"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
SINTEF

Chairman Transport Committee
Clean Hydrogen Partnership
Hydrogen Europe Research

Chairman of the Board
Norsk Hydrogenforum

An independent, not-for-profit research institute

Technology for a better society

SINTEF in short

SALES

NOK 3.4

billion

EMPLOYEES

2000

PROJECTS

6800

CLIENTS

3400

INTERNATIONAL

NOK 470 million

PUBLICATIONS

5100

NATIONALITIES

75

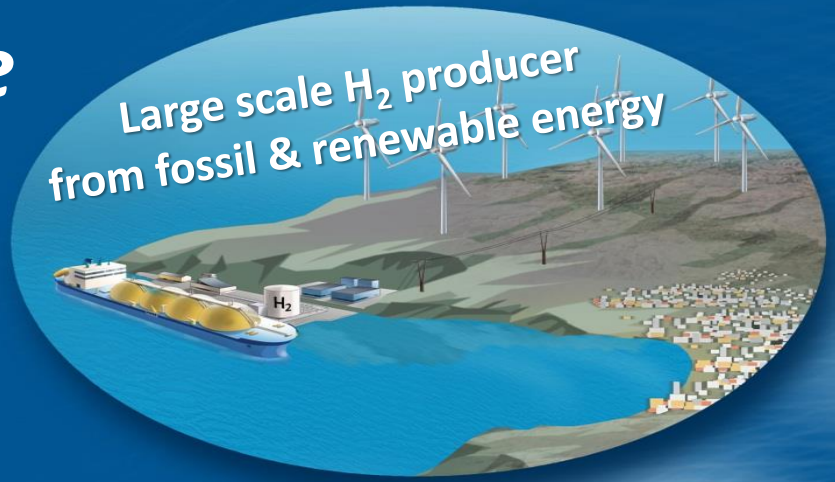
CLIENT SATISFACTION

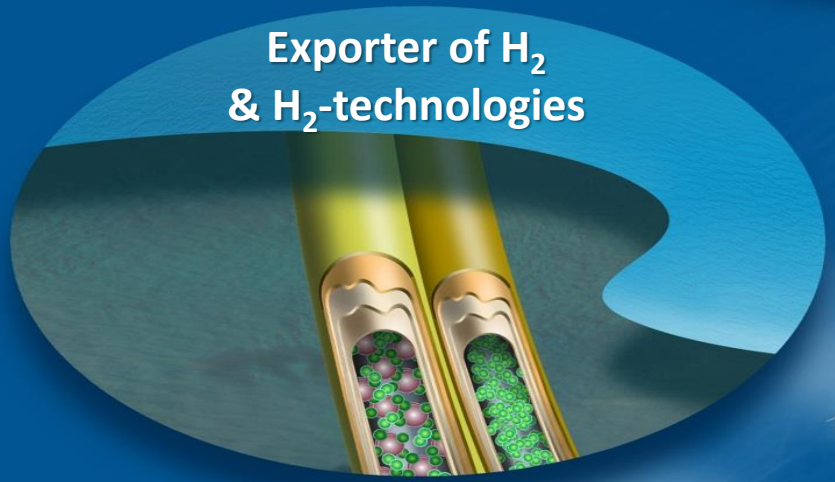
4.6 out of 5

Technology for a better society

Green, digital initiatives for interdisciplinary boost and good innovation conditions

Areas where Norway can play a key role internationally within hydrogen





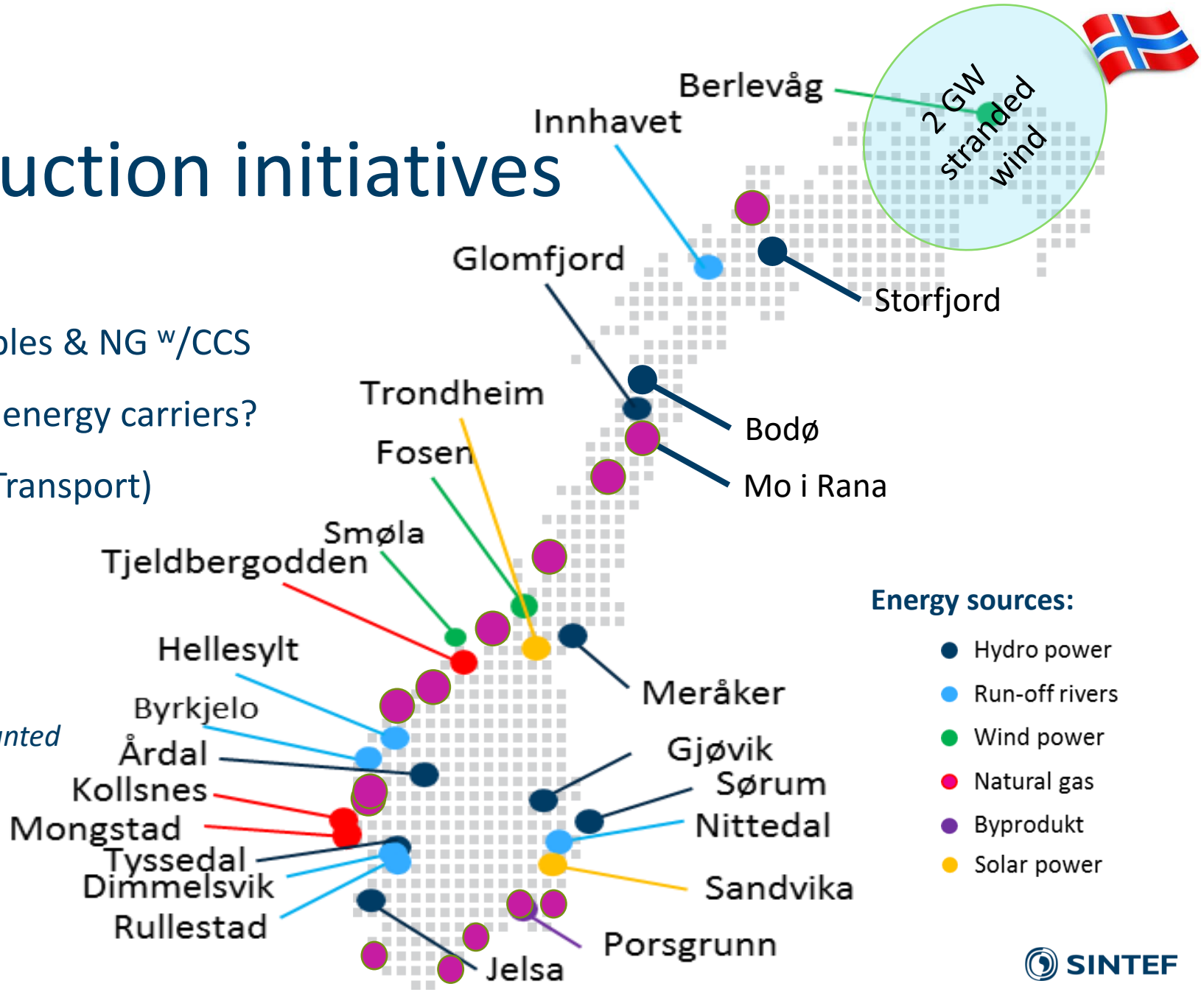
SINTEF *Technology for a better society*

