



SINTEF

"SINTEF's hydrogen activities at a glance - initiatives, engagements & projects"

*Dutch visit to NTNU/SINTEF,
Trondheim 24th June, 2022*

Steffen Møller-Holst
Vice President Marketing



Chairman Transport Committee



Norsk
Hydrogenforum

Chairman of
the Board





SINTEF

An independent, not-for-profit research institute

Technology for a better society



SINTEF

SINTEF in short

SALES



NOK 3.4

billion

EMPLOYEES



2000

PROJECTS



6800

CLIENTS



3400

INTERNATIONAL

NOK 470 million

PUBLICATIONS

5100

NATIONALITIES

75

CLIENT SATISFACTION

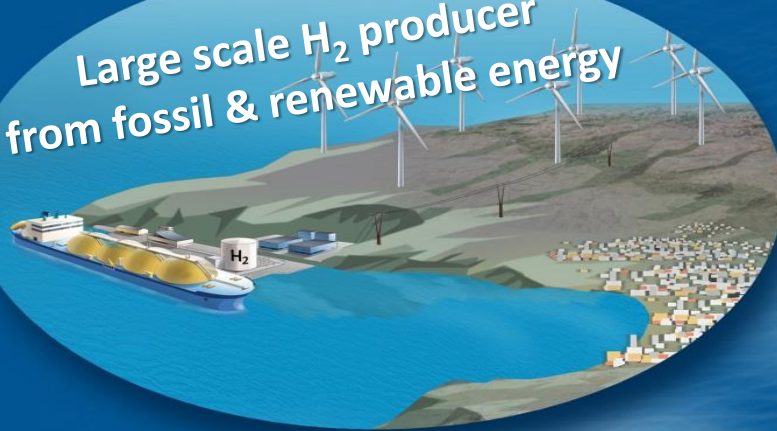
4.6 out of 5



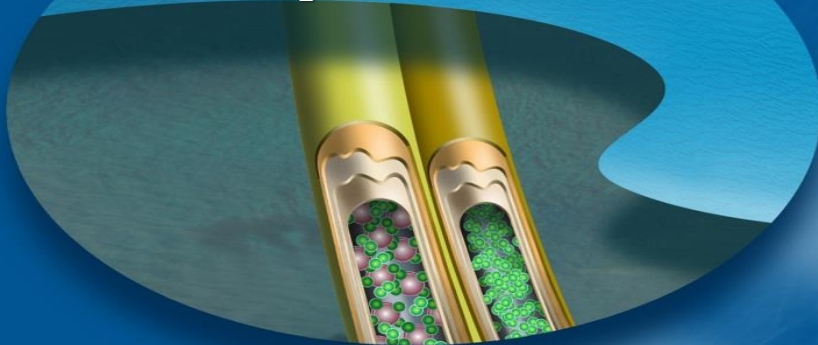
Green, digital initiatives for interdisciplinary boost and good innovation conditions

Areas where Norway can play a key role internationally within hydrogen

Large scale H₂ producer
from fossil & renewable energy



Exporter of H₂
& H₂-technologies




Early user of hydrogen
in transport & industry

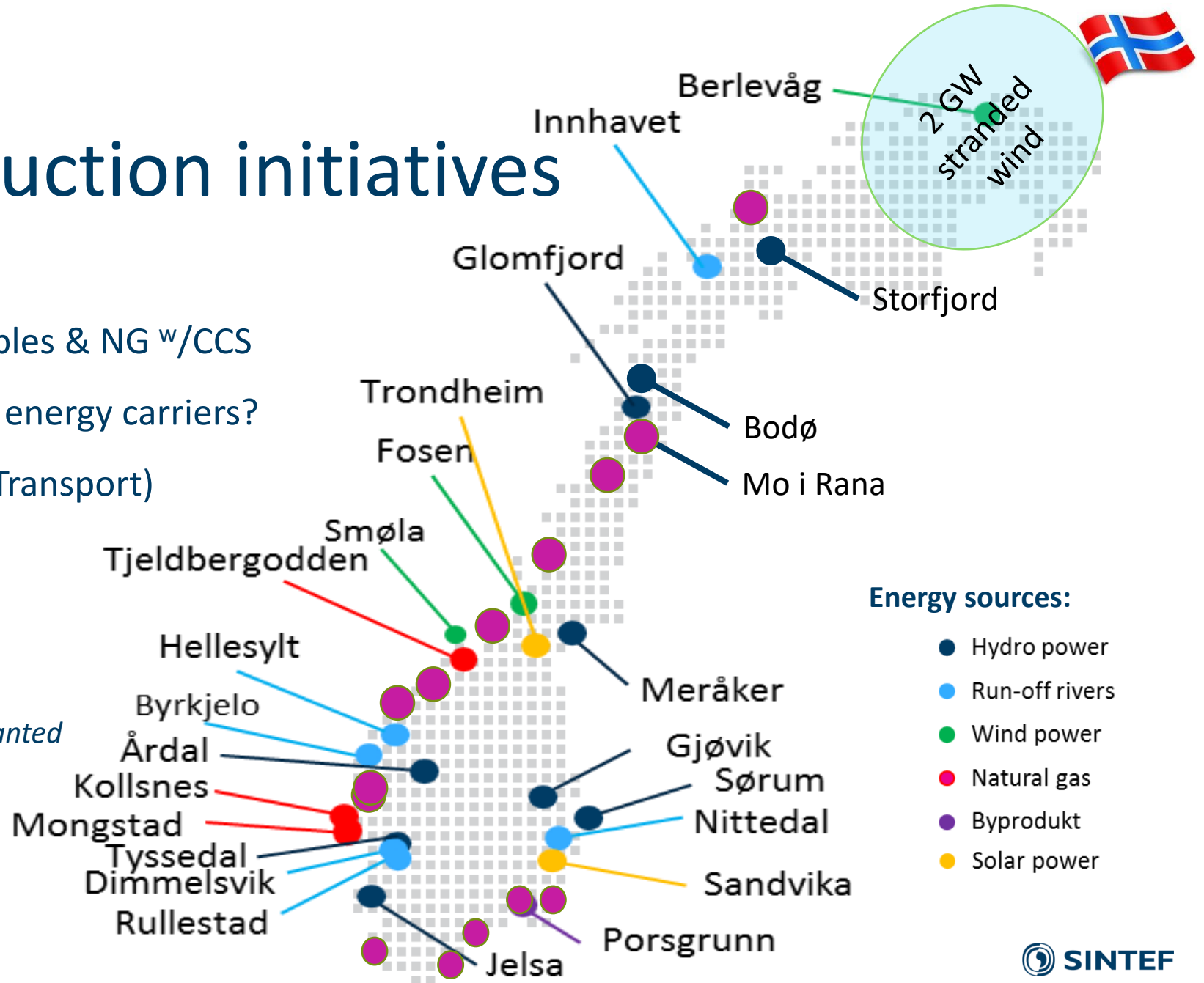


H₂ & NH₃ production initiatives

- H₂ & NH₃ prod. from renewables & NG w/CCS
- Energy export of H₂ & NH₃ as energy carriers?
- H₂ & NH₃ as fuels (Maritime Transport)

- Hydrogen Hubs 
 - 15 pre-studies financed Q3 2021
 - Five (5) full scale projects were granted ~ 15 M € each in public support yesterday (June 23rd)

