Energilagring

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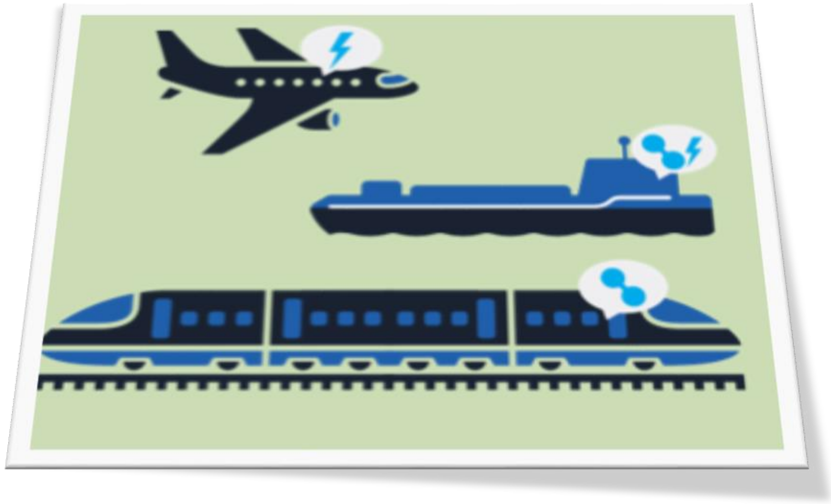
ZETA Workshop 10.mars 2020

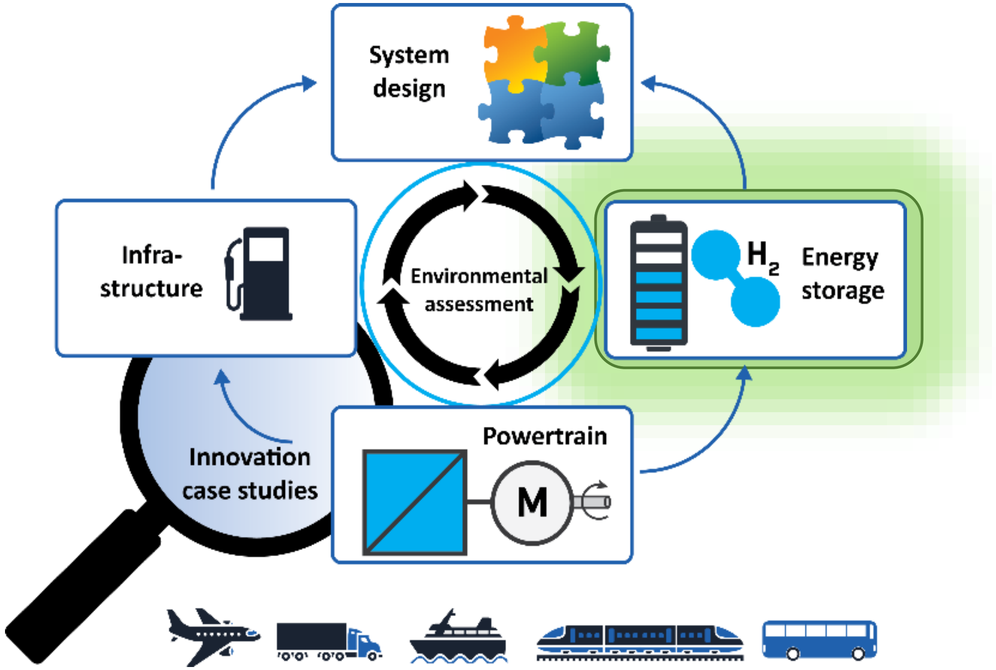
Energy storage for heavy duty transport

Heavy duty transport requires large scale energy storage

Batteries and hydrogen will both be neccessary

Different transport modes have different requirements





Energy storage for heavy duty transport

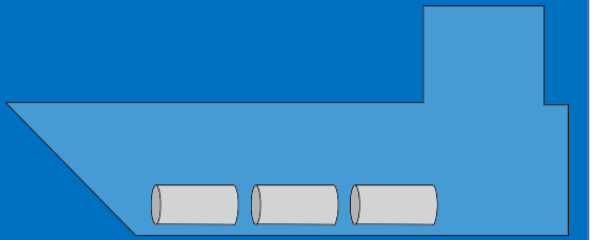
- Full electrification for zero emission operation
  - Not feasible for heaviest duty transport - e.g. Viking Energy ship: ~150 MWh energy consumption per day (LNG)
- Hybridization of drivetrains for reducing fuel consumption
- Hydrogen-based propulsion systems for zero emission operation