H_2 & NH_3 production initiatives

- H_2 & NH_3 prod. from renewables & NG ^{w}/CCS
- Energy export of H_2 & NH_3 as energy carriers?
- H_2 & NH_3 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



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

Stranded wind → 1 ton H_2/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

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FCH FUEL CELLS AND HYDROGEN JOINT UNDERTAKING

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VARANGER KRAFT

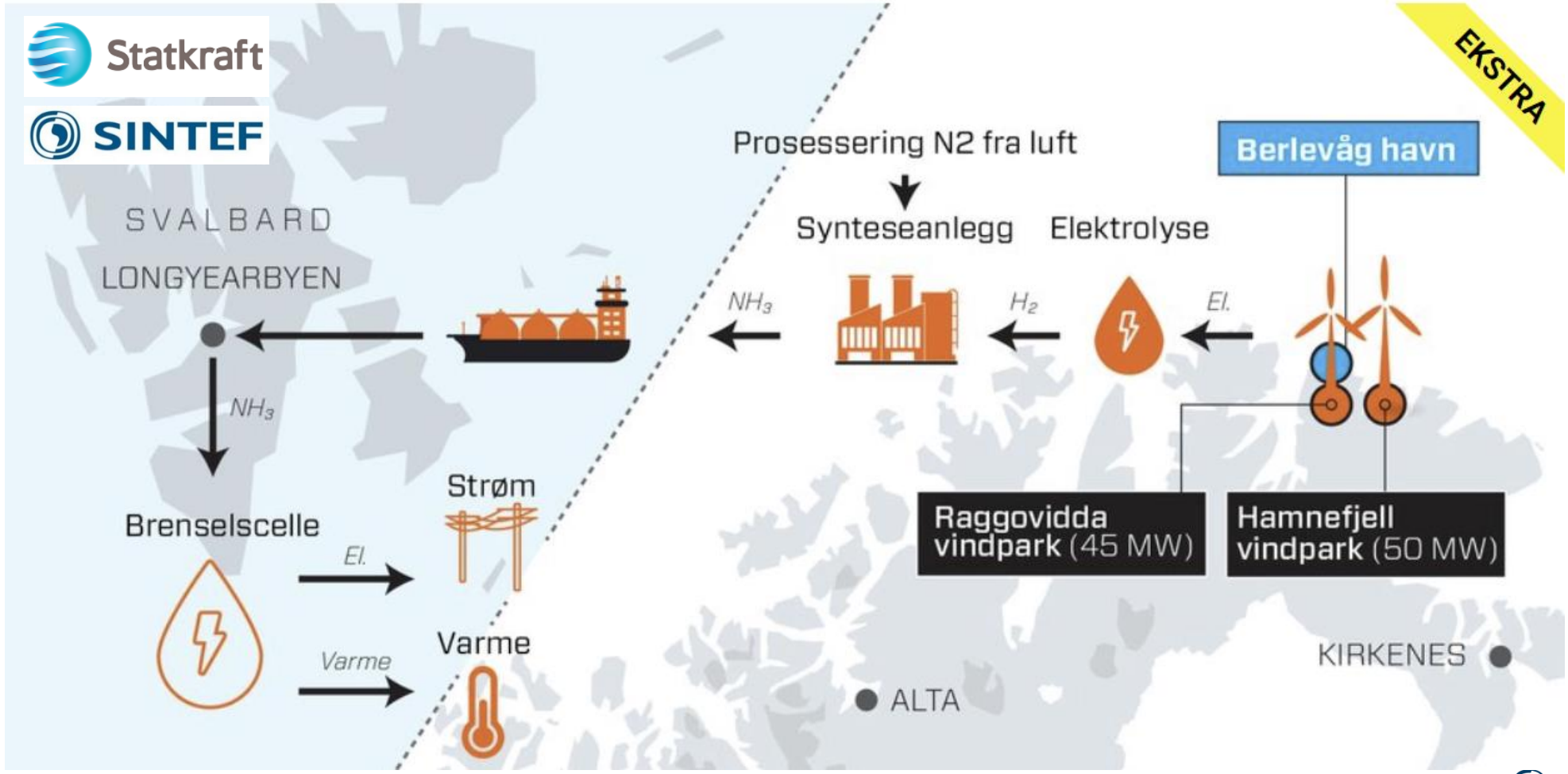
HYDROGENICS
SHIFT POWER | ENERGIZE YOUR WORLD

UBFC

tecnalia
Corporación Tecnológica

KES
Knowledge Environment Security Srl

Stranded wind → 0-emission @ Svalbard?