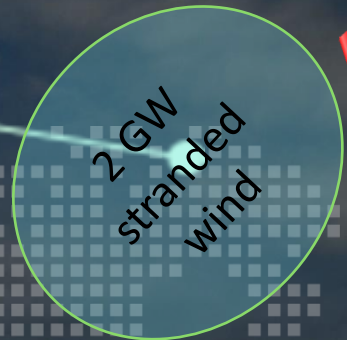
ENOVA



One of SINTEF's 30 EU-projects under the FCH JU-program



Berlevåg

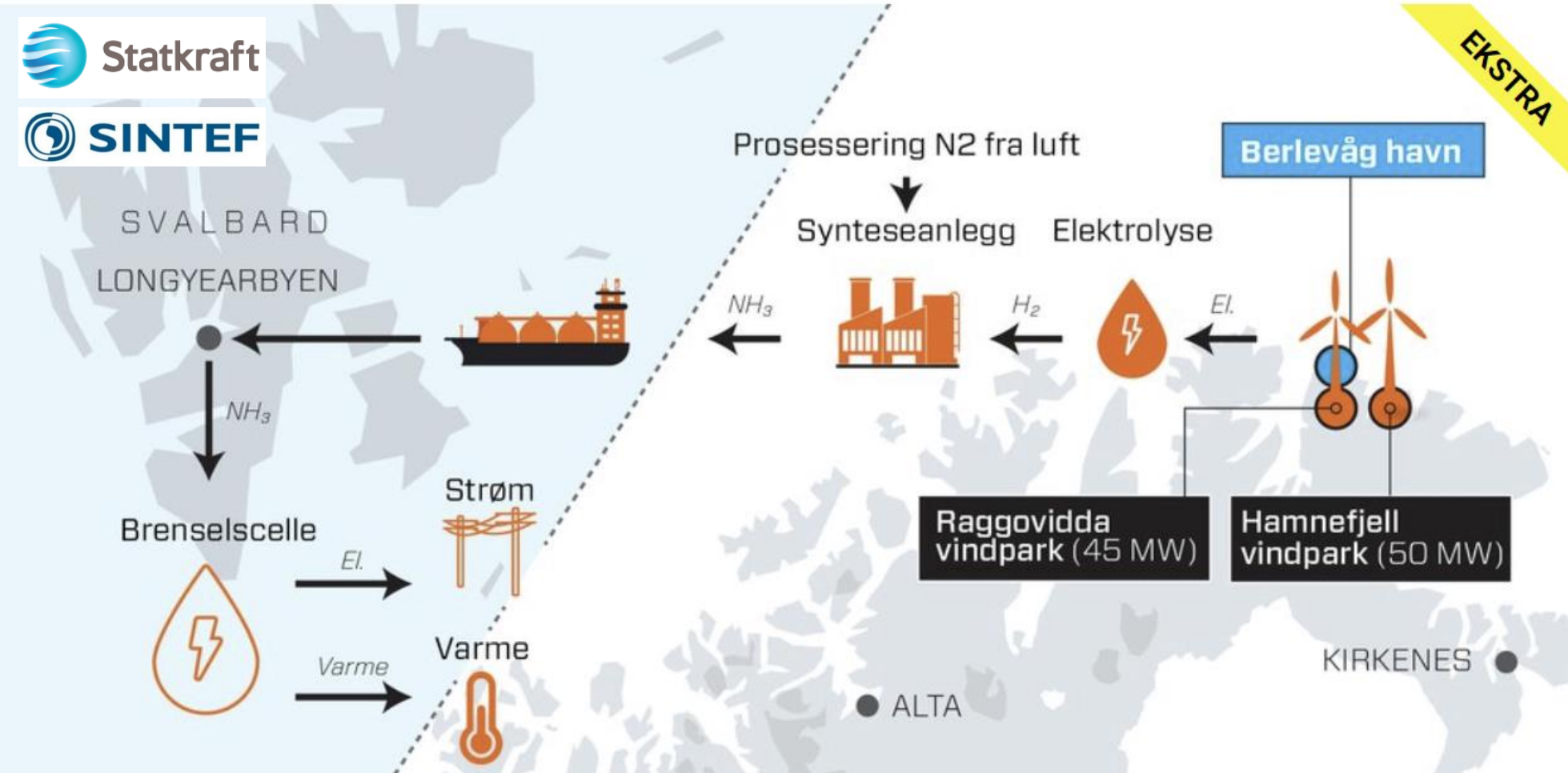


Stranded wind → 1 ton H₂/day

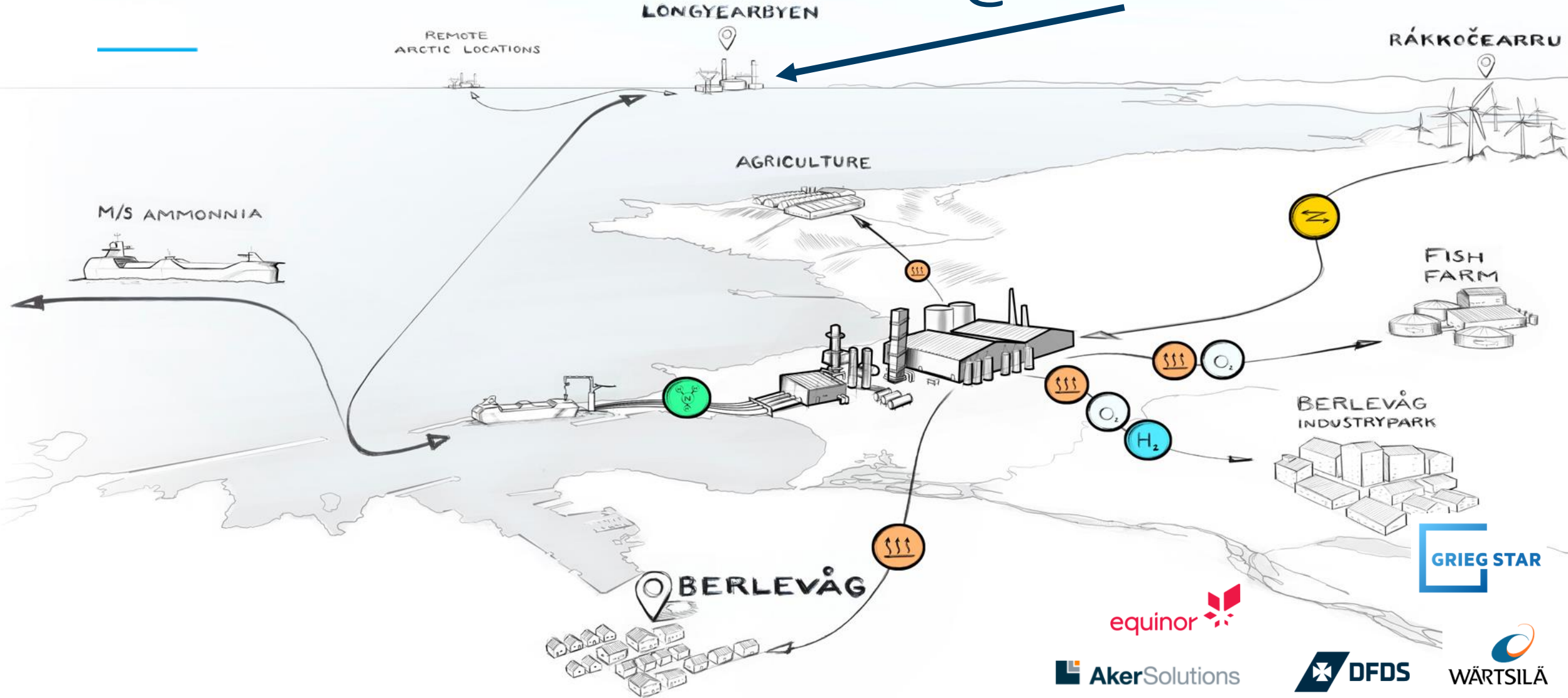
- Electrolyser (2,5 MW) installed in Berlevåg in 2021
- Directly connected to Raggovidda wind park (avoiding grid tariff)
- Electrolyser exhibit fast response
 - Stabilize grid voltage and frequency
- EU (FCHJU) -project:
 - Total budget 7 M€ (70 % public support),
 - Start January 2018, duration 6 years



