Forskning for en bedre fremtid

ESRA Seminar | Gardermoen | 27. mars 2019

Hydrogen i transportsektoren

Øystein Ulleberg

Forskningsleder IFE | Senterleder MoZEES

Institutt for energiteknikk

Innhold

IFE

Omsetning:

1

MRD

Vitenskapelige publikasjoner årlig:

120

1948: IFA

1980: IFE

Antall ansatte:

600

Nasjonaliteter: 32

Forskere: 218

PhDs: 105

14.000

Besøkende årlig

Forskningssentre for miljøvennlig energi:

2

Avanserte laboratorier:

24

Internasjonale inntekter:

>30%

IFE | Hovedvirksomheter

Forskning og utvikling

- Digitale systemer
- Strømningsteknologi og miljøanalyse
- Material- og prosessteknologi

Nukleærteknologi

- Nukleærteknologi, fysikk og sikkerhet
- Atomavfall og dekommisjonering

Radiofarmasi

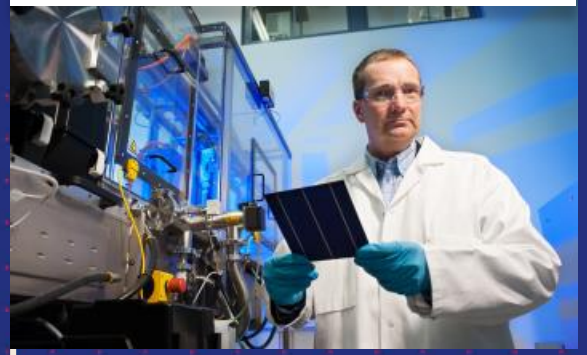
- Radiofarmasøytisk produksjon
- Radiofarmasøytisk grossist
- Radiofarmasøytisk FoU

IFE | FoU-områder

Digitale systemer

- Kontrollrom og interaksjonsdesign
- Virtuell og utvidet virkelighet
- Intelligente systemer
- Automatisering og brukerovervåkning
- Risiko, sikkerhet og sikring
- Menneskesentrert digitalisering

Material- og prosessteknologi



- Solenergi
- Batteriteknologi
- Fornybare energisystemer
- Nøytron materialkarakterisering
- Materialprosesser
- Miljøvennlige industriprosesser

Strømningsteknologi og miljøanalyse

- Strømningsteknikk
- Vindenergi
- Korrosjonsteknologi
- Sporstoffteknologi
- Miljøanalyse

IFE | Forskningsinfrastruktur & laboratorier

JEEP II Reactor

Solar PV Laboratory

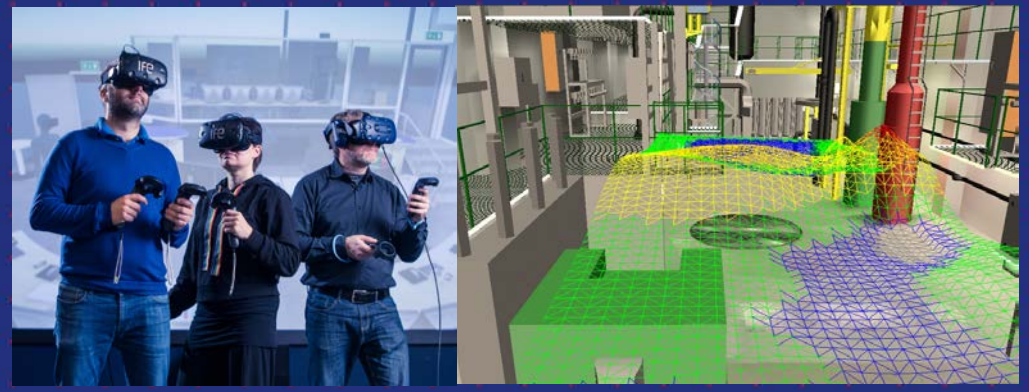
Fluid Flow Loop

HAMMLAB

Hydrogen Test Center

Isotope Laboratory

Virtual Reality Laboratory



IFE | Hydrogensystemer

- Satsningsområder
  - Brenselceller
  - Hybridisering med Li-ion batterier
  - Vannelektrolyse
- Metoder
  - Modellering og simuleringer
  - Testing i laboratorier: IFE Hynor
- Prosjekter
  - FME MoZEES
  - KPN H2Maritime
  - Norwegian FCH Centre
- Forskningsinfrastruktur

Hynor Hydrogen Technology Center

NORWEGIAN FUEL CELL AND HYDROGEN CENTRE
FUEL CELL & ELECTROLYSER SYSTEMS

MoZEES
Mobility Zero Emission Energy Systems

Hynor Hydrogen Technology Center

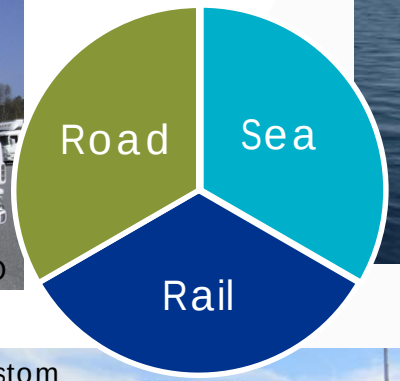
Innhold

MoZEES – A Research Center on Zero Emision Mobility

FME MoZEES – 1 of 8 National Centers

Heavy Duty Transport
– New Areas for Innovation & Value Creation

ASKO



Battery & Hydrogen – Technology Value Chains

Illustration: NFR

Materials → Components → Batteries & Fuel Cells → Modules → Systems

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Mobility Zero Emission Energy Systems

Research Partners

- Institute for Energy Technology
- NTNU – Norwegian University of Science and Technology
- SINTEF
- UiO : University of Oslo
- toi – Institute of Transport Economics, Norwegian Centre for Transport Research
- FFI – Forsvarets forskningsinstitutt, Norwegian Defence Research Establishment
- USN – University of South-Eastern Norway

Public Partners

- AKERSHUS County Council
- SØR-TRØNDELAG FYLKESKOMMUNE
- Statens vegvesen – Norwegian Public Roads Administration
- ENOVA
- Jernbane-direktoratet
- PORT OF OSLO
- KYSTVERKET