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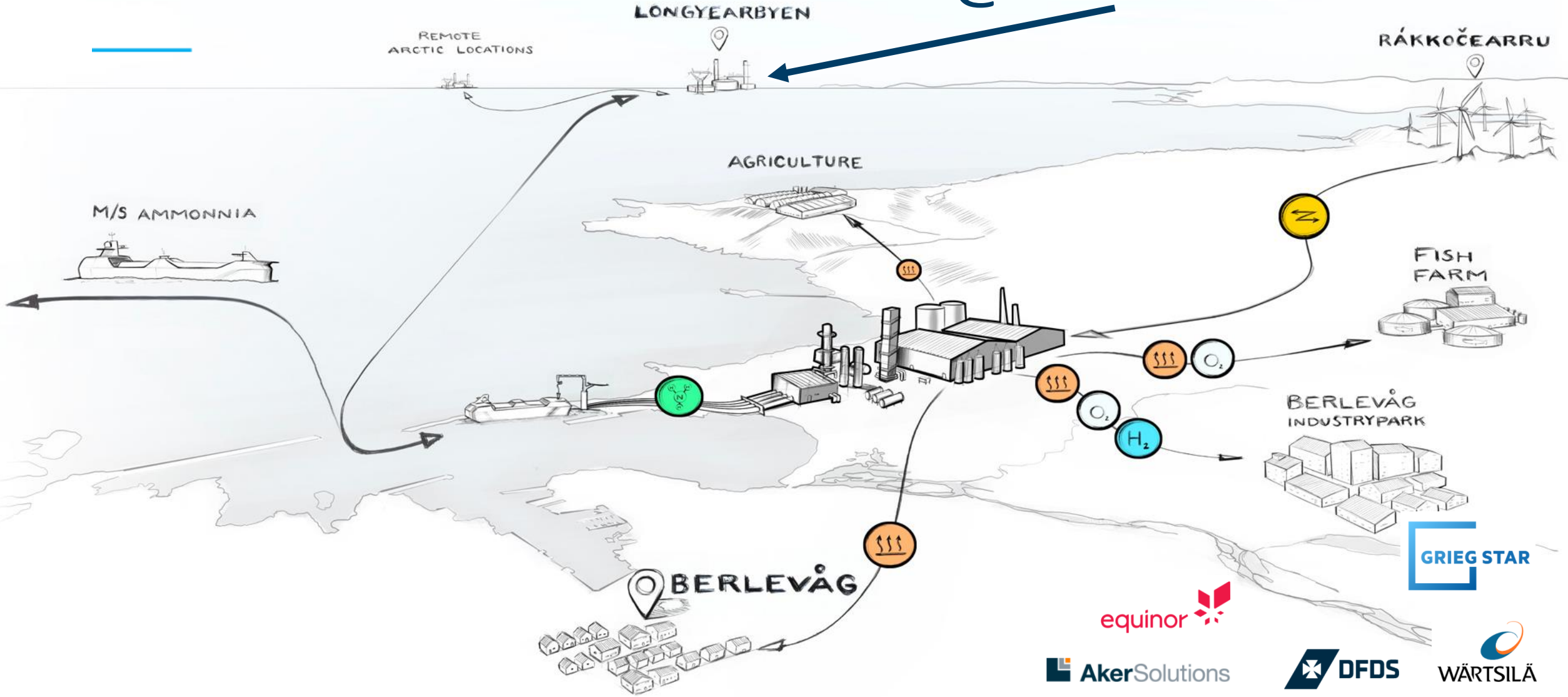
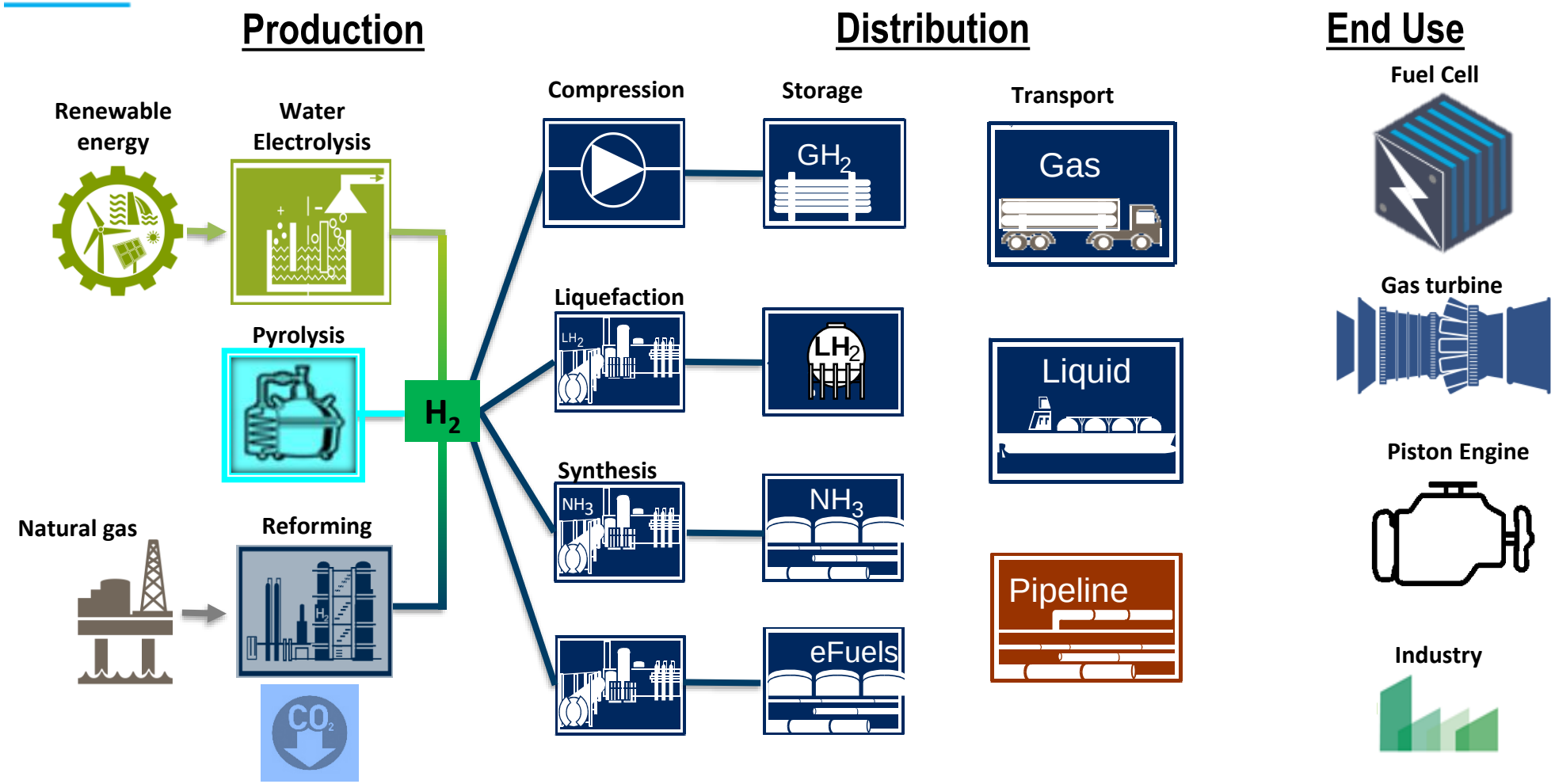
ZEEDS