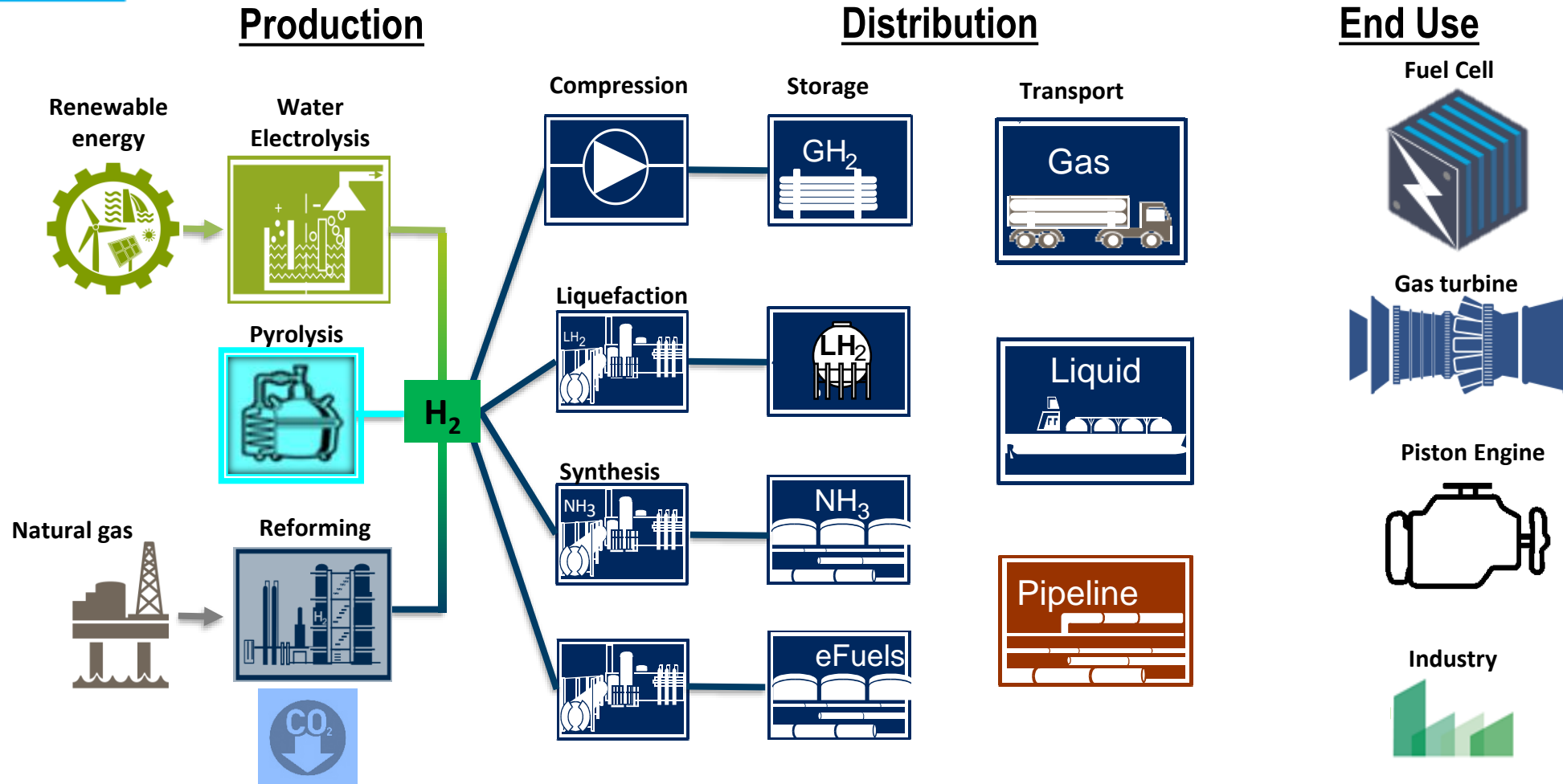
Stranded wind → 0-emission @ Svalbard?



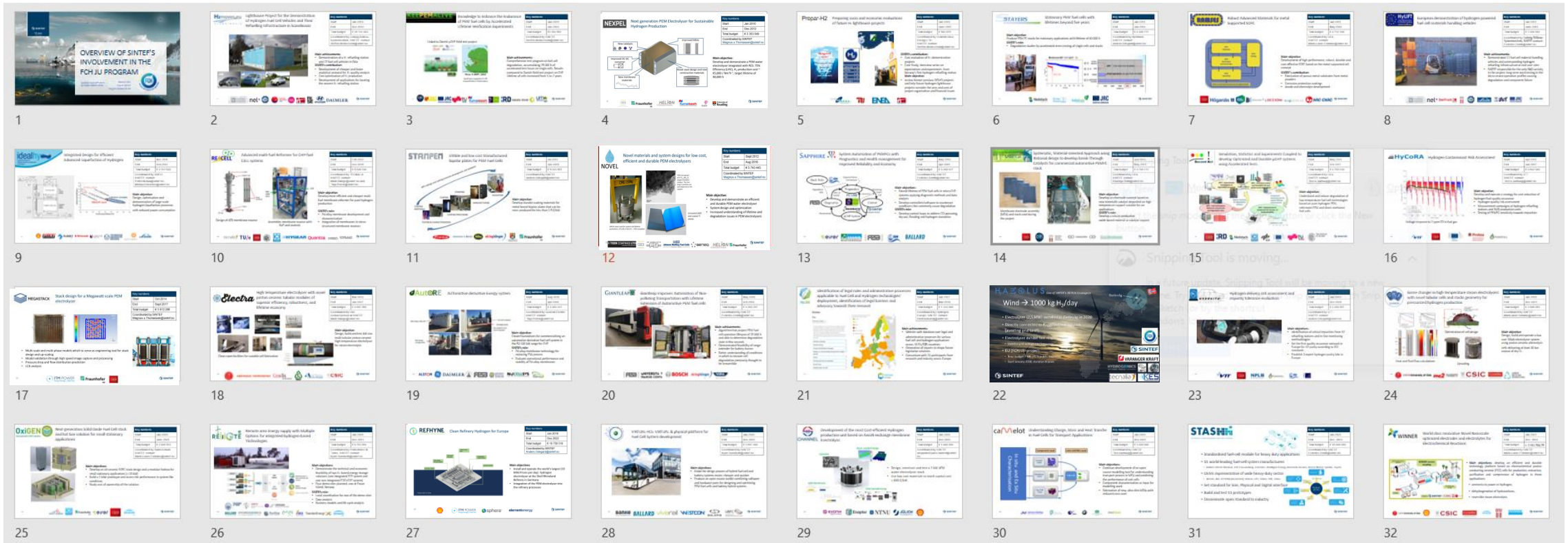
Stranded wind → 0-emission @ Svalbard?



