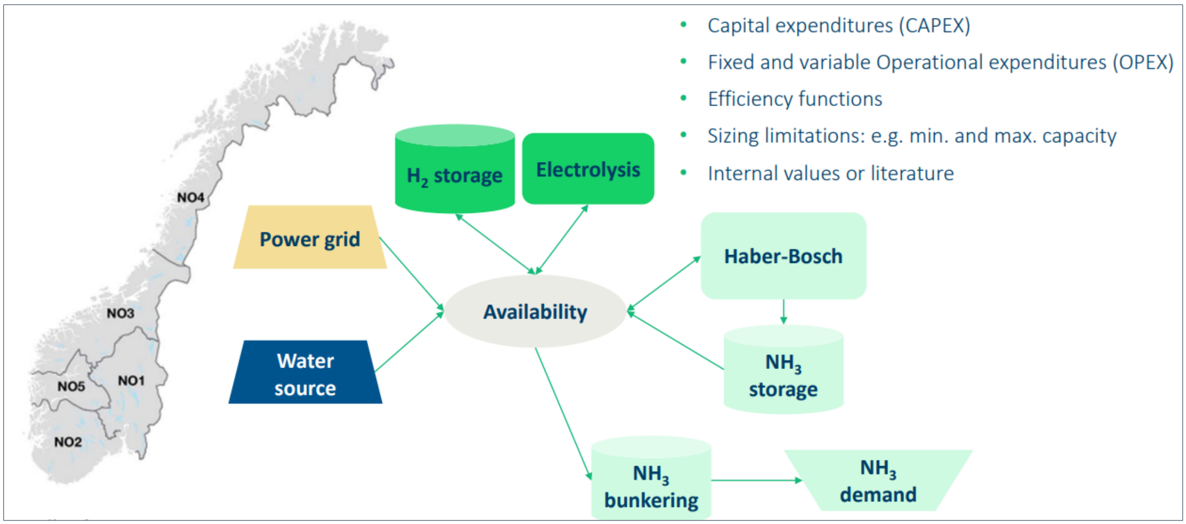


Stoichiometric combustion properties at 1 bar and 300 K	CH_4	H_2	NH_3
Flame Speed	40 cm/s	300 cm/s	6 cm/s
Flame Temperature	~2200 K	~2400 K	~2050K
Flammability Limits (by volume %)	5-15	4-75	15-28
Ignition Energy (mJ)	0.28	0.011	680
Ignition Delay Time (ms) @ 1000K/17bar	45.6	6.2	N/A
LHV (MJ/Kg)	50	120	18

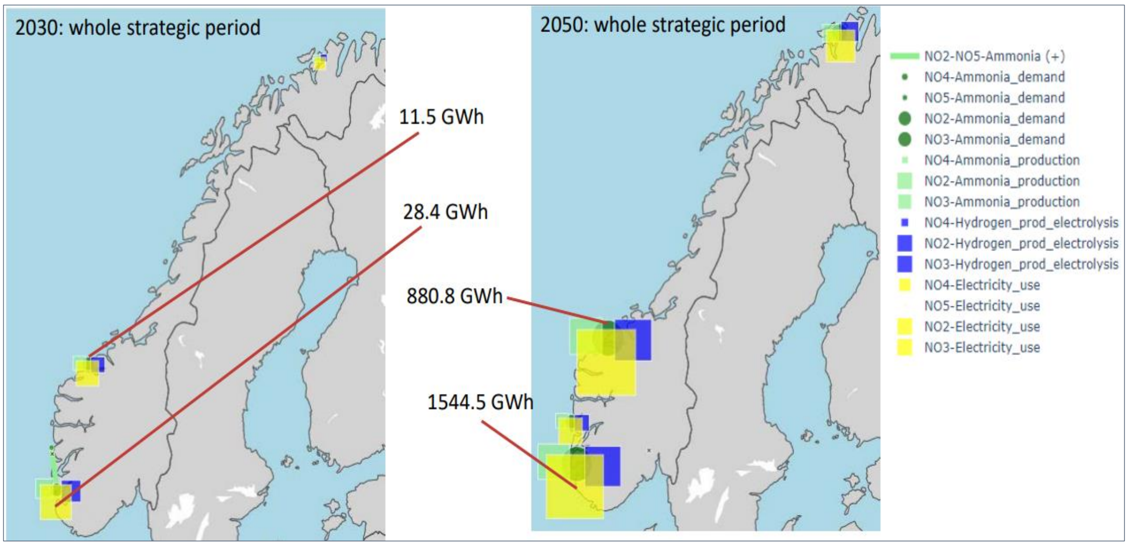
- NH_3 is a viable maritime fuel but strategies for improved ignition and combustion are needed.
- The current project focus is on performing "large-eddy simulations" (LES) of a spark-ignited H_2 pre-chamber with port injection and ignition of pre-vaporized NH_3 (pre-mixed combustion).
- Significant emissions of NO_x and N_2O can occur if fuel-lean combustion is present.
- Chemical reaction kinetics of ammonia flames is still uncertain and needs further validation.