Stranded wind → 0-emission @ Svalbard?



Hydrogen as energy carrier, value chains



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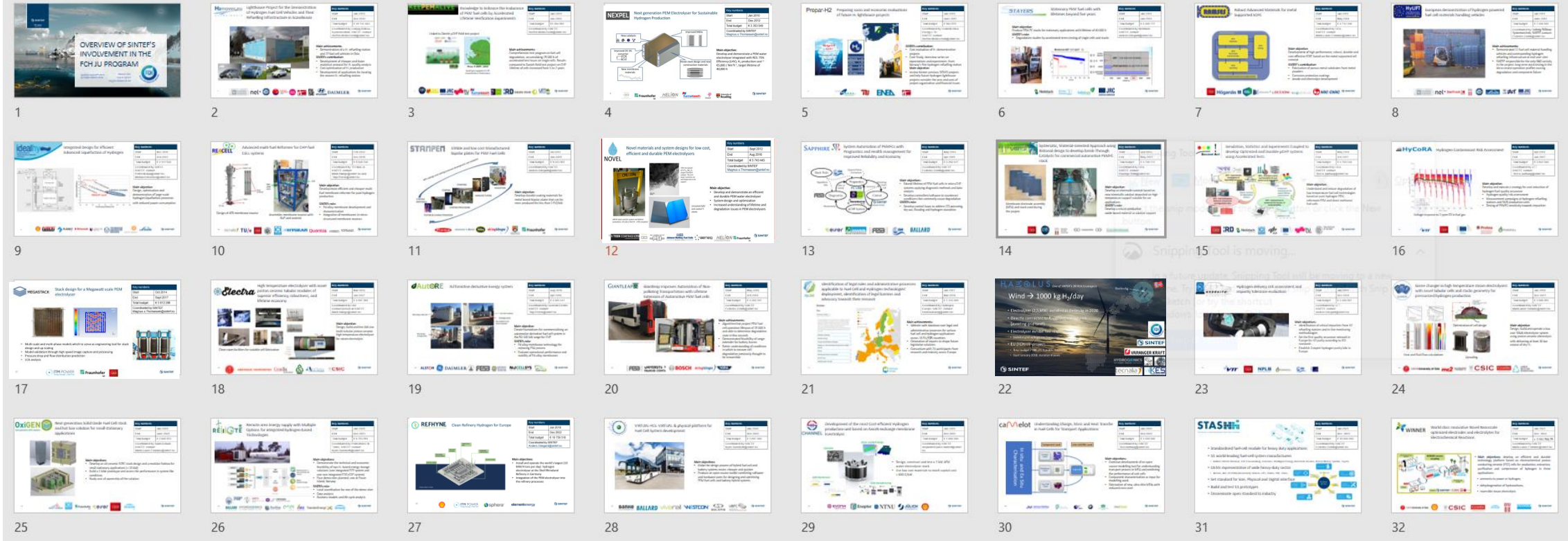
SINTEF's EU-project portfolio (2010-2021)



Water Electrolysis (PEM)