Hydrogen as energy carrier, value chains



SINTEF's EU-project portfolio (2010-2021)



The grid displays 32 project overview cards, each with a number in the bottom-left corner. The projects include:

- 1: OVERVIEW OF SINTEF'S INVOLVEMENT IN THE FCH JU PROGRAM**
- 2: Hydrogen Project for the demonstration of hydrogen fuel cell vehicles and their refueling infrastructure in Scandinavia**
- 3: Knowledge to reduce the incidence of fuel cell leaks in commercial (off-road) industrial applications**
- 4: Next generation PEM electrolyser for Sustainable Hydrogen Production**
- 5: Prepar-H2: Preparing safe and economic realisation of future hydrogen projects**
- 6: STAYERS: Sustainable PEM fuel cells with inherent liquid electrolyte**
- 7: H2SAFE: Robust Advanced Network for world supported H2FC**
- 8: HYPER: European demonstration of hydrogen powered fuel cell maritime handling vehicles**
- 9: Ideal: Integrated design for efficient industrial application of hydrogen**
- 10: RECELL: Advanced multi-fuel reformer for PEM fuel cell**
- 11: STRIPPER: Simple and low cost manufacturing routes for PEM fuel cells**
- 12: NOVEL: Novel materials and system designs for low cost, efficient and durable PEM electrolyzers**
- 13: SAPPHIRE: System realisation of PEMFC with hydrogen and multi management for improved flexibility and scalability**
- 14: Sustainable, material-efficient approach to industrial design for hydrogen tanks through catalyst for commercial automotive PEMFC tanks**
- 15: Simulation, validation and measurement enabled to develop liquid and double phase systems using computational tools**
- 16: HyCoRA: Hydrogen Compressed Air Reservoir**
- 17: HESASTACK: Stack design for a hydrogen stack PEM electrolyzer**
- 18: Electra: High temperature electrolyser with novel catalysts for improved efficiency, durability, and lower investment**
- 19: ALMORE: Autonomous detection-ready system**
- 20: GENTLEMAN: Scalable hydrogen production of hydrogen transportation with ultra-low emissions of hydrogen PEM fuel cells**
- 21: Identification of hydrogen and advanced process applications for fuel cell and hydrogen technologies: Applications, identification of hydrogen and safety through their research**
- 22: HAZELUS: Wind → 1000 kg H₂/day**
- 23: Hydrogen delivery cost assessment and safety release evaluation**
- 24: System design for high temperature proton electrolyser with novel catalyst, cell, and stack geometry for performance and hydrogen production**
- 25: OXIGEN: Fuel generation based on solar fuel cell and fuel gas solution for small stationary applications**
- 26: REINTE: Renewable energy supply with multiple sources for energy efficiency, reliability, and lower investment**
- 27: REHYDNE: Open Refinery Hydrogen for Europe**
- 28: HYDRA-H2: VPEM-FC and physical platform for fuel cell system development**
- 29: Development of the most cost-efficient hydrogen production and storage on-board vehicle storage technologies**
- 30: caViolet: Understanding design, test and field transfer in fuel cells for transport applications**
- 31: STASH: Standardised test-cell module for heavy-duty applications**
- 32: WINNER: World-class hydrogen fuel cell stack and electrolyser for the electrochemical industry**

Water Electrolysis (PEM)

• Six SINTEF-coordinated FCH JU-funded projects (2010 → 2027)
 Materials development → Up-scaling → Market implementation



NEXPEL Next generation PEM Electrolyser for Sustainable Hydrogen Production

Key numbers:

Start	2014
End	2017
Total budget	€ 10.5
Coordinated by	SINTEF
Coordinated by	Magnus & Thomas

Main objective: Develop and demonstrate electrolyser integrated with efficiency (LHV₂) of at least 65,000 / Nm³ h, target life 40,000 h

NOVEL Novel materials and system designs for low cost, efficient and durable PEM electrolyzers

Key numbers:

Start	2014
End	2017
Total budget	€ 10.5
Coordinated by	Magnus & Thom

Main objective:

- Develop and demonstrate and durable PEM water electrolyser
- System design and optimization
- Increased understanding of degradation issues in PEM

Logos: Fraunhofer, HELION, BurntTech, SINTEF

MEGASTACK Stack design for a Megawatt scale PEM electrolyser

Key numbers:

Start	2014
End	2017
Total budget	€ 10.5
Coordinated by	Magnus & Thom

Main objective:

- Multi-scale and multi-phase models which to serve as engineering tool for stack design and up-scaling
- Model validation through high speed image capture and processing
- Pressure drop and flow distribution prediction
- LCA analysis

Logos: ITM POWER, Fraunhofer, SINTEF

HAEOLUS One of SINTEF's 28 FCH JU-projects

Wind → 1000 kg H₂/day

Berlevåg

Key numbers:

Start	2014
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Total budget	€ 10.5
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Main objective:

- Electrolyser (2,5 MW) installed in Berlevåg in 2020
- Directly connected to Raggøvidda wind park (avoiding grid tariff)
- Electrolyser exhibit fast response
- Stabilize grid voltage and frequency
- EU (FCHIU)-project:
 - total budget 7 ME (70 % public support)
 - Start January 2018, duration 4 years

Logos: SINTEF, VARANGER KRAFT, HYDROGENICS, tecnoia

REFHYNE Clean Refinery Hydrogen for Europe

Key numbers:

Start	2014
End	2017
Total budget	€ 10.5
Coordinated by	Magnus & Thom

Logos: ITM POWER, sphera, elementenergy, SINTEF

REFHYNE From 10 to 100 MW REFHYNE 2 – world's largest PEM electrolyser

Key numbers:

Start	2014
End	2017
Total budget	€ 10.5
Coordinated by	Magnus & Thom

Main objective:

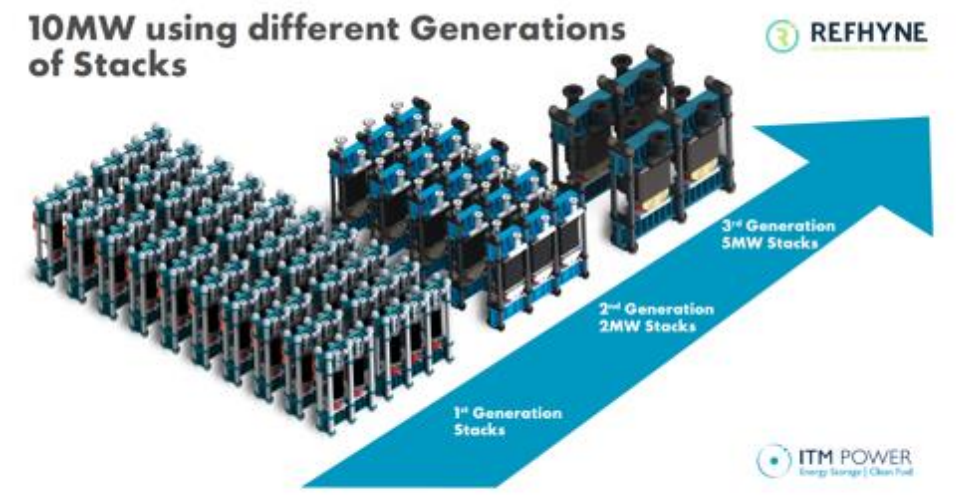
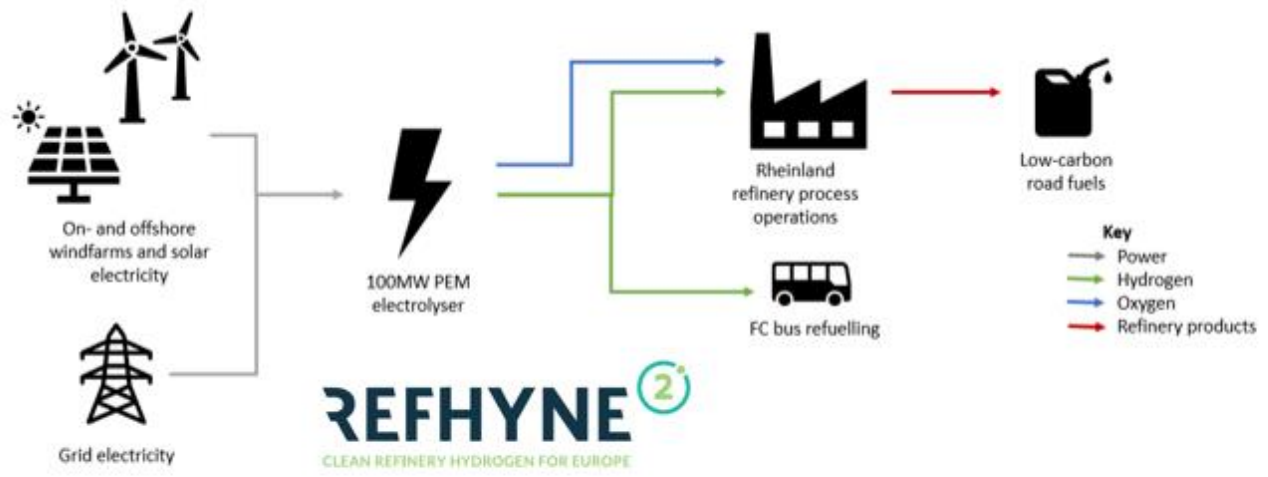
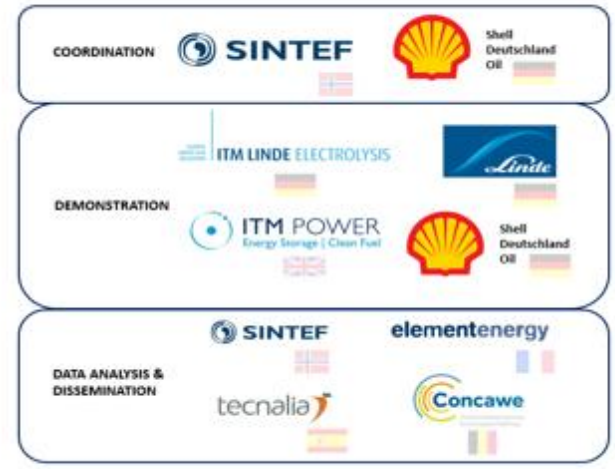
- > 30 ME in EU funding
- Production up to 40 tons hydrogen per day
- Hydrogen for industrial use (refinery) and as fuel
- At Shell Energy and Chemicals Park in Cologne, Germany
- Also exploit oxygen and heat, balancing of internal/external grid

Logos: SINTEF, REFHYNE, The European Green Deal

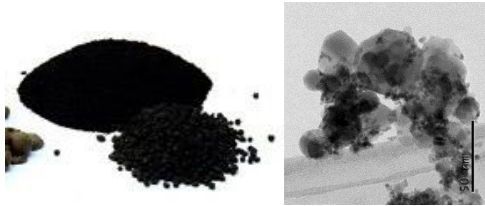
From 10 to 100 MW REFHYNE 2

– world's largest PEM electrolyser

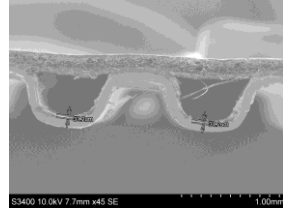
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SINTEF covers complete value chains



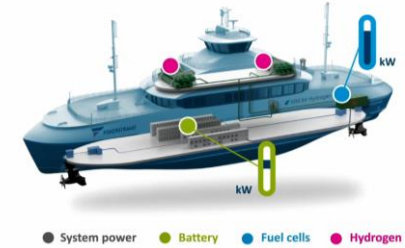
Materials development and characterization



Components and cell production processes



Modules and control systems



System design and integration

Multiscale modelling (from nano-scale to system level)