Webinar#2: Modelling a Norwegian NH_3 value chain for maritime transport.

- Presented by Miguel Muñoz Ortiz and Truls Flatberg



- The approach for modelling a NH_3 value chain (from production to bunkering) was described.
- Input data for a simplified national case was presented, such as spatial and time resolution (five Norwegian regions, 18 operational periods) and the expected maritime NH_3 demand.
- Some, very preliminary, results were shown in terms of regional NH_3 demand and production, electricity demand and H_2 production, as well as CO_2 emissions, and NH_3 production method.

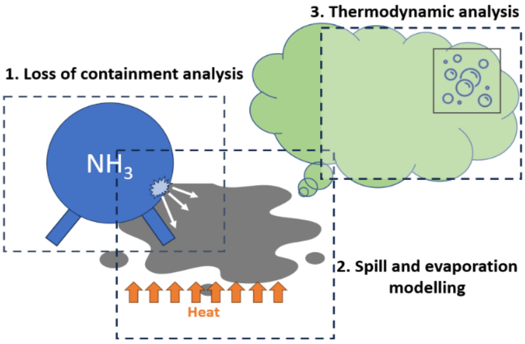


- Next modelling steps are to add maritime-based transport of NH_3 and H_2 (costs an emissions), and fully implement the new NH_3 production model, with its updates on production costs.
- A sensitivity analysis will be performed, by varying parameters like NH_3 demand, electricity price, and availability of blue H_2, as well as increasing the operational period resolution.

Webinar#3: Release of refrigerated NH_3: modelling and safety analysis

Presented by

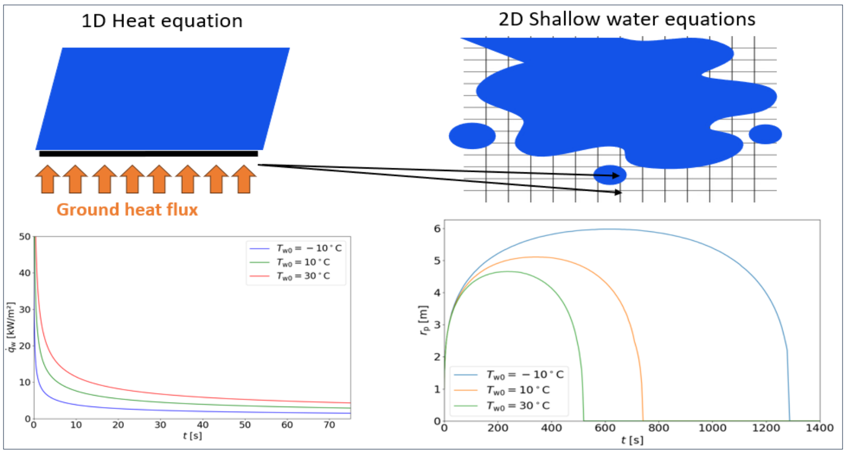
- [Hans L. Skarsvåg]
- [Marta Bucelli]
- [Martin S. Grønli]
- [Ailo Aasen]



1. Loss of containment analysis of a stationary, refrigerated, double containment tank

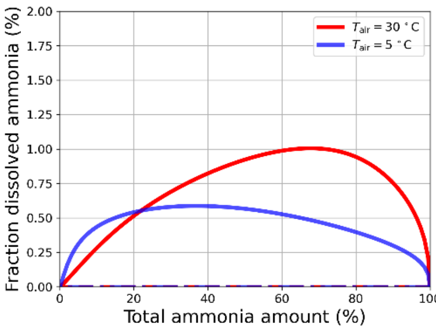
- Leakage rates for 4 accident scenarios were estimated: catastrophic tank rupture, loss of tank connections (pipe, valve) and instrumentation, and bunkering pipe rupture in the retention pit.