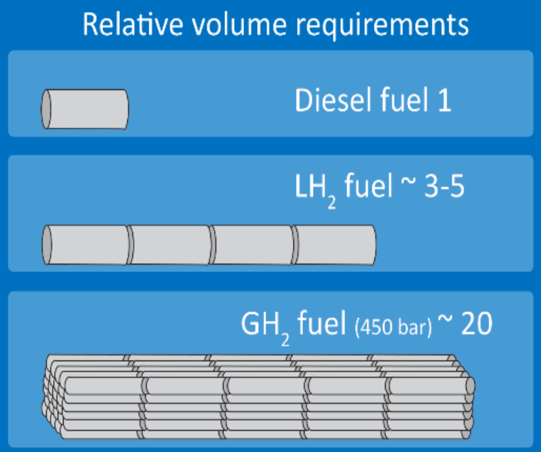
Electric power conversion technology will be important for reducing emissions

Energy storage - compressed, liquid or other H2-carrier?

Fuel cell and battery – integration, ageing prospects?

Able to reach necessary energy and power density?





Liquid hydrogen: scaling-up is feasible

LNG

1959: 5 500 m^3

1964: 28 300 m^3

1973: 87 600 m^3

2018: 182 000 m^3

LH_2

2020: 1 250 m^3 = 3000 MWh

Mid-term: 9 000 m^3

Long-term: 160 000 m^3

Research challenges

- Hydrogen storage technology:
  - Tradeoffs for different hydrogen carriers - compressed H_2 has low energy density, liquid H_2 requires advanced tank insulation to ensure acceptable boil-off rate and dormancy, alternative carriers need further study and development (e.g. N_2O from ammonia?)
- Safety of hydrogen use:
  - strong efforts already, collaboration w/ Sandia (HyRAM), SH2IFT, PRESLHY, SVV, ++
- Hybrid hydrogen/battery solutions:
  - Balance-of-plant, significant potential for synergies e.g. with respect to heat integration
- Battery and fuel cell use in heavy duty and marine/cold environment
  - Ageing prospects of these components in the ZETA context