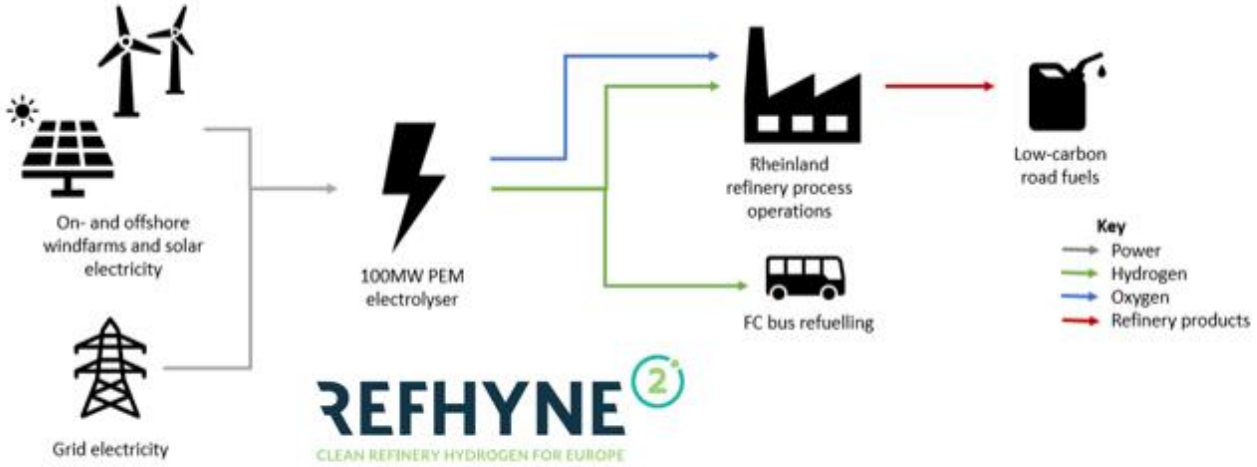
- **Six SINTEF-coordinated FCH JU-funded projects (2010 → 2027)**
  Materials development → Up-scaling → Market implementation

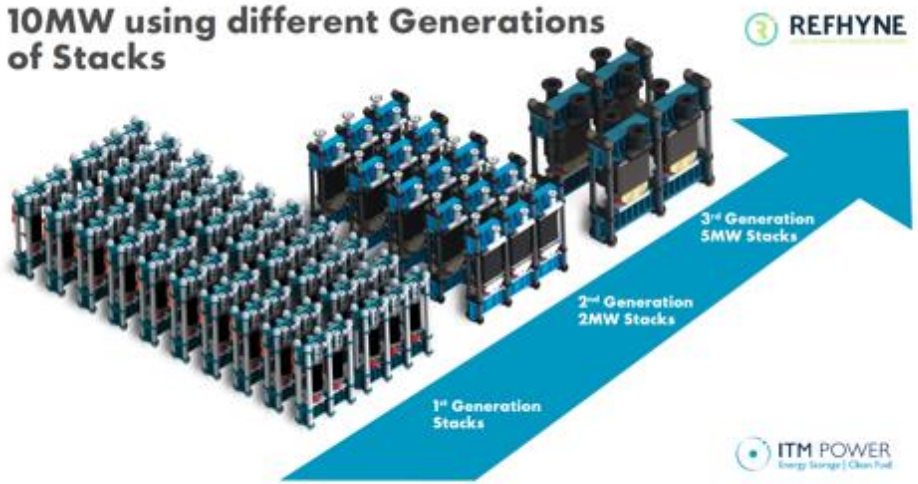
From 10 to 100 MW REFHYNE 2

– world's largest PEM electrolyser

REFHYNE 2
CLEAN REFINERY HYDROGEN FOR EUROPE

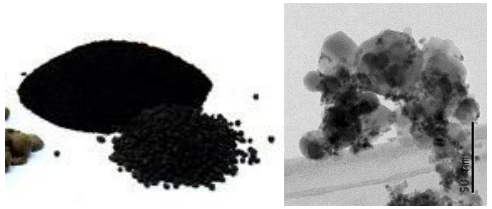
- > 30 M€ in EU funding
- Production up to 40 tons hydrogen per day
- Hydrogen for industrial use (refinery) and as fuel
- At Shell Energy and Chemicals Park in Cologne; Germany
- Also exploit oxygen and heat, balancing of internal/external grid



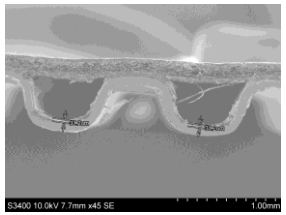


Technology for a better society

SINTEF covers complete value chains

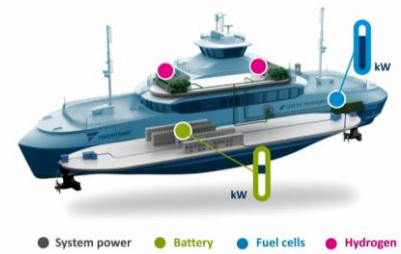


Materials development and characterization



Components and cell production processes

Modules and control systems

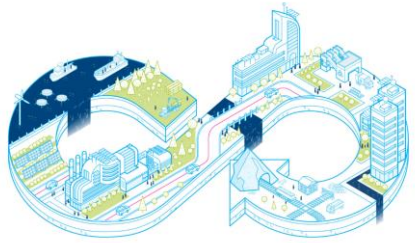


System design and integration

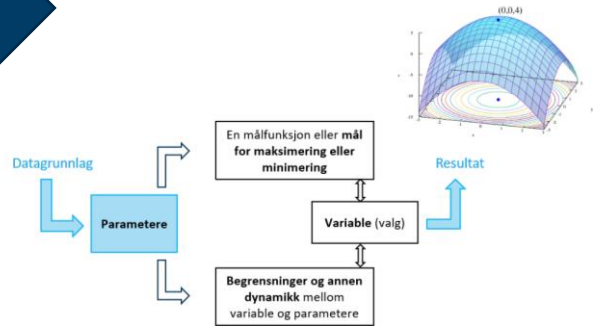
Multiscale modelling (from nano-scale to system level)