Private & Industrial Partners

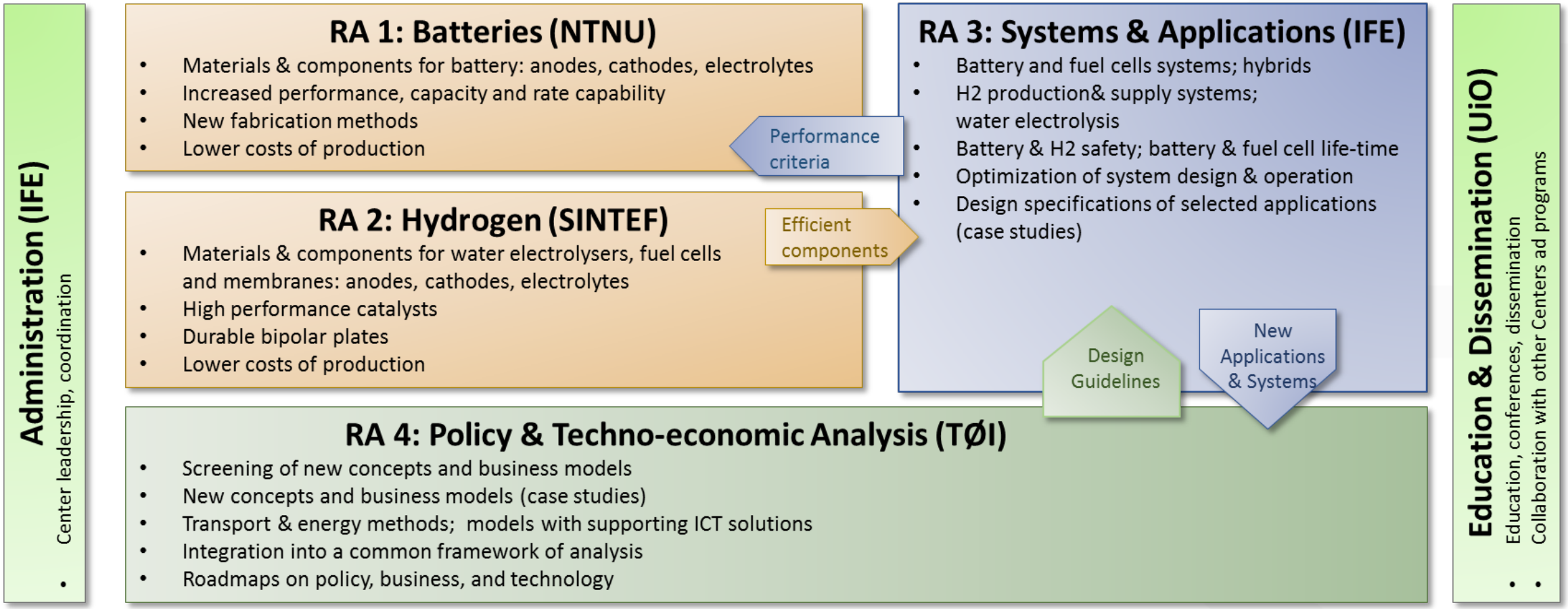
- ABB
- A Member of The Linde Group | AGA
- ASKO – vi forsyner Norge med mat
- BASF The Chemical Company
- baldur – BALDUR COATINGS AS
- BELLONA
- OREEC – KUNNSKAPSBYEN
- DYNATEC ENGINEERING
- HEXAGON COMPOSITES
- JM Johnson Matthey Fuel Cells – the power within
- CerPoTech – Ceramic Powder Technology
- MARITIM FORENING SOGN OG FJORDANE
- Elkem
- Innovation in Motion – Miba
- nel
- GrapheneBatteries
- ZEG Power
- ZEM Marine – Zero Emission Energy For the Marine Industry
- saft
- DNV·GL
- Selfa Arctic
- Lloyd's Register
- GRENLAND ENERGY
- UNIBUSS

260 MNOK (2017-2024)

38 partners

MOZEES – Mobility Zero Emission Energy Systems

MoZEES Research Areas



13 PhDs + 5 Post.docs. ++

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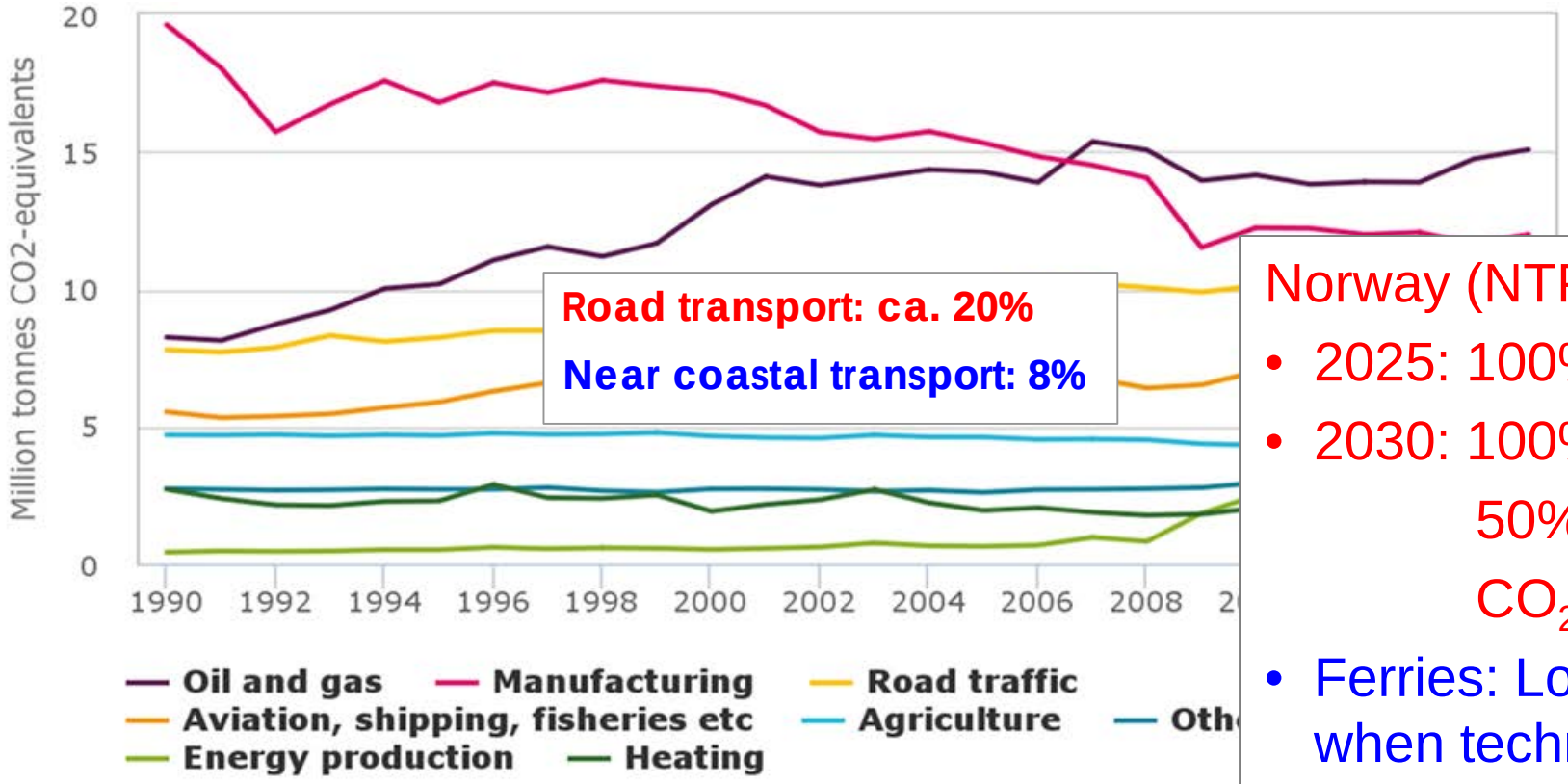
Innhold