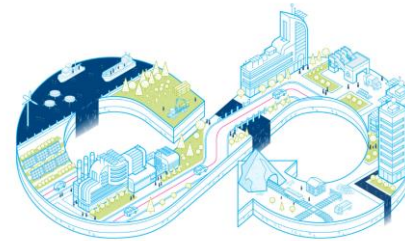


NORWEGIAN FUEL CELL AND HYDROGEN CENTRE
LOW TEMPERATURE FUEL CELLS & ELECTROLYSERS

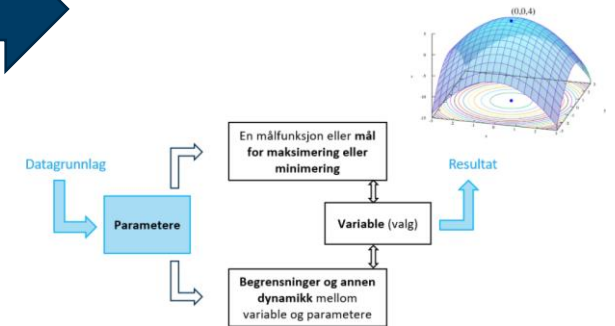
Performance and lifetime optimisation



Demonstration and piloting



Circular economy and recycling



Value chain optimisation and feasibility studies

H₂ as fuel in Transport





GHG emissions in transport- H_2 -projects SINTEF



Passenger vehicles, 4,4 mill tonnes

CO₂

Vans and heavy duty vehicles 4,2 mill tonnes

CO₂

Domestic maritime and fishing, 2.9 mill tonnes

Other mobile sources 2.3 mill tonnes

Domestic air traffic 1,3 million tonnes

Motor bikes and scooters 0,1 million tonnes

Railroads, 0,05 million tonnes



Passenger trains 2018→ ALSTOM



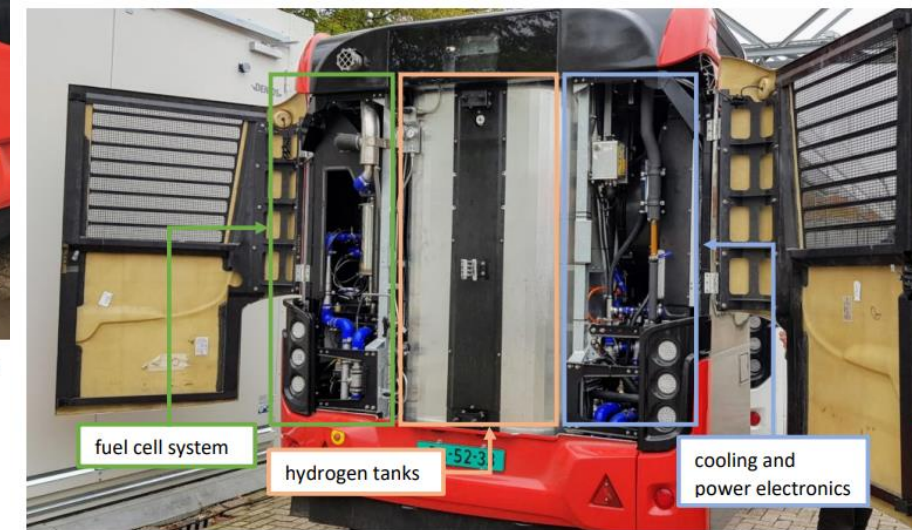
Solar powered H₂ heavy duty trucks & forklifts



Giantleap Improves Automation of Non-polluting Transportation with Lifetime Extension of Automotive PEM fuel cells



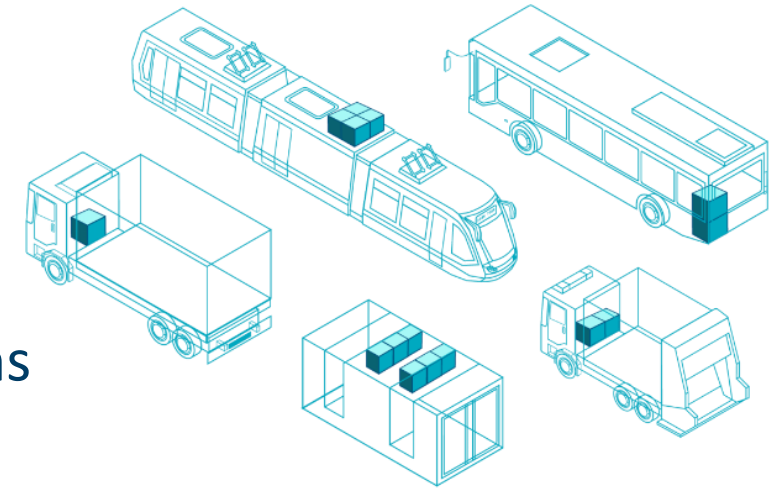
Fig. 10: VDL Citea test vehicle with GiantLeap FC range extender trailer



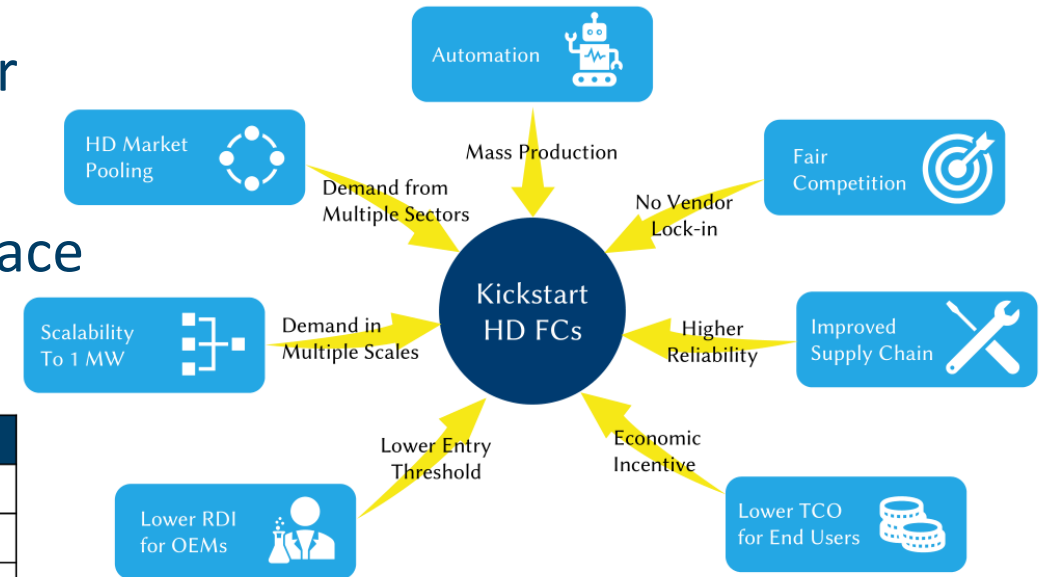
Key numbers	
Start	May 2016
End	Oct. 2019
Total budget	€ 3 260 297
Coordinated by SINTEF Federico.Zenith@sintef.no	

Main achievements:

- Algorithm that project PEM fuel cell operation lifespan of 15 000 h and able to determine degradation state in few seconds
- Demonstrated feasibility of range extender for battery busses
- Better understanding of conditions in which to recover cell degradation previously thought to be irreversible

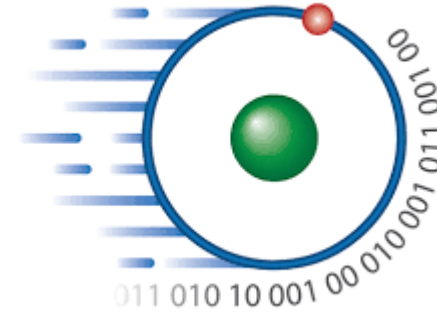


- Standardised fuel-cell module for heavy duty applications
- 11 world-leading fuel-cell system manufacturers
 - Ballard, Plastic Omnium, FCP, Freudenberg, Cummins, Intelligent Energy, Nedstack, Nuvera, Proton Motor, Symbio, Toyota
- OEMs representative of wide heavy-duty sector
 - Alstom, AVL, CETENA (Fincantieri), Damen, FPS, Solaris, VDL, Volvo
- Set standard for Size, Physical and Digital interface
- Disseminate open standard to industry
- Build and test 11 prototypes



Key numbers	
Start	Jan.2021
End	Dec. 2023
Total budget	€ 15 000 000
Coordinated by SINTEF Federico.Zenith@sintef.no	

VIRTUAL-FUEL CELL SYSTEMS



- Topic: FCH-01-3-2019
- Total budget: € 1 897 806
- Duration: 36 months
- Coordinator: **SINTEF**

Fuel cell specialists

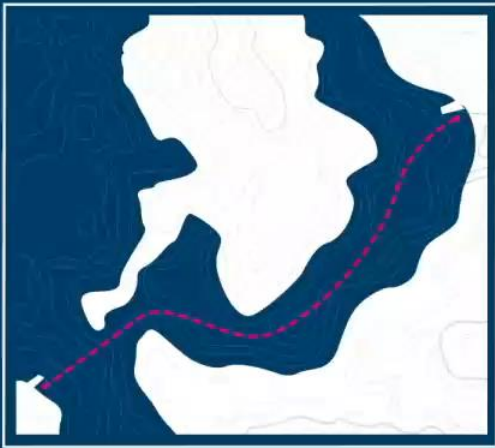
System integrators/ end- users

The VIRTUAL-FCS project will develop a fully open source software- hardware (cyber-physical) tool that can be adopted as a global standard for FC system design.