Performance and lifetime optimisation

Demonstration and piloting



Circular economy and recycling



Value chain optimisation and feasibility studies

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H_2 as fuel in Transport

SINTEF *Teknologi for et bedre samfunn*

GHG emissions in transport-*H_2-projects SINTEF*

Passenger vehicles, 4,4 mill tonnes

CO_2

Vans and heavy duty vehicles 4,2 mill tonnes

CO_2

Domestic maritime and fishing, 2.9 mill tonnes

Other mobile sources 2.3 mill tonnes

Motor bikes and scooters 0,1 million tonnes

Railroads, 0,05 million tonnes

Domestic air traffic 1,3 million tonnes

Solar powered H_2 heavy duty trucks & forklifts

nel HEXAGON SCANIA ENOVA SINTEF

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

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

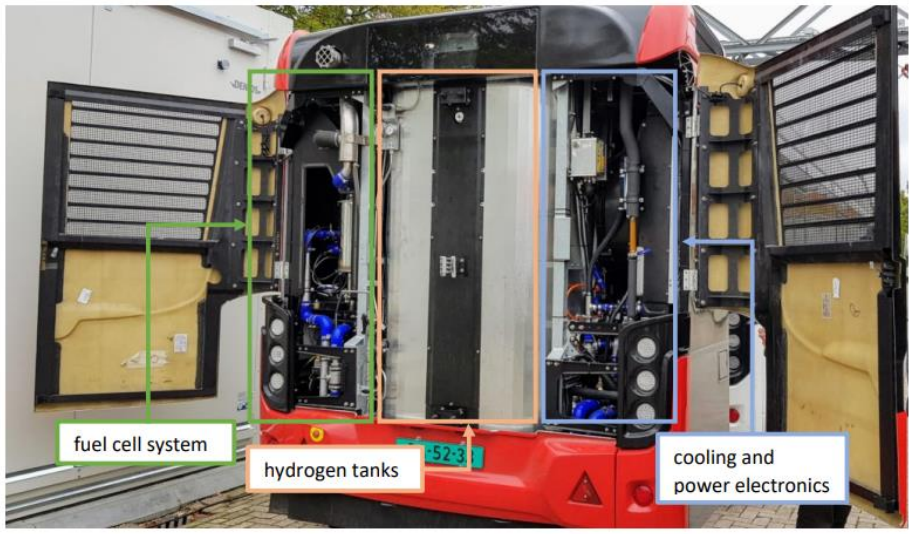


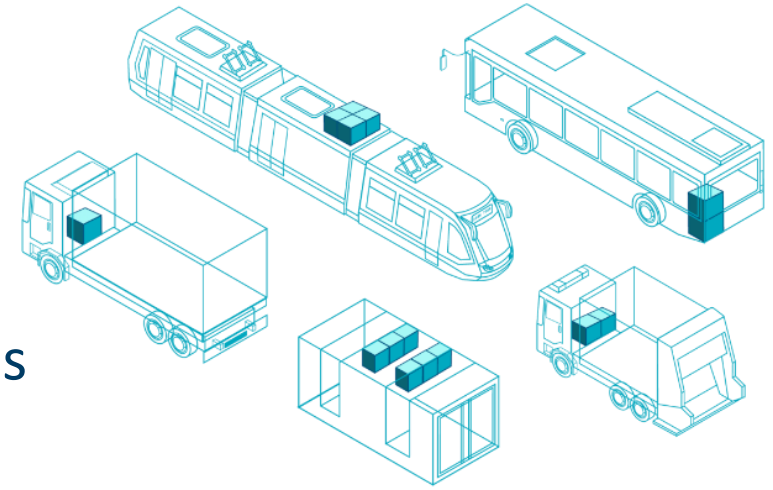
Fig. 10: VDL Citea test vehicle with GiantLeap FC range extender trailer

Main achievements:

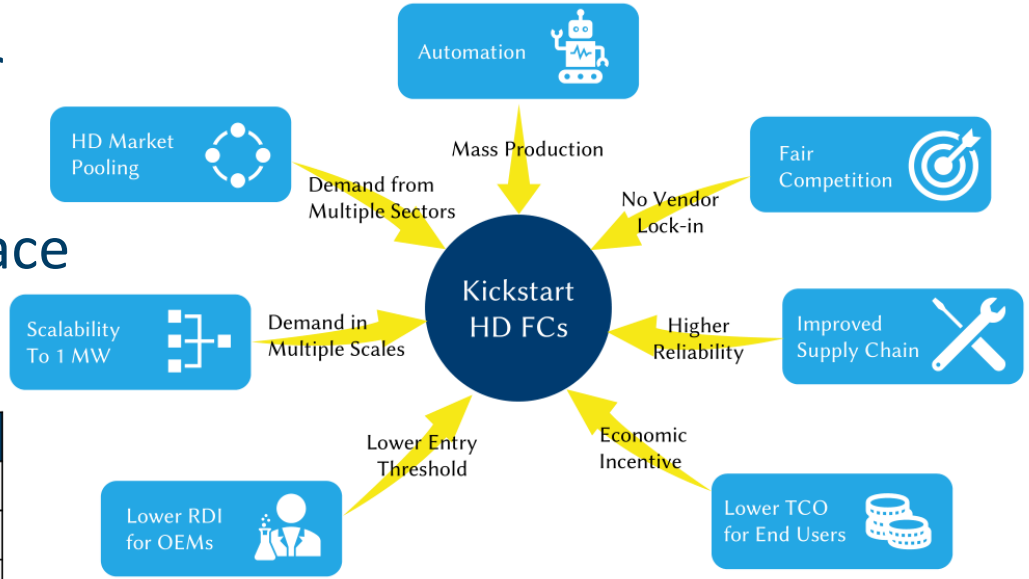
- Algorithm that project PEM fuel cell operation lifespan of 15 000 h and able to determine degradation state in few seconds
- Demonstrated feasibility of range extender for battery busses
- Better understanding of conditions in which to recover cell degradation previously thought to be irreversible

