DNVA Seminar
The Norwegian Academy of Science and Letters

The Future of Gas

Oslo
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Hydrogen and Ammonia for Maritime Applications

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Associate Professor UiO

Synopsis

Energy Storage

- Short Range – **Compressed Hydrogen** (CH2)
- Medium Range – **Liquid Hydrogen** (LH2) & **Ammonia** (NH3)
- Long Range – **Ammonia** (NH3)

Power Systems

- Low-Temperature **PEM Fuel Cells** (H2)
- High-Temperature **Solid Oxide Fuel Cells** (H2,NH3)
- **Internal Combustion Engines** H2/NH3

Maritime Hydrogen Projects in Norway (2023)

- National Support for Maritime Projects – Hydrogen & Ammonia

Ocean Infinity (**H2**) – 148,6 MNOK

Færder Tankers (**NH3**) – 93 MNOK

Færder Tankers (**NH3**) – 112,6 MNOK

Thor Dahl Bulk (**H2**) – 97 MNOK

Egil Ulvan (**H2**) – 104 MNOK

Loran (**H2**) – 92,5 MNOK

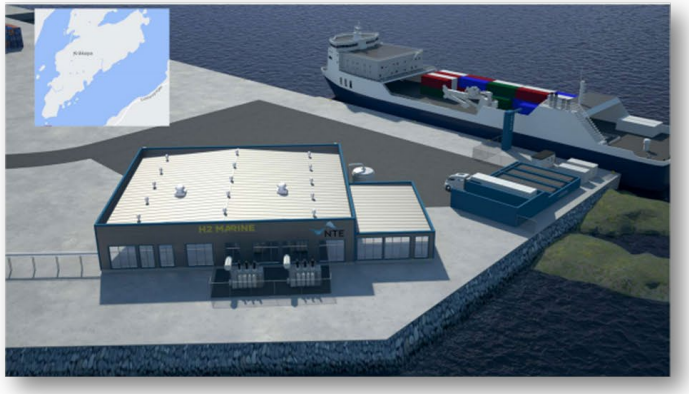
1 EUR = 11.3 NOK

Hydrogen Infrastructure for Maritime Projects (2023)

- National Support for the establishment of five Hydrogen Hubs along the coast of Norway