GHG Emissions from Transport in Norway

- 54 millon tonnes of CO_2-equivalents per year → ca. **30% from Transport**



Norway (NTP 2018-2029):

- 2025: 100% ZE light duty vans
- 2030: 100% ZE heavy duty vans
  50% ZE trucks
  CO_2-neutral city distribution
- Ferries: Low and zero emission when technology is available

Source: SSB (2015)

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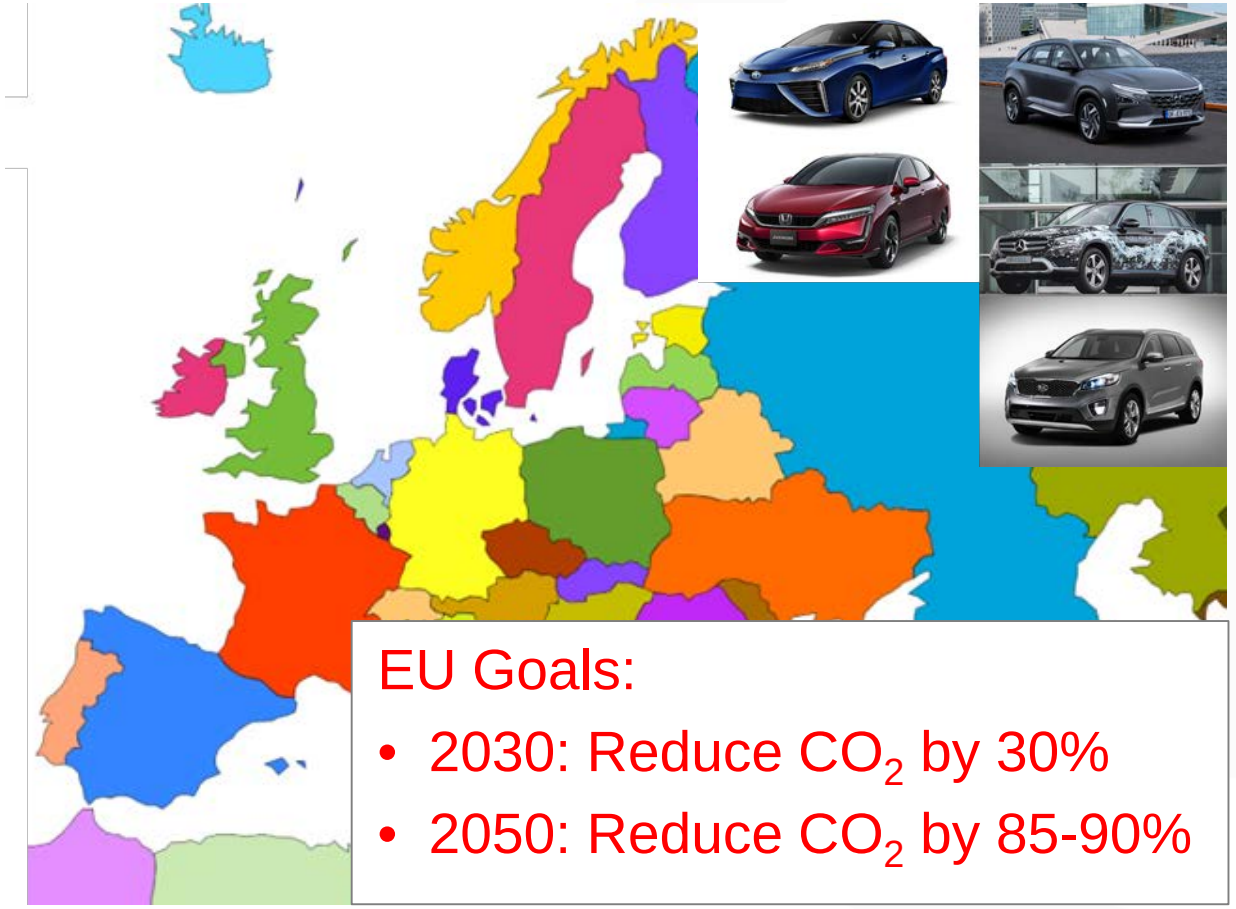
Reality Check

- **Example: Passenger cars in Europe**
  - EU-total today: 230 million
  - Replacement: 12 million/year (5%)
  - **2 500 000 FCEVs (1%)**
- **Fuel Cell Electric Vehicles**
  - H2-consumption: 120 kg_{H2}/year
  - 2 500 000 FCEVs
  - → **300 000 $tonnes_{H2}$/year**
    (H2-stations: ca. 1000 × 825 kg/day)
- **Renewable Energy Power Demand**
  - Water Electrolysis: 60 kWh/kg_{H2}
  - → **18 TWh/year**
    (WE-capacity: ca. 1000 × 2 MW_{WE} = **2 GW**)



