FCH Systems activities at IFE
Case study: LH_2 for supply ship

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NCE Maritime CleanTech seminar
Tech update: Hydrogen and Fuel Cells
22 February 2017, Haugesund

Institute for Energy Technology

- Independent foundation est.1948
- R&D on Energy Technologies
- Laboratory intensive activities
- 650 employees (Kjeller & Halden)
- Turnover: 1000 MNOK
- Contract Research
- Internationally oriented

JEEP II reactor, Kjeller

IFE's focus on Hydrogen . . .

1950s

Metal Hydride
Materials

Acta Cryst. (1955)

1995

RE/H_2- Systems
Water Electrolysis
H_2-Storage

Utsira

2000

H_2-Production
Reforming
CO_2-Capture

ZEG

2005

FCH Systems
UPS & Mobility
PEM Fuel Cells

REHYS H2 THINK

2010

H_2-Supply
for Transport
H_2-stations

Hynor

2015

Transport
Applications
FCH Systems

MoZEES

MoZEES

Mobility Zero Emission Energy Systems

CENTRE FOR ENVIRONMENT-FRIENDLY ENERGY RESEARCH

Motivation

- Unite **battery** and **hydrogen technology** perspectives with the actual **needs of the transport sector**

- Assist in the design of **safe**, **reliable**, and **cost competitive** zero-emission transport solutions for the future

MoZEES

Mobility Zero Emission Energy Systems

CENTRE FOR ENVIRONMENT-FRIENDLY ENERGY RESEARCH

Research Partners

- 4 Research institutes: IFE (host), SINTEF, TØI, FFI
- 3 Universities: UiO, NTNU, HSN

User Partners

- 28 Commercial & Industrial partners: Battery and hydrogen materials, components, and system suppliers, developers, and users
- 7 Public Organizations: Norwegian Road, rail, and coastal authorities, Akershus and Sør-Trøndelag county councils, Oslo Port authority, Enova

Project

- Period: 2017-2024
- Budget: **260 MNOK**

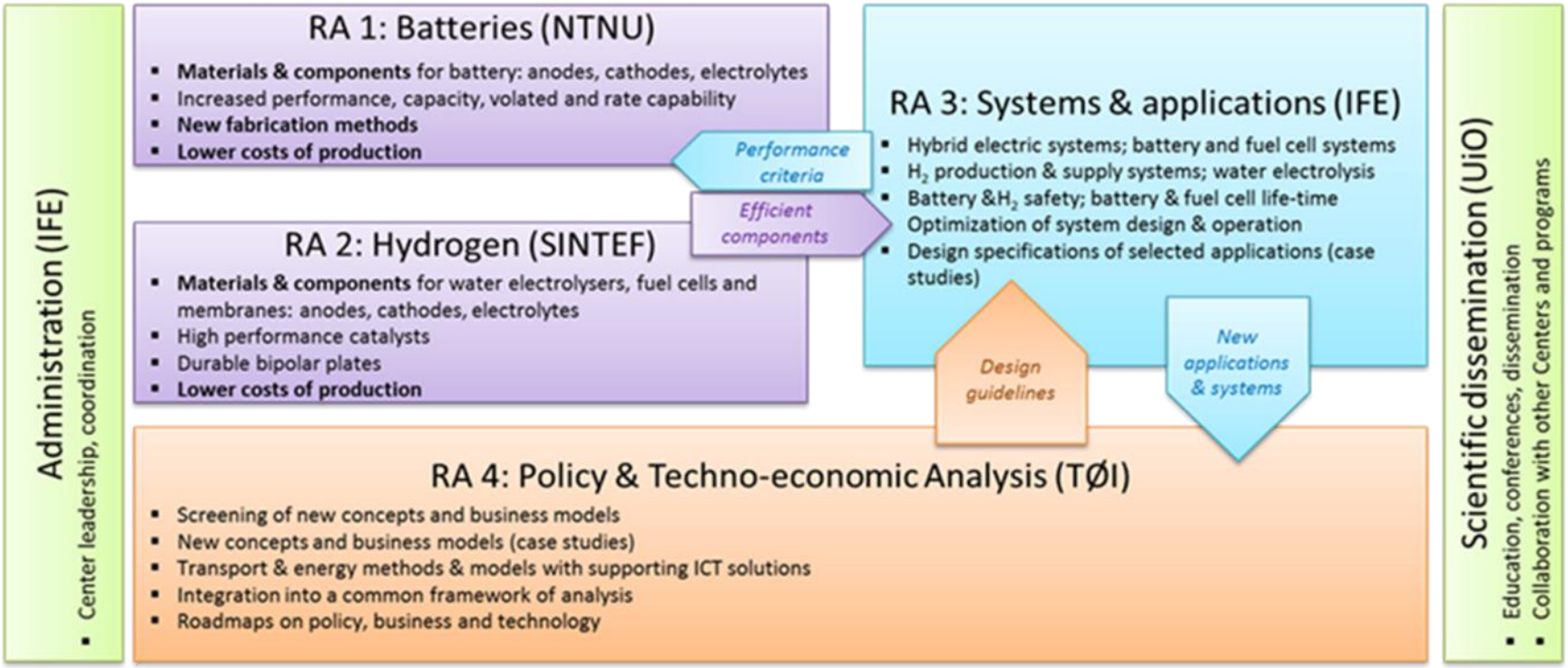
13 PhDs & 5 Post.Docs.