STASH

Towards a standardised fuel cell module



- 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	

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FUEL CELLS AND HYDROGEN JOINT UNDERTAKING

VIRTUAL-FUEL CELL SYSTEMS

- Topic: FCH-01-3-2019
  Cyber-physical platform for hybrid Fuel Cell systems

- Total budget: € 1 897 806
- Duration: 36 months
- Coordinator: SINTEF

Fuel cell specialists

SINTEF
UBFC UNIVERSITÉ BOURGOGNE FRANCHE-COMTÉ
BALLARD

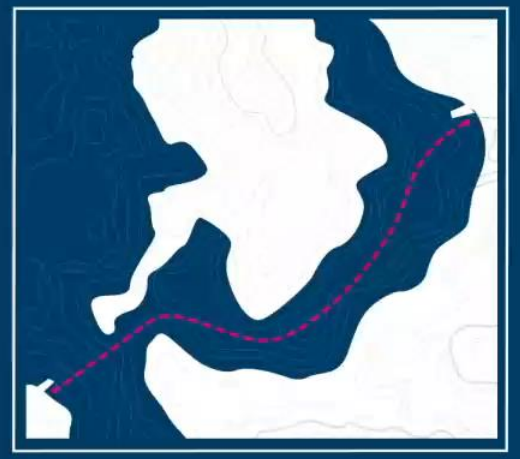
System integrators/ end- users

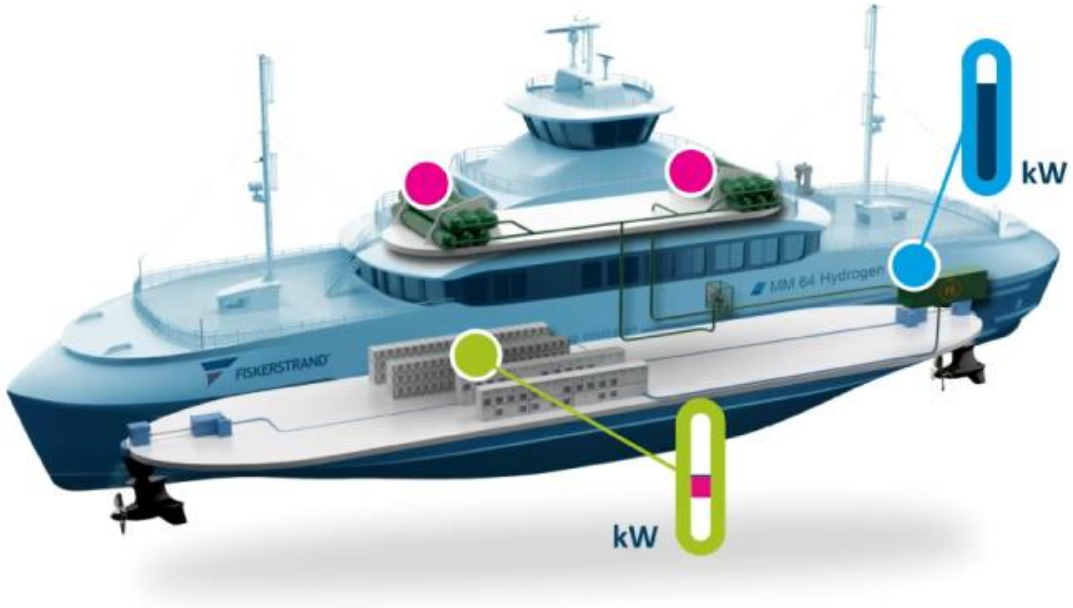
WESTCON
Banke
vivarail
SOLARIS A CAF GROUP COMPANY

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.

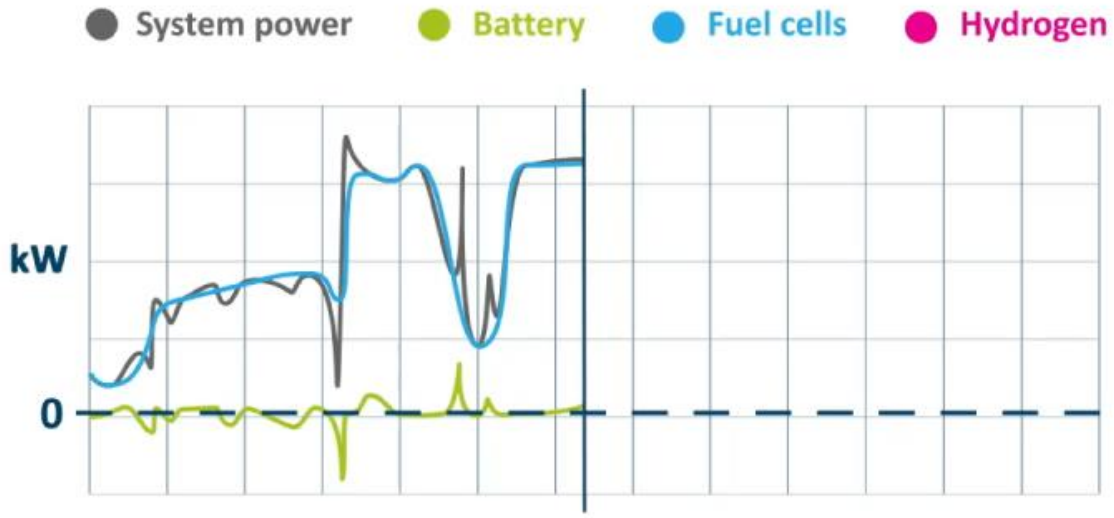
Overall objective: To make the design process of hybrid fuel cell and battery systems easier, cheaper and quicker.