FCEV Photos: Toyota, Honda, Hyundai, Mercedes-Benz, KIA

Trend i Norge: Hydrogen til Heavy Duty transport

- Busser

Ruter

- Ferger

Norled

- Lastebiler

Nikola

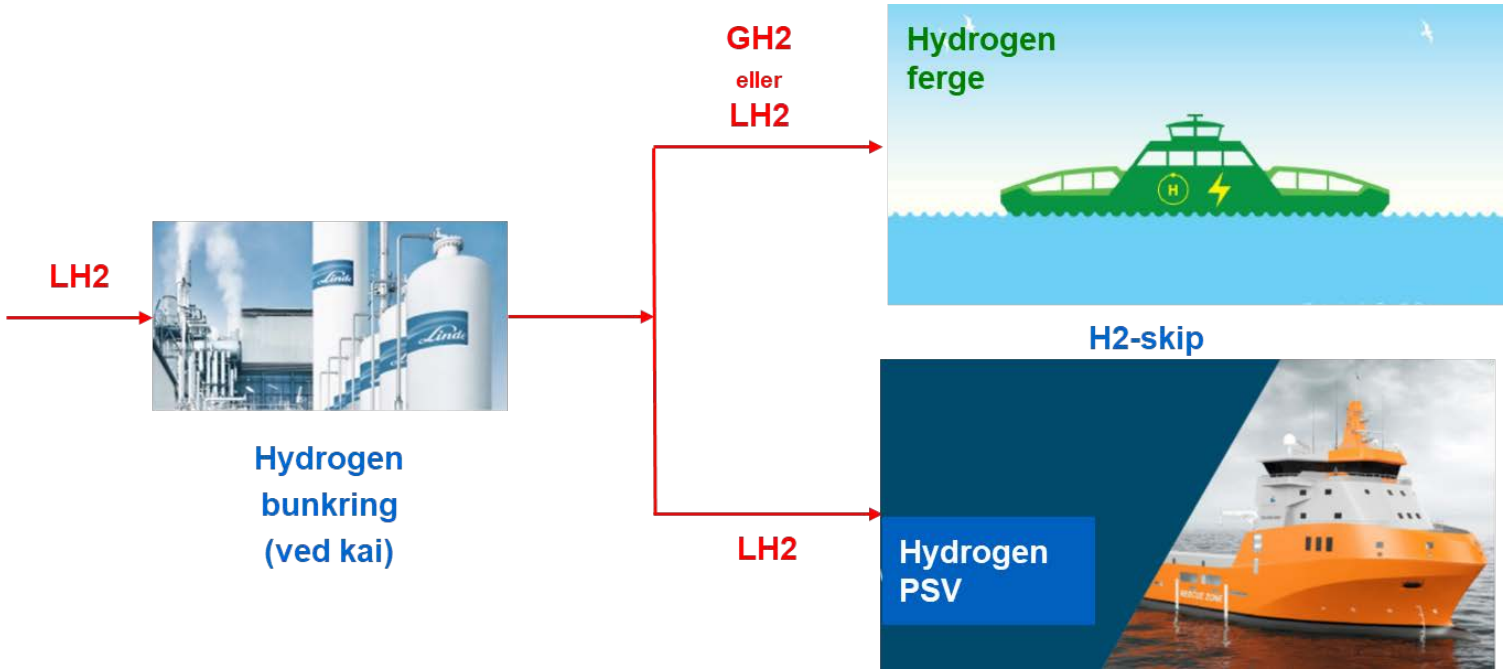
- Hurtigbåter

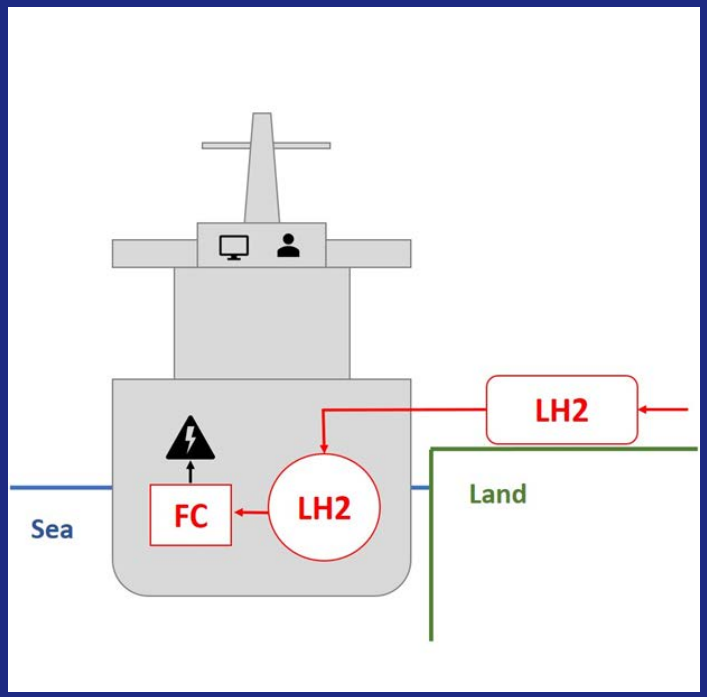
Selfa

Hydrogen til busser og biler

Photos: Ø. Ulleberg, IFE

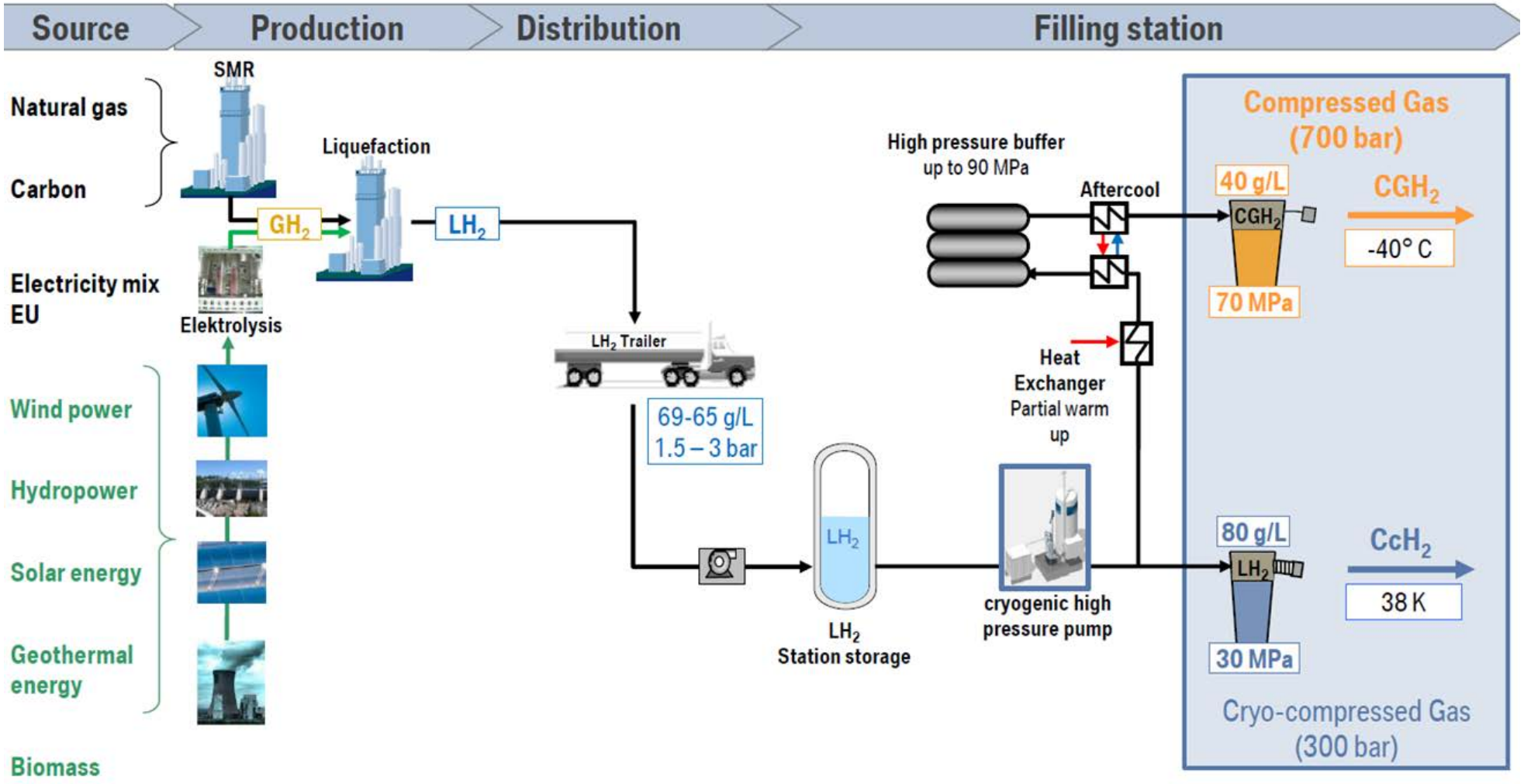
Hydrogen til ferger og skip





Bunkring av flytende hydrogen