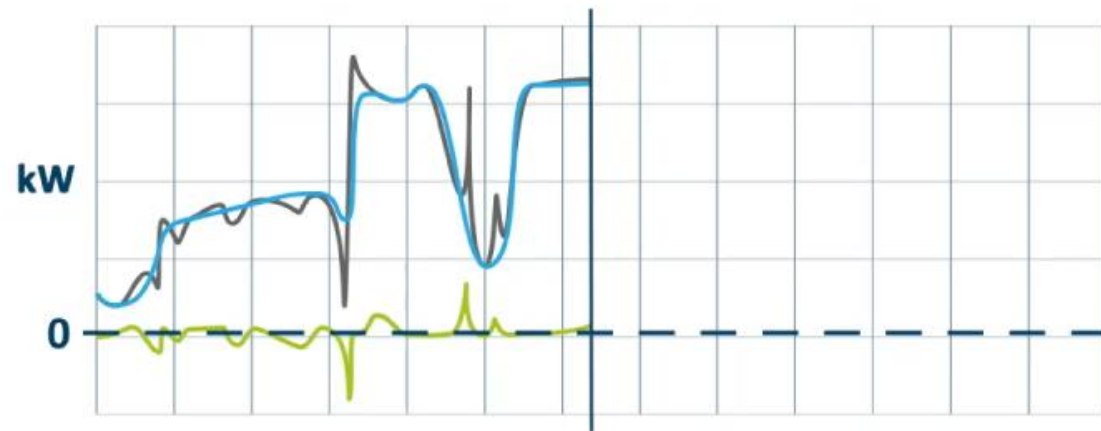
Overall objective: To make the design process of hybrid fuel cell and battery systems easier, cheaper and quicker.



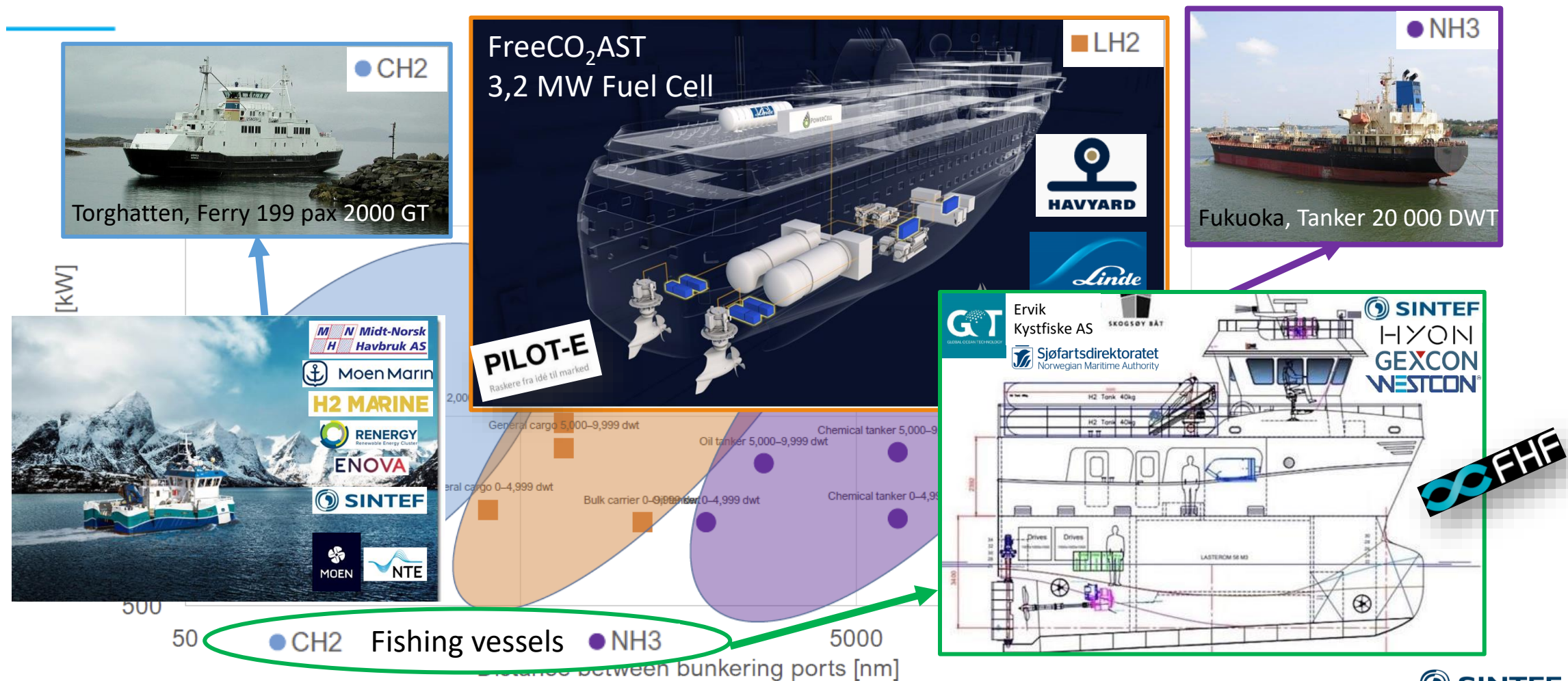
System design and optimal operation



● System power ● Battery ● Fuel cells ● Hydrogen



Alternative fuels for maritime transport

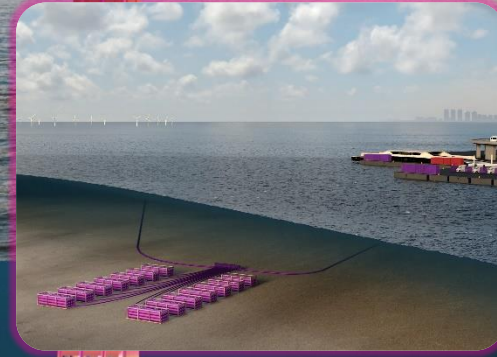




Deep Purple™ Pilot



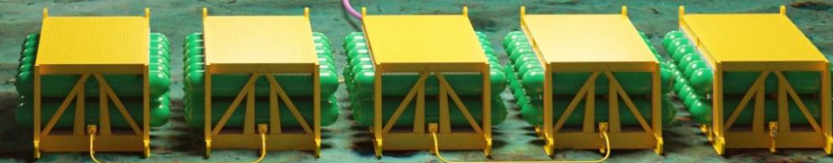
Offshore, large scale green H₂-production