MoZEES

Mobility Zero Emission Energy Systems

CENTRE FOR ENVIRONMENT-FRIENDLY ENERGY RESEARCH

Research Areas



NORWEGIAN FUEL CELL AND HYDROGEN CENTRE

Open Access Infrastructure Fuel Cells and Electrolysers

www.nfch.no

NTNU SINTEF IFE

Background

The Research Council of Norway

Part of national infra-roadmap in 2015

Funding for establishment phase received 2016

Establishment phase 2016-2018

Operating phase 2017-2026

Centre structure

LT fuel cell & electrolyser lab (SINTEF, NTNU):
Evaluation of components for low temperature fuel cells and electrolysers (PEM, alkaline) and performance and lifetime evaluation of cells and stacks. (Single cell and short stack test stations)

Fuel cell and electrolyser system integration lab (IFE):
Infrastructure for evaluation and validation of system performance

HT fuel cell & electrolyser lab (SINTEF):
Infrastructure for evaluation of components for high temperature fuel cells and electrolysers (SOFC/SOEC, PCFC/PCEC) and performance and lifetime evaluation of cells and stacks.

IFE NTNU SINTEF

IFE Hynor Hydrogen Technology Center

(formerly Hynor Lillestrøm)

- **IFE Hynor infrastructure (2010 – 2015)**
  - Biogas supply system: 15 Nm^3/h (CH_4)
  - Hydrogen supply system: 10 Nm^3/h
  - H_2-storage (40 kg) & H_2-compressors (1-700 bar)
  - Process air supply & water cooling systems (80 kW_{th})
  - SOFC power conditioning system: 20 kW_{el}
  - Grid-connected PV/UPS 350 VDC mini-grid: 20 kW_{el}