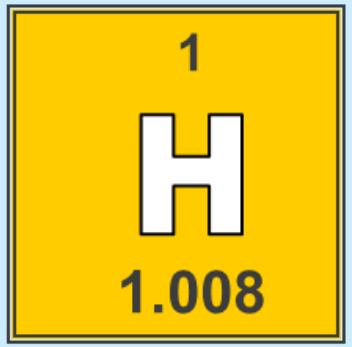
Hydrogeninfrastruktur



Kilde: LInde

Innhold

Hydrogen



1 m^3 = 90 gram

@STP

- Hydrogen er en gass ved standard atmosfære
- 1 elektron + 1 proton

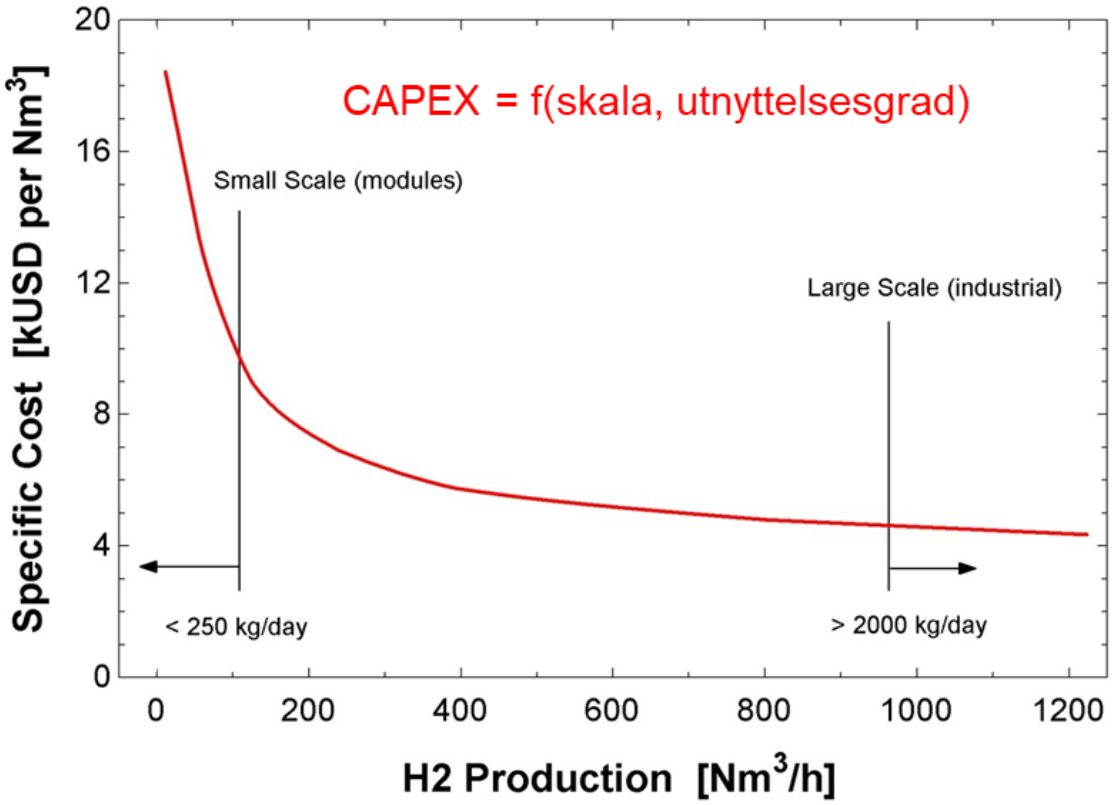
- Ikke-giftig (fargeløs, ingen lukt eller smak)
- Brennbar (usynlig flamme)

- Lav volumetrisk tetthet (lettere enn luft)
- Høy gravimetrisk tetthet (3 × bensin)
- Kokepunkt: -253˚C