Near-shore, subsea H₂ infrastructure & storage



Renewable and stable power supply to remote areas



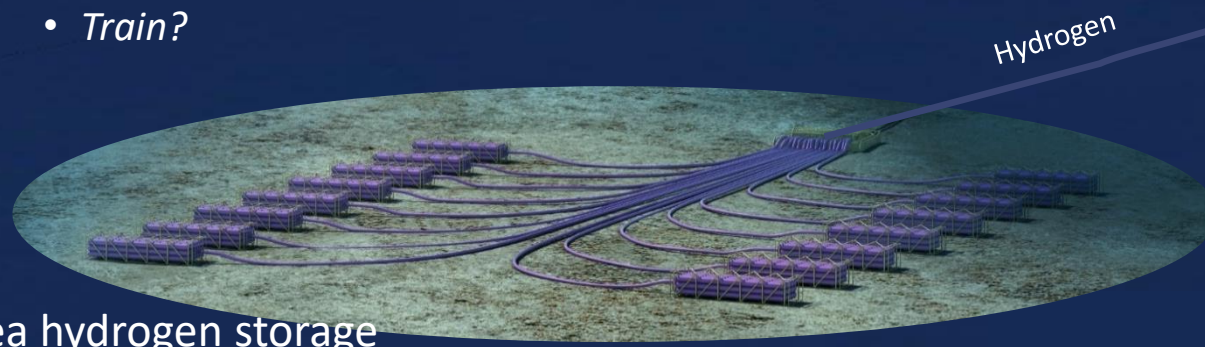
An example, for the City of Trondheim

Large scale subsea hydrogen storage in ports



H₂-refueling station for:

- *High Speed passenger boats*
- *HD Trucks and Buses*
- *Car ferries*
- *Train?*



Subsea hydrogen storage

Techno-Economic Assessments

- SINTEF provides Decision Support:
 - Hybrid car ferry (Fiskerstrand Yard), 2017 - 2021
 - Cruise ships (Viking Cruises), 2016-2019 →
 - Trains (Rail Administration) Alternative fuels, 2015, 2019
 - High speed passenger boats (Trøndelag County), 2017/18
 - Fleet vehicles (Trondheim Municipality) 2017-2018
 - H₂ as fuel in transport (4 largest Norw. Cities) 2016
 - Emission reductions on fish farming (NVE) 2017/18
 - Wind-H₂ (Varangerkraft) @ Raggovidda 2013 →
 - H₂-production from small scale hydro power Hellesylt 2020 →

Contact Point: steffenh@sintef.no





Laboratories and test facilities

- World-class infrastructure for
 - *Hydrogen technology development*
 - *Materials syntheses & Characterization*
 - *Testing of hydrogen (and hybrid) systems*
- Open access (only operation cost)
- Close collaboration with industry
- International collaboration
- Financial support from industry and:



The Research Council
of Norway



NORWEGIAN FUEL CELL
AND HYDROGEN CENTRE
LOW TEMPERATURE FUEL CELLS & ELECTROLYSERS

Contact: Ingeborg.Kaus@sintef.no

Background

- A substantial increasing interest in the market on a higher TRL level
- SINTEF has strong competence on the most relevant technologies for RES systems: (Electrolysis, Fuel Cells, Batteries and PhotoVoltaics)
- SINTEF has developed leading knowledge on electrochemical modelling, hybrid system's optimisation and techno-economic assessments



Ambitions

- Consolidate & Extend SINTEF activities towards market implementation (e.g., System labs / Pilot plants)
- Utilize data from real world market implementation projects in modelling activities
- Comprise all relevant technologies for remote and autonomous RES (hybrid) systems
- Further develop SINTEF's systems modelling capabilities in close collaboration with leading industry and academic partners, e.g., *Machine Learning, AI, LCSA, electrochemistry, decision support*





SINTEF

SINTEF's strategic positions in Europe

- **European Clean Hydrogen Alliance**
 - *CEO-Round Table on Hydrogen Production*
 - *Alexandra Bech Gjørvi*
- **European Energy Research Alliance**
 - *Nils A. Røkke, re-elected as president in 2021*
 - *Participation in multiple Joint Programmes*
- **Hydrogen Europe Research (2008→)**
 - *Steffen Møller-Holst, Executive Board Member*
- **Clean Hydrogen Partnership (2022→)**
 - *Nils A. Røkke, elected Chair of Stakeholders Group, and thereby becoming an observer to the Governing Board*
- **Co-chair Research, ETIP ZEP, AC member, ACEC member (2006-→)**
- **Zero-emission Waterborne Transport**
 - *Trond Johnsen, Board member*
- **Clean Aviation Partnership**
 - *Trond Bakken & Ida Hjort, Members of Technical Committee*
- **Processes 4 Planet**
 - *Duncan Akporiaye, Executive Board Member*

European Clean
Hydrogen Alliance



Hydrogen Europe
Research



Clean Hydrogen
Partnership



WATERBORNE

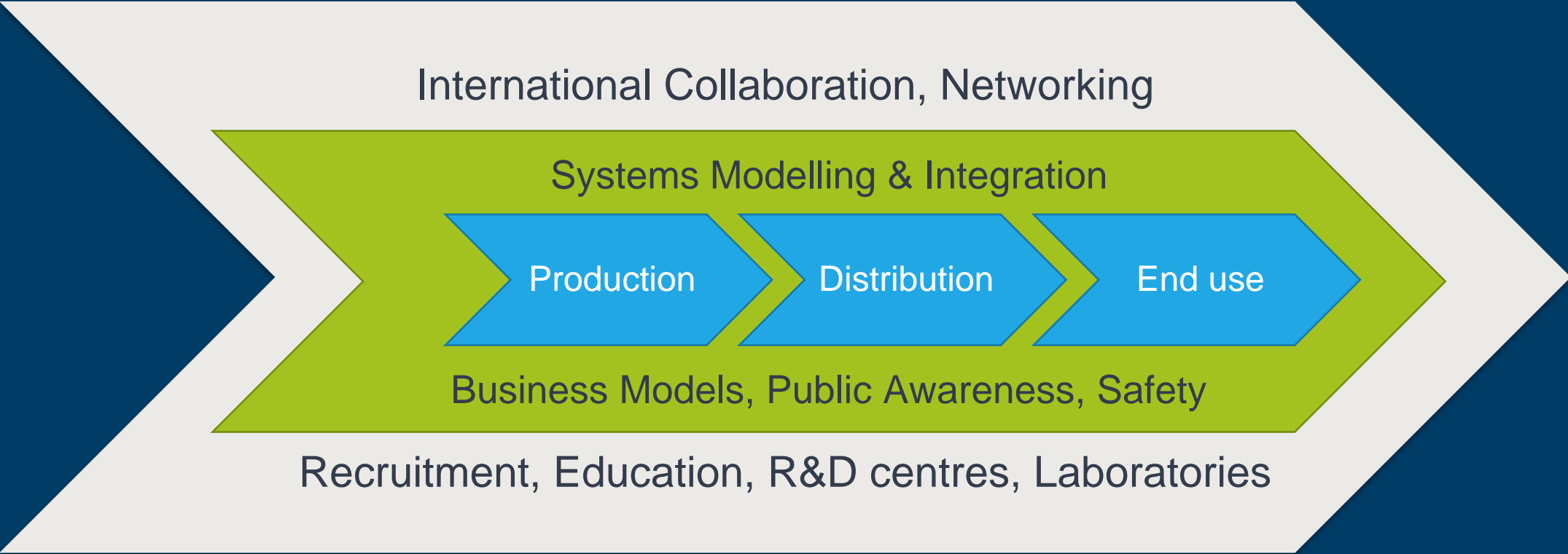


CLEAN AVIATION



PROCESSES4PLANET

Hydrogen value chain, SINTEF's engagement





Technology for a better society