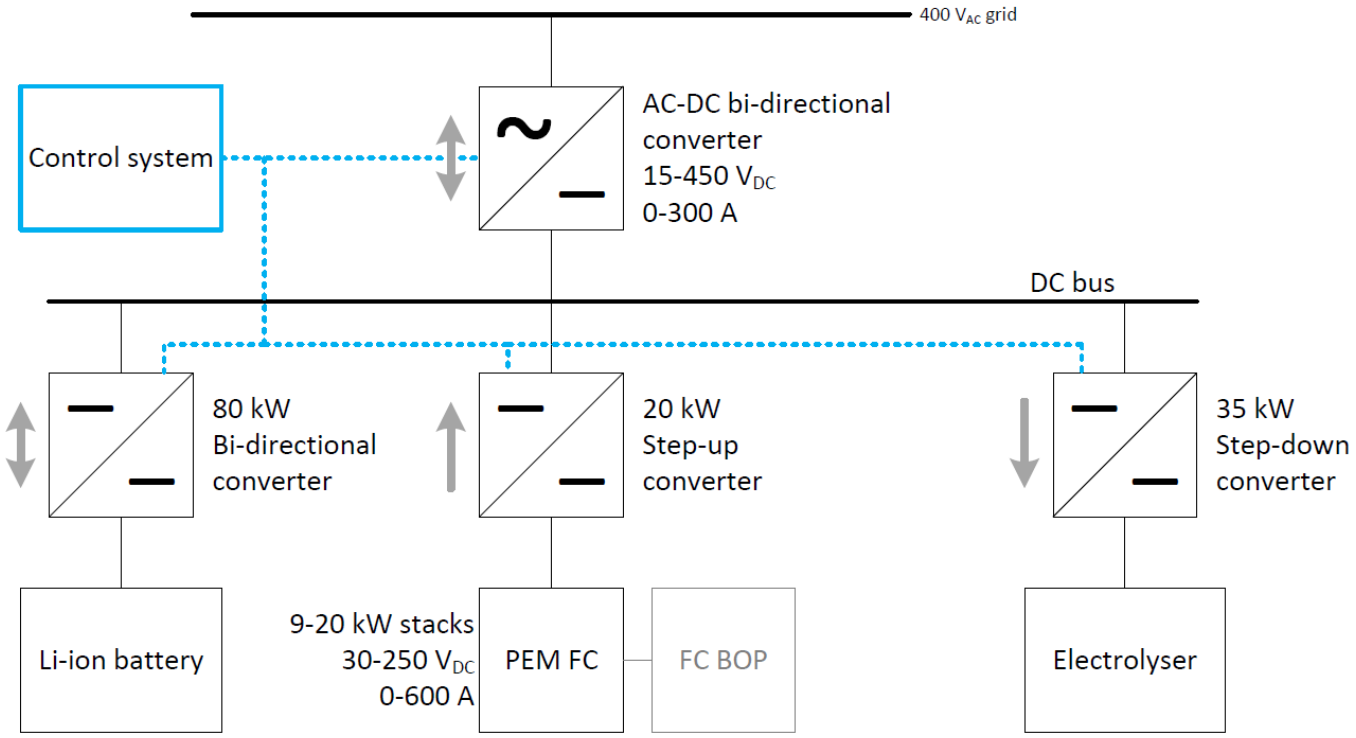
- **New infrastructure (2016 –)**
  - **Norwegian Fuel Cell and Hydrogen Centre - Systems Laboratory**

N-FCH Centre – Systems Laboratory

1. Hybrid Fuel Cell, Electrolyser and Battery system
   a. 20 kW PEM FC
   b. 30 kW High pressure PEM Electrolyser
   c. 100 kW Battery

2. Gas supply and monitoring system
   a. Gas mixing cabinet (to emulate reformate gas mixtures for HRS and FC)
   b. Mass spectrometry
   c. Gas chromatography

Electrical System – Hybridization with Batteries



N-FCH Centre – Systems Laboratory

- **MoZEES Research topics:**
  - **Advanced fuel cell control systems**
  - **Battery performance and lifetime testing and modeling**
  - **Combine battery and fuel cell degradation models to enable optimization of system design**

Hydrogen for Transport

Research & Development → Demonstration & Innovation

Fuel Cell Cars (Hynor)

Mobile Applications

Hydrogen & Fuel Cells

Maritime Applications

Fuel Cell Buses (Ruter)

Passenger Ferries (Rødne)

Supply Ship (Eidesvik)

H2-ship Feasibility Study (2014)

Hydrogen as Fuel for Ships – From Renewable Energy to Zero Emission Propulsion

- Project Partners:
  - Ship design: NCE Maritime CleanTech
    Wave Propulsion AS
    Hordaland Maritime Miljøselskap AS
  - Ship building: Brødrene Aa
  - Ship operation: L. Rødne og sønner AS
    Eidesvik Offshore ASA
  - Ship power systems: Westcon Power and Automation AS
    Wärtsilä Norway AS
  - Energy supply: SKL Produksjon AS
  - Fuel Cell systems: CMR Prototech
  - Hydrogen systems: Institute for Energy Technology
- Funding: Partners & Transnova (now Enova)

H2-ship Feasibility Study (2014)
Scope of Work

- Regulatory issues for use of Hydrogen & Fuel Cells in ships
- Preliminary Design & Costing of a Hydrogen Fuel Cell Passenger Ferry

  → **Demonstration Project (short-term perspective)**
- Case Study: H_2-production & supply to a Fuel Cell Ship