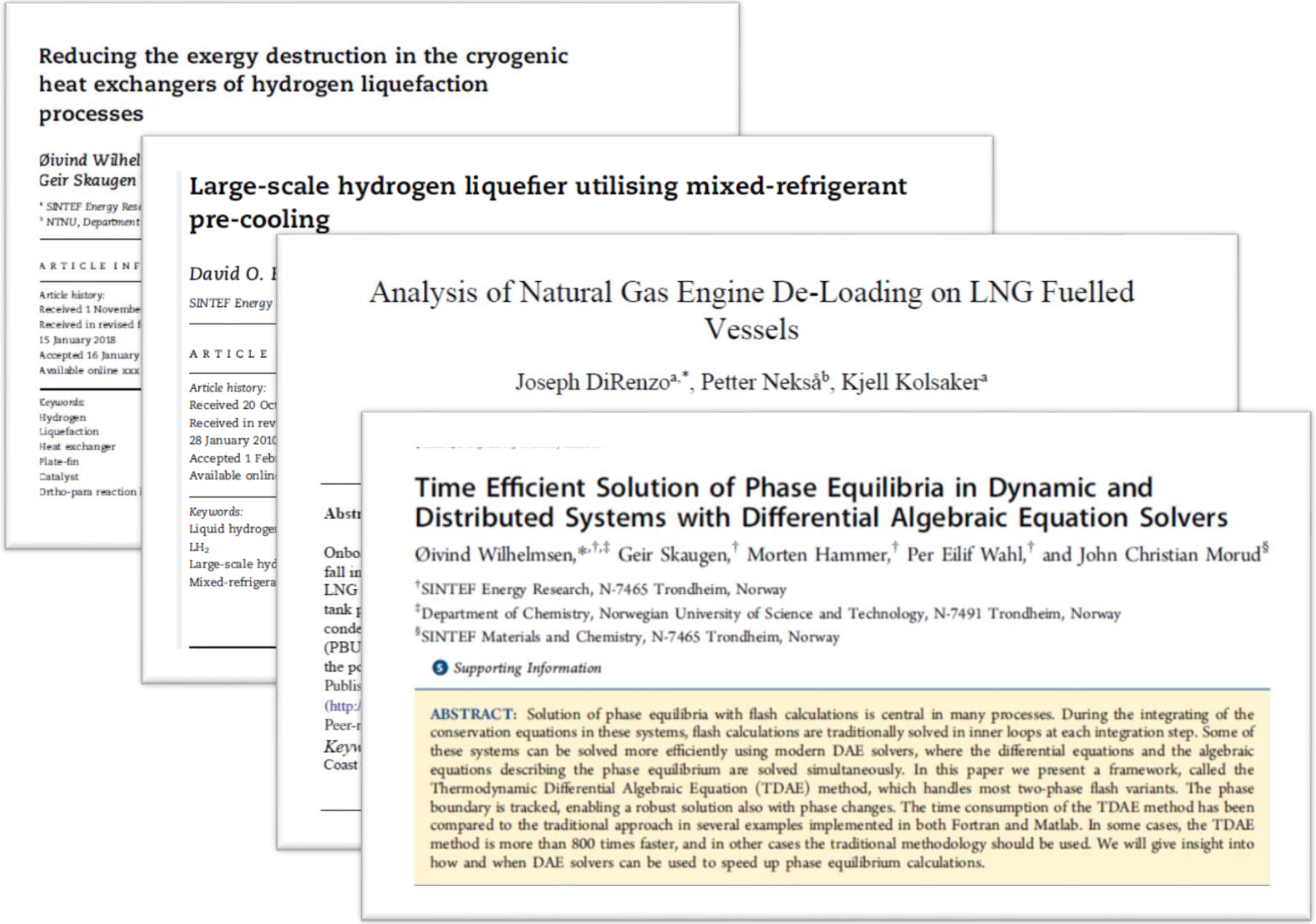
State-of-the-art

- Today's use of hydrogen within the transport sector is limited, dominated by compressed gaseous storage onboard small vehicles.
- There are large energy demands in many applications, such as many maritime vessels, requiring novel technological concepts.
- Knowledge from use of hydrogen available from other fields (e.g. aerospace).
- Many of these are areas where Norway has a large home market and an export oriented vendor industry.
- First concepts are being developed today
- Need to get on the ship before it leaves the quay

LH_2 fuelled super-yacht

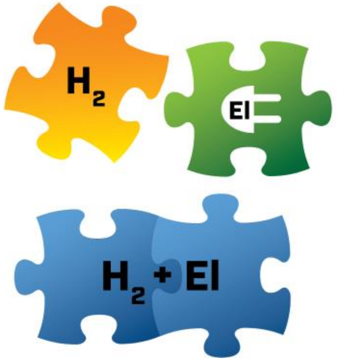
State-of-the-art

- Sophisticated modeling can be performed from the systems to the component level – multiple scales
- Novel concepts for hydrogen storage and end-use can be evaluated in this context
- Models are based on physical theories and experimental data



Potential contributions and innovations

- Modelling frameworks for fuel handling using accurate fluid- and thermodynamics
  - Boil-off rates in tanks and transfer lines, use of waste heat/cold, dynamic responses, etc.
- Concept evaluation for different hydrogen carriers
  - Compressed hydrogen (CH2), Liquid hydrogen (LH2), Gelled liquid hydrogen, Ammonia (NH3) and Liquid organic H2 carriers
- Component and system evaluation/development for selected hydrogen carriers
  - Storage tanks, fuel transfer lines, compressors/pumps, engine supply systems
- Large capacity fuel cell concepts for alternative fuels
  - Recirculation systems modelling, cooling and heat integration systems
- Battery and fuel cell integration in heavy duty transport
  - Ageing prospects, hybrid systems and synergies with hydrogen power
- Norwegian industry is very well suited to supply fuel and concepts utilizing different hydrogen carriers, thus enabling large value creation.



Alignment with European R&D strategy

R& I: Horizon Europe & Clean Hydrogen for Europe

PILLAR H2 PRODUCTION	PILLAR H2 DISTRIBUTION	PILLAR H2 END USES
SO1: LOW CARBON H2 PRODUCTION 1. Electrolysis 2. Other modes of production	**O3: H2 STORED & DELIVERED AT LOW COST** 4. Large scale storage 5. H2 in the gas grid 6. Transport & storage in liquid carriers 7. Transport by road, ships, etc 8. Key techno for distribution	**SO5: TRANSPORT VEHICLES** Priorities 10. Technology building blocks 11. Truck and large vans (HD) 12. Maritime (Ships & Port) Other new applications 13. Aviation 14. Train 15. Coach
SO2: INTEGRATION OF RENEWABLES 3. Role of electrolysis	**SO4: REFUELING INFRASTRUCTURE** 9. HRS for multiple applications	**SO6: H2 FOR HEAT AND POWER (in building and industry)** 16. H2 Stationary FC 17. H2 Burners and turbines (also gas grid cf. distribution pillar)