- Reaksjon: $H_2 + ½\ O_2 = H_2O$

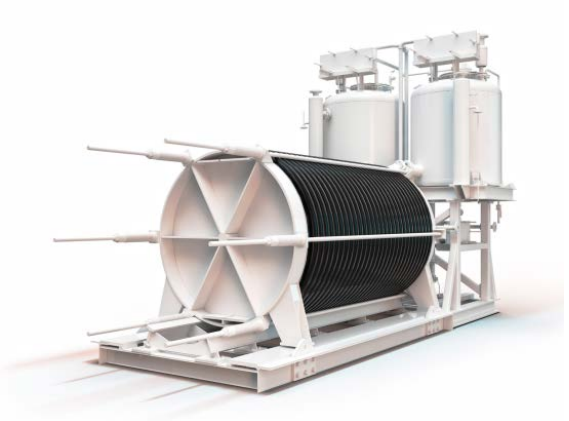
Hydrogenproduksjon fra vannelektrolyse

Hydrogenics



1000 kg/dag
8500 timer/år
0.30 NOK/kWh$_{el}$

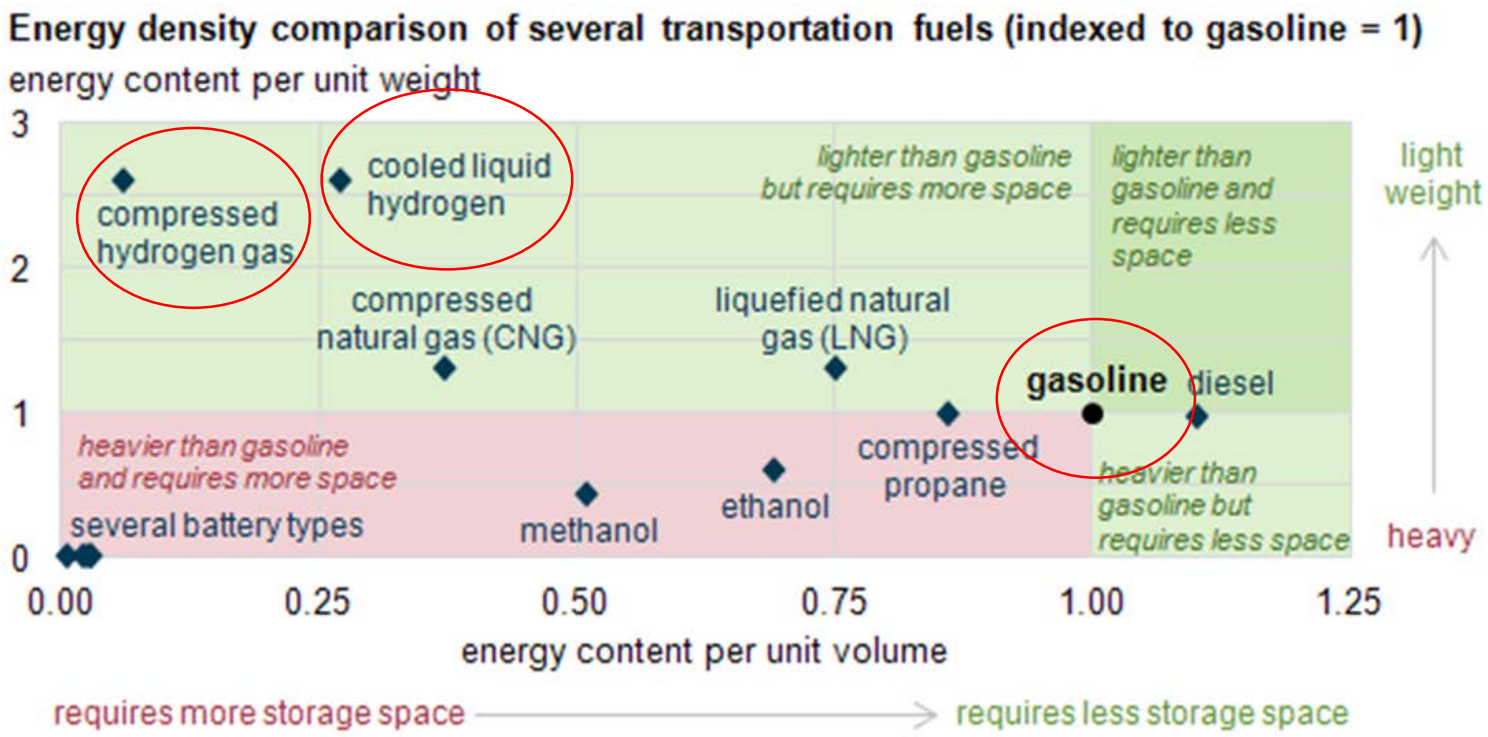
30 NOK kg H2



Nel Hydrogen

Kilde: IEA Hydrogen Technology Collaboration Programme

Hydrogenlagring – vekt og volum



Kilde: U.S. Department of Energy

Hydrogendistribusjon

Kilde: Linde

Kilde: Hexagon

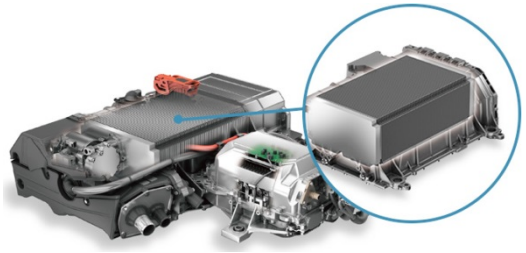
Kilde: IFE Hynor

Brenselceller – teknologi

Supplier	FC Stack (Model)	Power Capacity (kW)	Power Density (kW/kg)	Power Density (kW/L)	Comment
Ballard	HD7	150	0.37	0.23	FC module for HD transport
Hydrogenics	HyPM HD180	198	0.42	0.24	FC module for HD transport
Toyota	Mirai	114	2.0	3.1	FC stack for FCEVs