  → **Business Case for a supply ship (long-term perspective)**

H2-Production & Supply to a Fuel Cell Ship

Case Study: Water Electrolysis + Liquefaction

Hydro Electric Power

EL

Regional Grid

EL

Water Electrolysis

H_2

GH_2

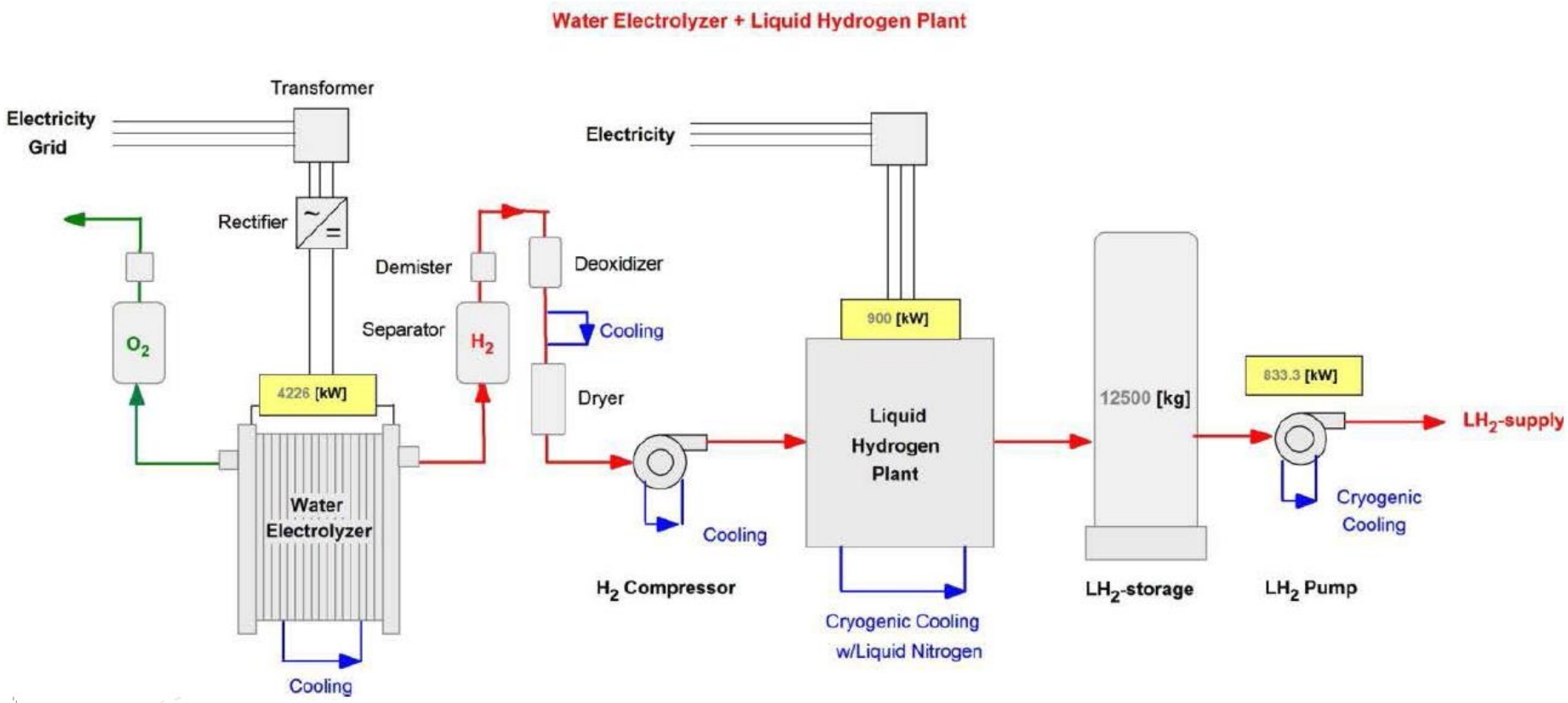
Hydrogen Liquefaction

LH_2

Fuel Cell Ship (10 MW_{el})

Techno-Economic H2 Production Simulator

Data based on Standard Industrial H2 Technology



H2-infrastructure for FC Supply Ship
Design & Assumptions

- **Overall System Design**
  - Average daily H_2-consumption: **1800 kg/day**
  - Alkaline Water Electrolyzer: 850 Nm^3/h 4.2 MW
  - LH_2-production: 850 Nm^3/h 0.9 MW
  - LH_2-storage: 12 500 kg
  - LH_2-pump: 175 000 liter/h 0.8 MW

- **Main Assumptions**
  - Power demand water electrolysis: 4.9 kWh/Nm^3
  - Power demand overall LH_2-plant: 1.1 kWh/Nm^3

  - Electricity costs: **0.5 NOK/kWh (8 JPY/kWh)**
  - O&M costs: 4% of Annual CAPEX
  - Life time & interest rate: n = 20 years, i = 5%