Trønderenergi Hydrogen AS (113 MNOK) – **Hitra**

Glomfjord Hydrogen AS (150 MNOK) – **Glomfjord**



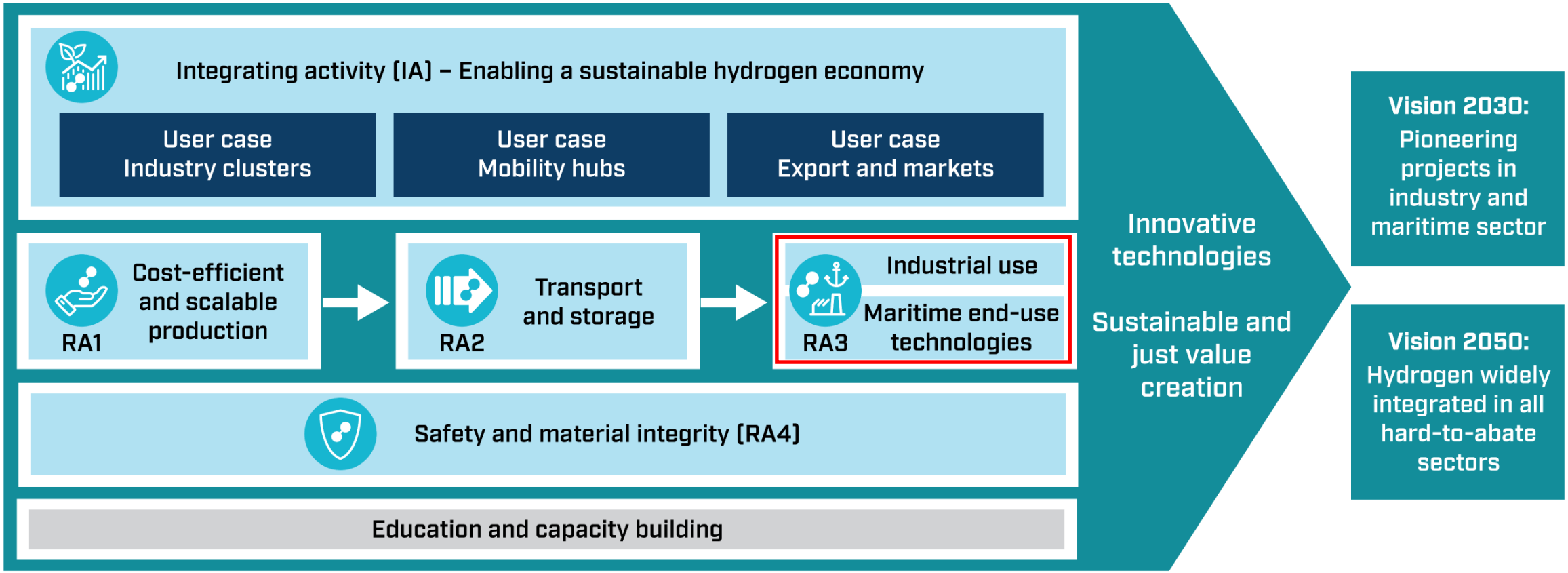
NTE Energy AS (125 MNOK) – **Rørvik**

Greenstat ASA (148 MNOK) – **Kristiansand**

HyFuel AS (132 MNOK) – **Florø**

1 EUR = 11.3 NOK

Hydrogen & Ammonia End-Use Technologies



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Maritime H2 and NH3 Technologies

R&D Partners: IFE, SINTEF, NTNU, UiT-Narvik, SINTEF

- **Hydrogen based Power & Propulsion Systems (WP3.2)**
  1. Fuel cell stacks and system
  2. H2/NH3-fired combustion engines
  3. System integration

- **PhD Studies** (2023 – 2026)
  1. UiT-Narvik ***"Electrical System Integration and Controls of Large Maritime PEM Fuel Cell Systems"***
     Main supervisor: Prof. Bjarte Hoff. PhD-student from Q1 2024:

  2. NTNU IMT ***"Combustion of Ammonia and Hydrogen Fuel Mixtures in Marine Engines"***
     Main supervisor: Prof. David Emberson. PhD-student from Q3 2023: Duc Duy "Joey" Nguyen

  3. NTNU IMT ***"Hydrogen-Electric Propulsion for Zero-Emission Shipping"***
     Main supervisor: Prof. Mehdi Zadeh. PhD-student from Q1 2024: Spiros Brouzas

Fuel Cell Stacks and Systems

Maritime Fuel Cell Stacks & Systems

Goals:

- Maritime FC systems for zero-emission power
- PEMFC system validation and demonstration

PEM Fuel Cell

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Research Challenges & Methodology

- Optimize **lifetime** of **H2-based** low-temperature **PEM fuel cells** (high TRL)
- **Accelerated Stress Tests** (AST) of PEMFC stacks
- **Electrochemical analysis** (EIS, IV, CV)
- PEMFC system design & electrical system integration
- **Develop** next generation **NH_3-based** high-temperature **SOFCs** (low TRL)

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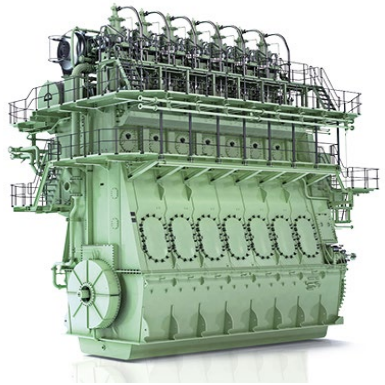
NH3/H2-fired Combustion Engines

Optimization of IC-engines for carbon-free fuels (NTNU, SINTEF Energy)

Goals:

- Identify crucial technology shortcomings
- Propose mitigation measures



H2/NH3 IC-Engines

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Research Challenges & Methodology

- **Reliable ignition** (spark/pre-chamber) of NH_3–rich fuels
- **Emissions** of GHG (**N_2O**) and pollutants (**NO_x**) from NH_3- & H_2-flames
- Early ignition of H_2-fired engines (spontaneous-propagation regime)
- Advanced **numerical studies** (SINTEF) and **laboratory experiments** (NTNU)