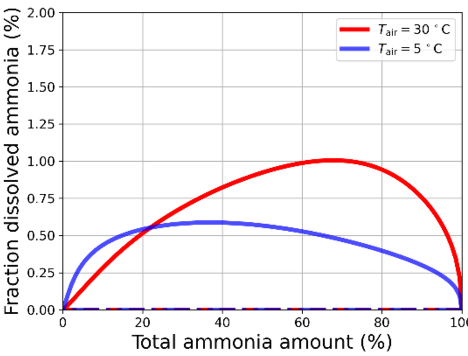
2. Modelling of spill and evaporation rate from a refrigerated atmospheric tank (-33°C)



- The open-source modelling tool enables to describe the spill radius on solid ground and the local evaporation rates, being important input to modelling NH_3 dispersion in the atmosphere.
- The model can handle different geometries and is applicable to other fluids, like LH_2.

3. Thermodynamic modelling and analysis on the behaviour of NH_3 release in humid air





- To estimate the buoyancy of NH_3 dispersed into humid air it is important to understand the amount of NH_3 gas being dissolved in water droplets or adsorbed on the droplet surfaces.
- Modelling results shows that mixtures of NH_3 (-30°C) and humid air (5°C) are always buoyant, and that 99% of the NH_3 gas is found in the vapor phase, 1% in droplets and 0.01% on droplet surface.

Some news from our industry partners

Ammonia, and the AFBN project, are well represented in this year's Maritime Hydrogen Conference, arranged by Ocean Hyway Cluster. Håkon Skjerstad, Azane Fuel Solution, participates in the panel debate "*Ammonia safety at sea",* and Olav Hansen, HYEX Safety, is among the speakers.

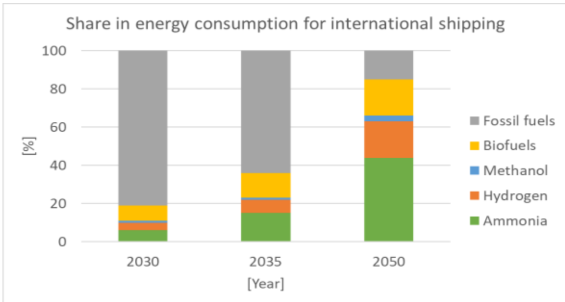
Equinor has started a NH_3 bunkering study together with Amon Maritime. In the project, AFNO 2030, it will be studied how clean NH_3 can be introduced as a fuel to decarbonize the Norwegian offshore sector. It will cover logistical optimization, operational planning, and safety aspects.

In September it was announced that Yara Clean Ammonia and North Sea Container Line (NCL) have received Enova support for the construction of a clean NH_3-fuelled container vessel. The NH_3 are to be delivered from the bunkering barge developed in the AFBN project.

Some other "Ammonia News"

IEA (International Energy Agency) has updated their Net Zero Roadmap, where they suggest that NH_3 must emerge as the key shipping fuel if the industry is to reach net-zero emissions by 2050.

The estimated NH_3 share in the fuel mix for international shipping is 15% in 2035 and 44% in 2050.



EMSA (European Maritime Safety Agency) has updated their report on the Potential of Ammonia as Fuel in Shipping, including a number of advantages that NH_3 would have over other low-flashpoint fuels, as well as technology and regulatory gaps that would prevent its immediate application, and some incentives that would encourage its adoption.

Within the "Nordic Roadmap project", led by DNV, a complete base document for draft *Interim Guidelines for the Safety of Ships using Ammonia as Fuel* has been developed and submitted to IMO, on behalf of the Nordic Countries. The interim guidelines are expected to be finalised by IMO in the end of 2024.

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