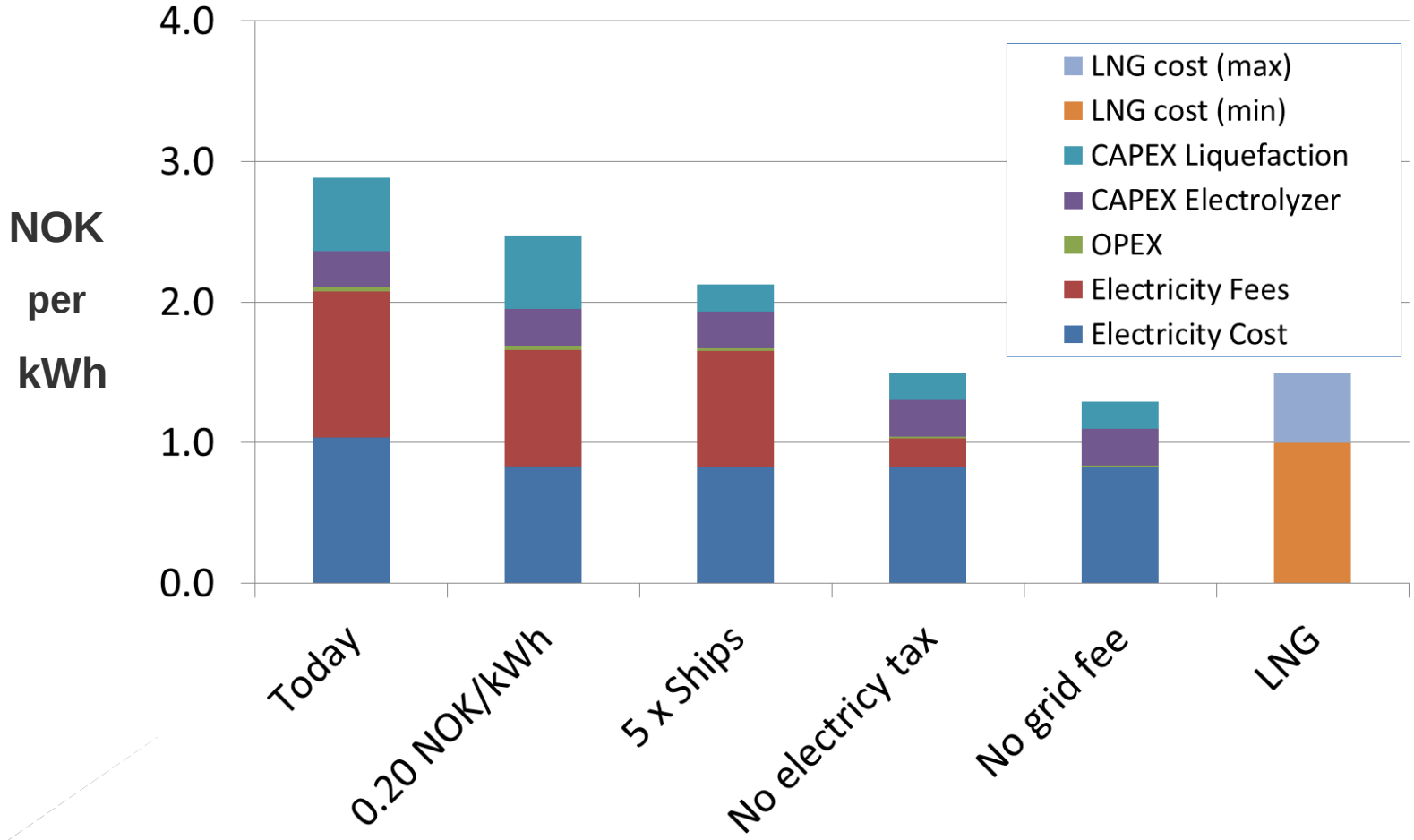
H2-infrastructure for FC Supply Ship

Main Results

• **Capital Costs (CAPEX):**	**112 MNOK**	
• Water Electrolyzer:	36 MNOK	32%
• LH_2-production:	51 MNOK	46%
• LH_2-storage:	14 MNOK	13%
• LH_2-pump:	10 MNOK	9%
• **Annual Costs:**	**32 MNOK/year**	
• CAPEX:	9 MNOK/year	28%
• OPEX (mainly electricity):	23 MNOK/year	72%
• **Hydrogen Cost:**	**50 NOK/kg**	

Business Case for a FC Supply Ship?

LH_2-production costs normalized wrt. FC power on ship



Thank you for your attention!

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*Prosjektleder