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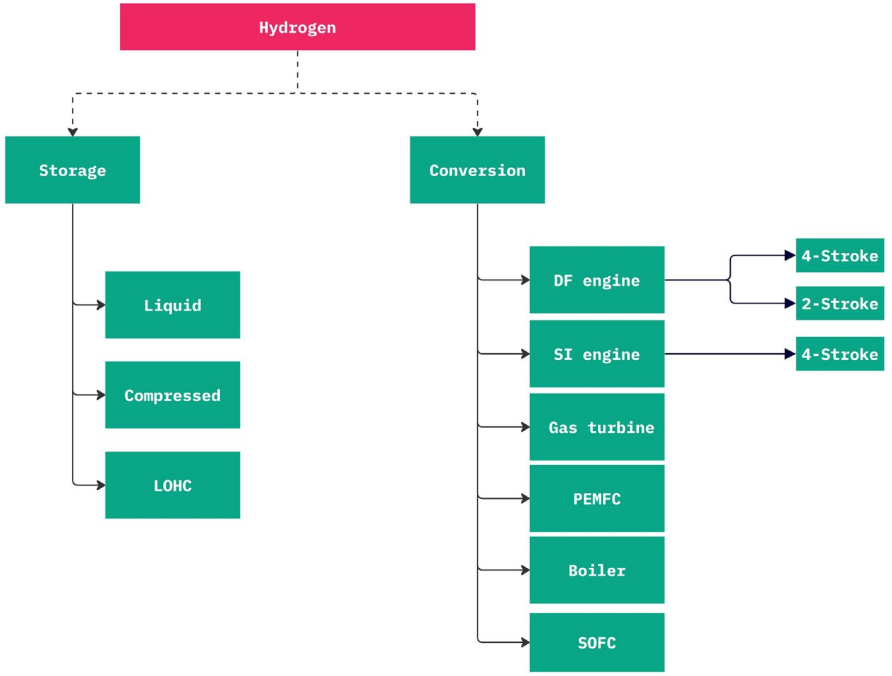
System Integration & Hybridization

Safe, Efficient and Reliable Integration of Technologies

Goals:

- Identify effective pathways use of H_2 and NH_3
- Design for realistic operational scenarios



H2 Key Technologies

Research Challenges & Methodology

- **Establish efficient pathways** for maritime end use of H_2 & NH_3
- Develop **generic methodology** for analyzing impact of the technology
- Develop the model for the **cost of ownership** for maritime application of H_2 and NH_3

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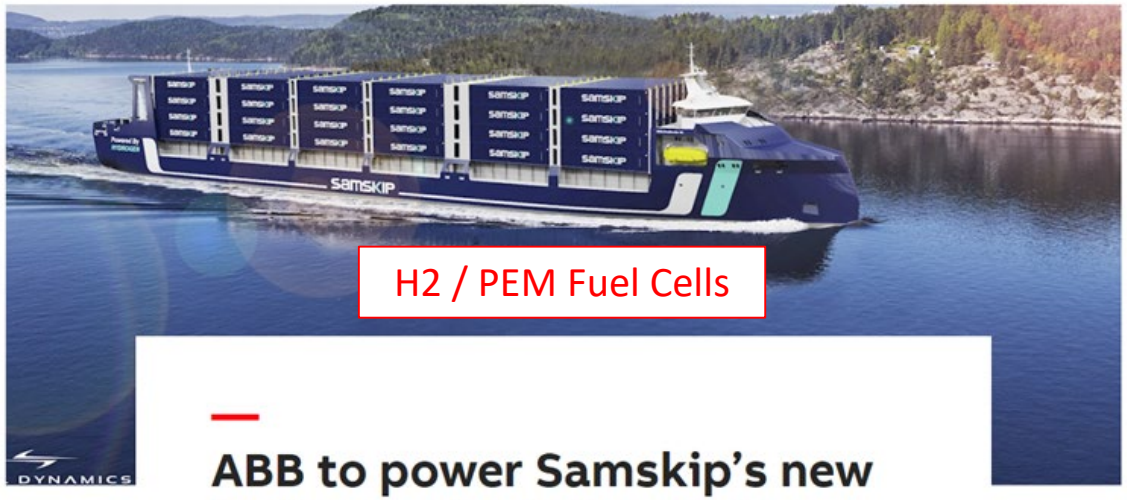
Latest H2 & NH_3 Maritime Technology Developments



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Thank You for your Attention

RA3
End-Use Technologies
Øystein Ulleberg, IFE

WP 3.1
Industrial Use of H2
Halvor Dalaker, SINTEF Industry

T3.1.1
H2 for Industrial Heat
Martin Syversen, SINTEF Industry

T3.1.2
H2 as Reducing Agent
Halvor Dalaker, SINTEF Industry

WP 3.2
Maritime H2 and NH3 Technologies
Trond Johnsen, SINTEF Ocean

T3.2.1
Fuel Cell Stacks and Systems
Piotr Bujlo, IFE

Task 3.2.2
Internal Combustion Engines
David Emberson, NTNU

Task 3.2.3
System Integration and Hybridization
Sadi Tavakoli, SINTEF Ocean

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