Hydrogenics

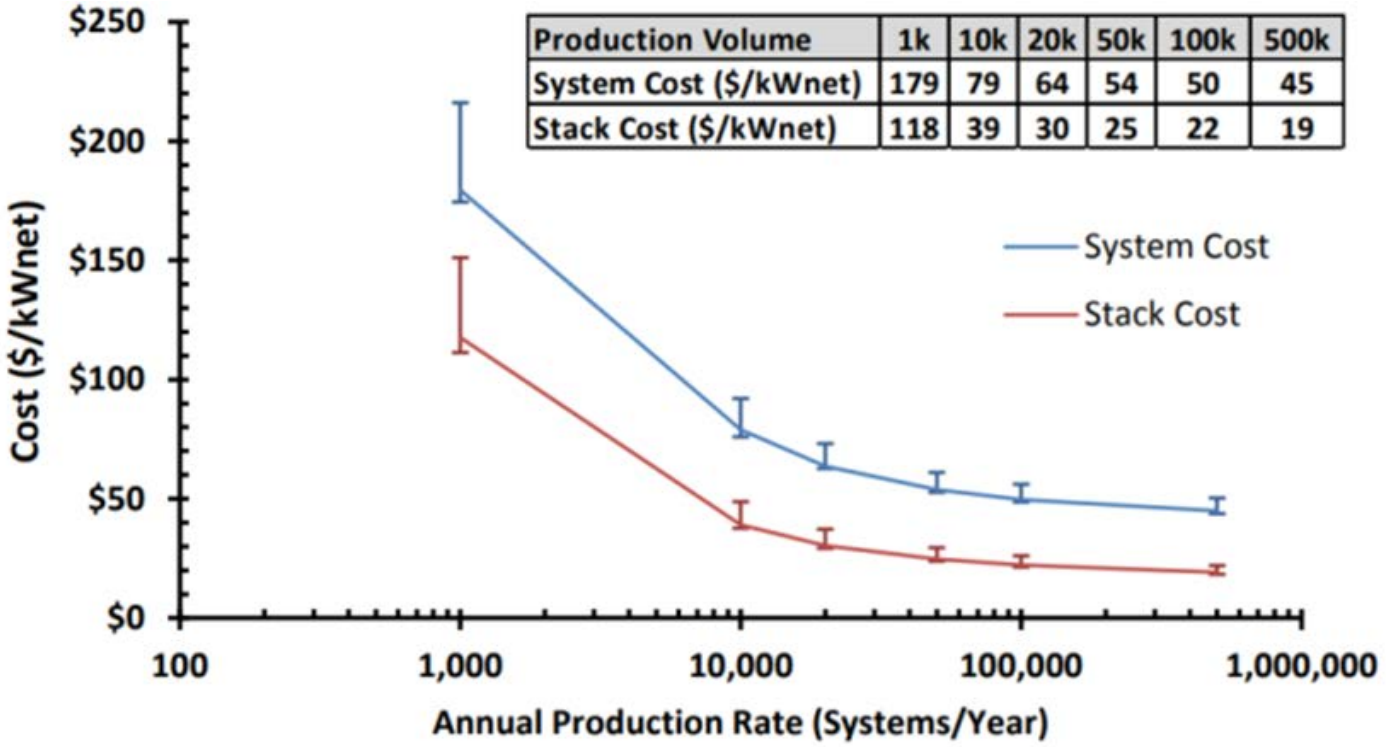
Ballard



Toyota

Brenselceller – kostnader

Cost of 80 kW Automotive Fuel Cell stacks as a function of number of units (1000 – 500,000)



Kilde: U.S. Department of Energy (2017)

Innhold

MoZEES Maritimt Case Studie (2017-2019)

- Hurtiggående passasjerbåt
  - Båt: Brødrene Aa
  - Rute: Florø-Måløy (Florø Skyssbåt)
  - Energi: ca. 6300 kWh/dag → 390 kg H_2/dag

- MoZEES-arbeid
  - Etablering og evaluering av lastprofiler
  - Evaluering av hydrogen og brenselcellesystemer
  - Sikkerhet- og risikoanalyser
  - Tekno-økonomiske beregninger

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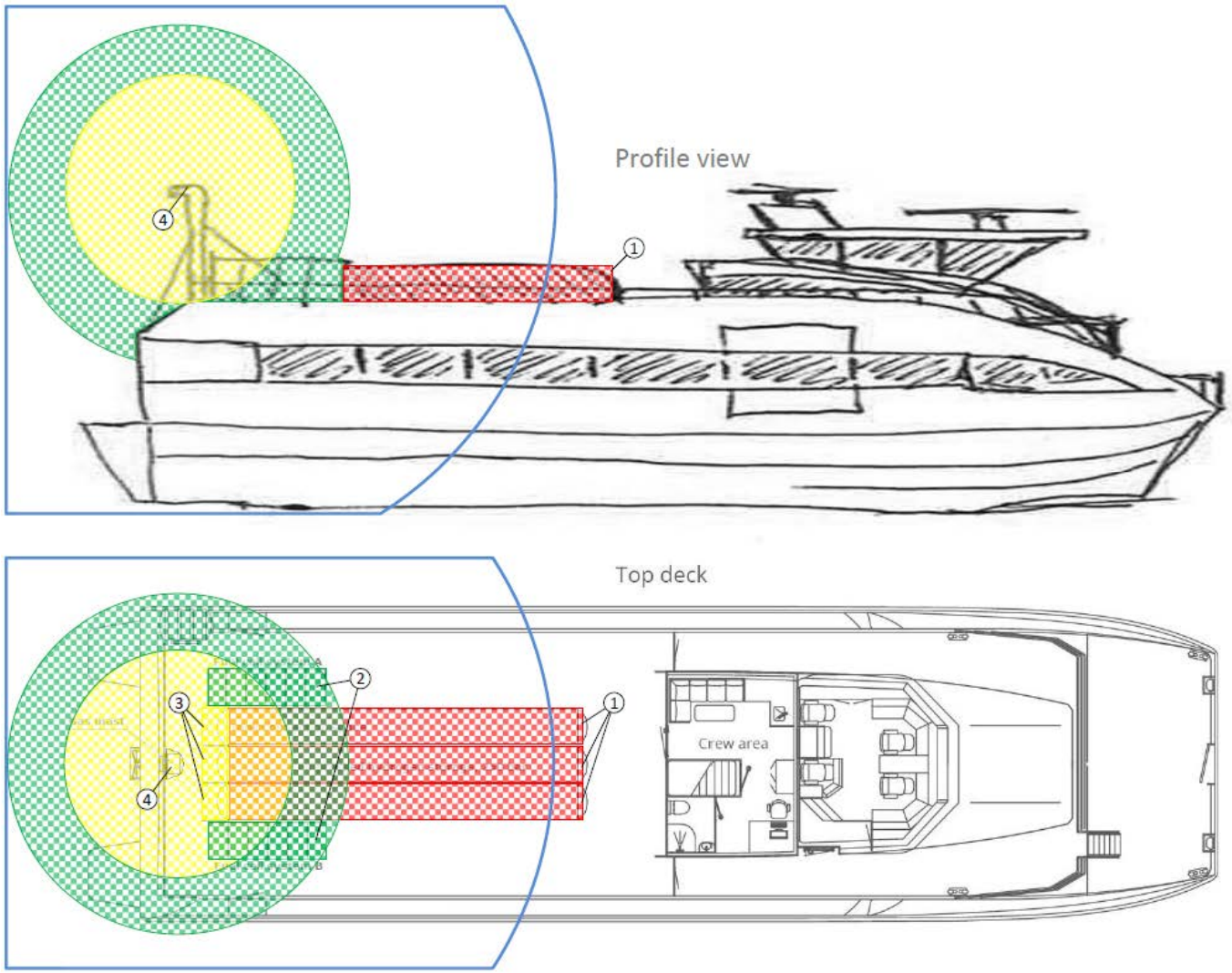
Identifisering av farlige områder & sikkerhetssoner



Pre-HAZID Worshop:

- Lloyd's Register
- DNV GL
- NEL Hydrogen
- Hexagon
- ZEM Energy
- Selfa Arctic
- Brødrene Aa
- IFE, SINTEF, USN

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Pre-HAZID & Risikovurdering av konsept

Lloyd's Register

Working together for a safer world

MoZEES
Mobility Zero Emission Energy Systems

Memo

Pre-HAZID October 31, 2017 - Maritime case study GKP7H2 MoZEES

To:	MoZEES RA3	Cc:	
From:	Lloyd's Register	Date:	14 November 2017 CONFIDENTIAL
Project no:	106575		

1 Introduction

A pre-HAZID for the hydrogen systems of the GKP7H2 high speed passenger ferry was held at Sintef Oslo on October 31. The purpose of the event was to identify any potential major hazards related to the hydrogen systems on-board that could represent a risk to life of people on the vessel or in the surroundings.

Following this workshop a concept risk analysis will be performed. Since the project is in a very early phase, and lots of design options are unclear, some Post-HAZID reflections and suggestions regarding design and dimensioning have been added at the end of this document. The purpose of this is to limit the different options to be evaluated in the risk assessment.

The draft document is distributed for comments among the participants (deadline for comments to be considered in the risk assessment is November 10), thereafter a final version is issued and the risk assessment work initiated.

Confidentiality:

Please note that any information provided as input to, or discussed, during the workshop, which is not yet in the public domain, is to be considered confidential information and shall not be shared outside the MoZEES RA3 consortium and workshop participants, all bound by the MoZEES confidentiality contract.

Lloyd's Register

Working together for a safer world

GKP7H2 high speed passenger ferry

Concept Risk Assessment

MoZEES
Mobility Zero Emission Energy Systems

Report for:
MoZEES project

MoZEES
Mobility Zero Emission Energy Systems

Sikkerhetskrav – antagelser i risikoanalyse

IGF Requirements – Safety must be equivalent to vessel with conventional fuel (diesel)

Challenge 1: What is equivalent safety level?

- 0.6 fatalities per 1 billion (1×10^9) passenger km 1970-1994 (TØI, 2001)
- 1.0 fatalities per 1 billion km for new technologies (NMA, 2002)
  - ➔ Less than 0.5-1.0 fatalities per 1 billion km from H2 systems should be OK
- Vessel may spend significant time in harbor
  - ➔ Evaluate safety level wrt. land planning regulations

Challenge 2: Many design details are unclear in early stage of development

- Need to make numerous assumptions
  - ➔ Assume best design practice wrt. ventilation of leaks, limit jet fires etc.

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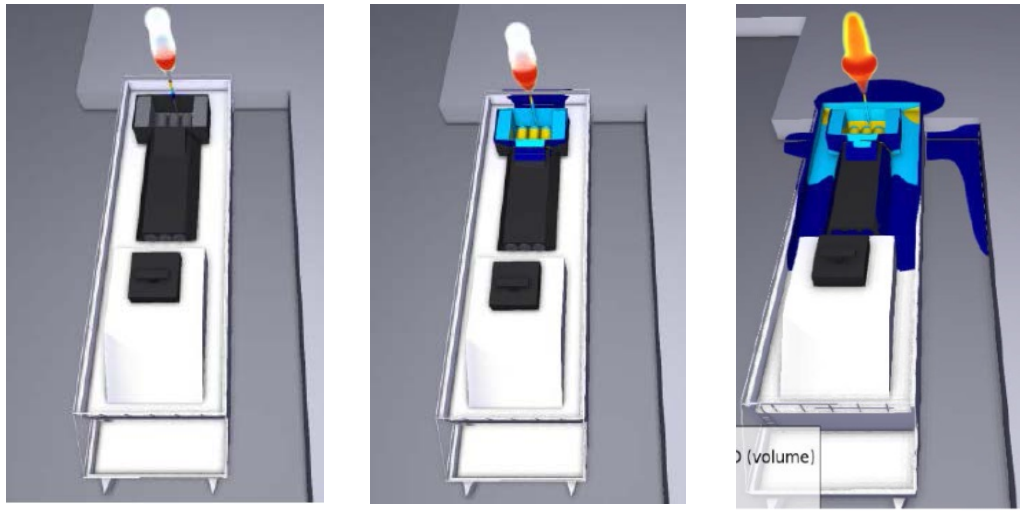
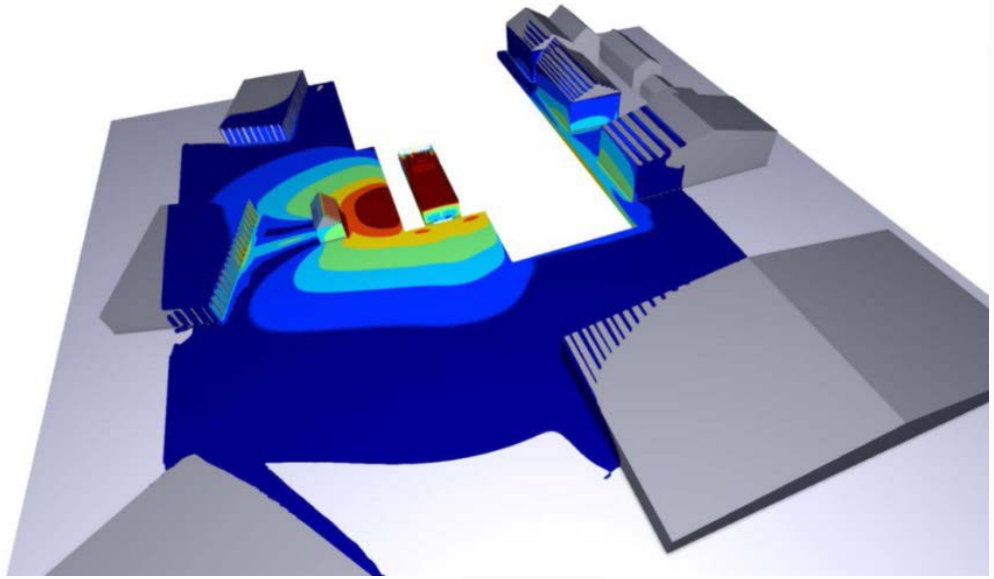
Risikovurderinger – eksempler på mulige hendelser

Antenning av H2 i ventilasjonspipe



Brudd i H2-lagertank ved kai (*worst case*)



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Risikovurderinger – konklusjon

Hydrogen systems	**Hazards**
Storage tanks	Vessel burst
HP piping/equipment (250 bar)	Leak, jet fire, explosion
LP piping/equipment (10 bar)	Leak, jet fire, explosion
Fuel cells	Leak and explosion
Emergency vent	Radiation/explosion

Konklusjon

Risiko med hydrogen og brenselceller er på samme nivå som konvensjonelle systemer basert på karbonbaserte drivmidler (diesel)

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Mobility Zero Emission Energy Systems

Innhold

Oppsummering

- Hydrogen i transport
  - Biler – Busser – Lastebiler – Hurtigbåter – Ferger
  - Brenselcelleteknologi er moden, men kostnader må ned
- Hydrogenproduksjon
  - Fornybar hydrogen fra vannelektrolyse er standard
  - Storskala LH2-produksjon er mer krevende, både økonomisk og teknisk
- Hydrogenlagring
  - Trykksatt hydrogen (350-700 bar) til kjøretøyer er standard
  - Bunkring og lagring av flytende hydrogen (LH2) er mer utfordrende, både økonomisk og teknisk
- Sikkerhet og risiko
  - Standarder for hydrogenstasjoner og kjøretøyer er etablert
  - Flytende hydrogen (LH2) til maritimt krever utvikling av nye standarder

Utsira, 2005

Spørsmål?

Takk for meg!

Øystein Ulleberg
Forskningsleder IFE

oystein.ulleberg@ife.no