System design and optimal operation





Technology and energy carriers



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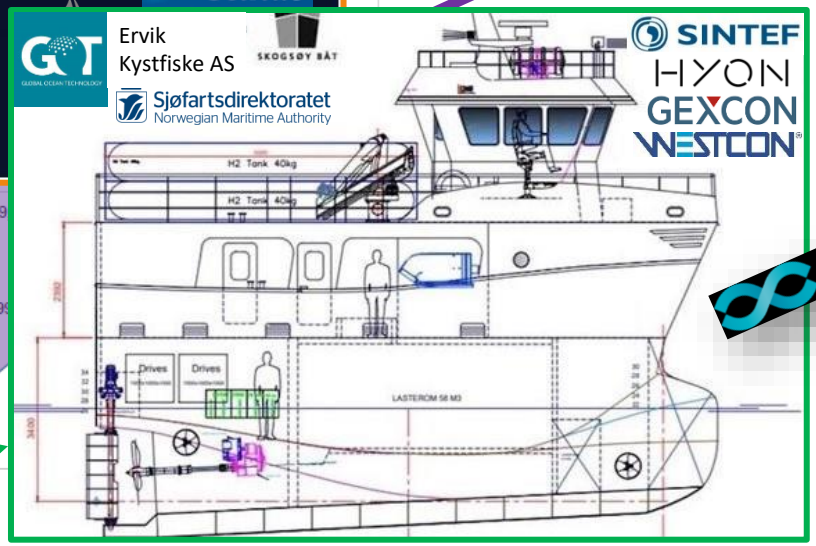
Hydrogen Europe

Alternative fuels for maritime transport



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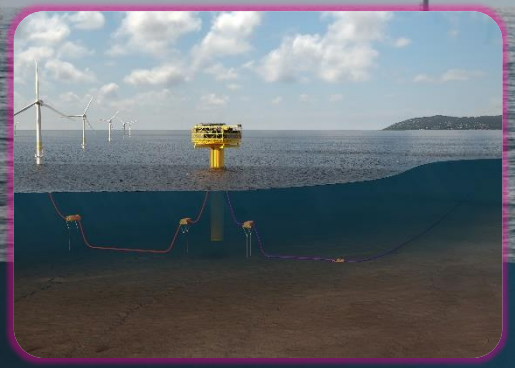
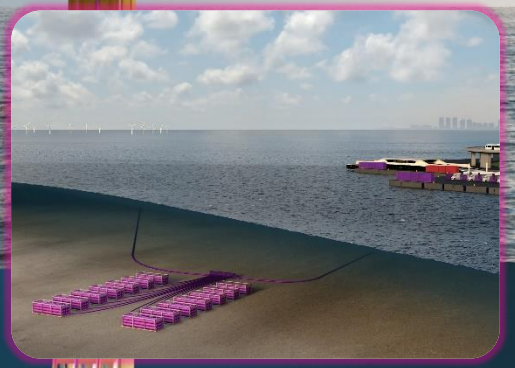
Deep Purple™ Pilot



Offshore, large scale green H_2-production



Near-shore, subsea H_2 infrastructure & storage

Renewable and stable power supply to remote areas

VATTENFALL REPSOL nel DNV UMOE SLÅTTLAND ABB SINTEF USN Universitetet i Sørøst-Norge Ocean Technology Arena Ocean Cluster SINTEF energy valley Innovasjon Norge

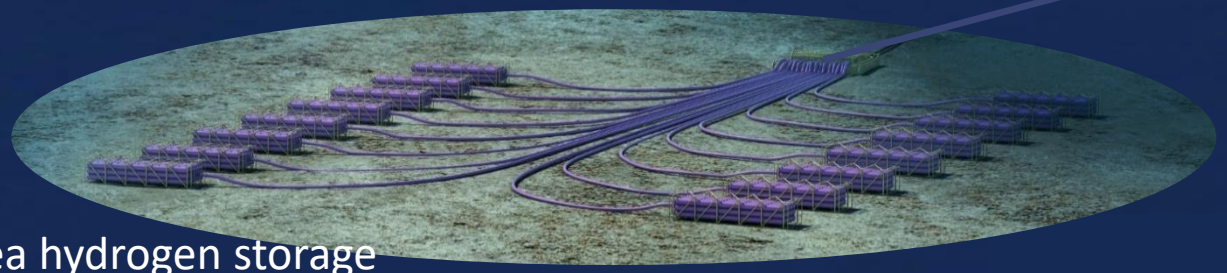
An example, for the City of Trondheim

Large scale subsea hydrogen storage in ports

H_2-refueling station for:

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

Hydrogen



Subsea hydrogen storage

TechnipFMC Deep Purple SINTEF

Techno-Economic Assesments

- 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
  - H_2 as fuel in transport (4 largest Norw. Cities) 2016
  - Emission reductions on fish farming (NVE) 2017/18
  - Wind-H_2 (Varangerkraft) @ Raggovidda 2013→
  - H_2-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

SINTEF

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

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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's strategic positions in Europe

- European Clean Hydrogen Alliance
  - CEO-Round Table on Hydrogen Production
  - *Alexandra Bech Gjørv*
- 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

EERA European Energy Research Alliance

Hydrogen Europe Research

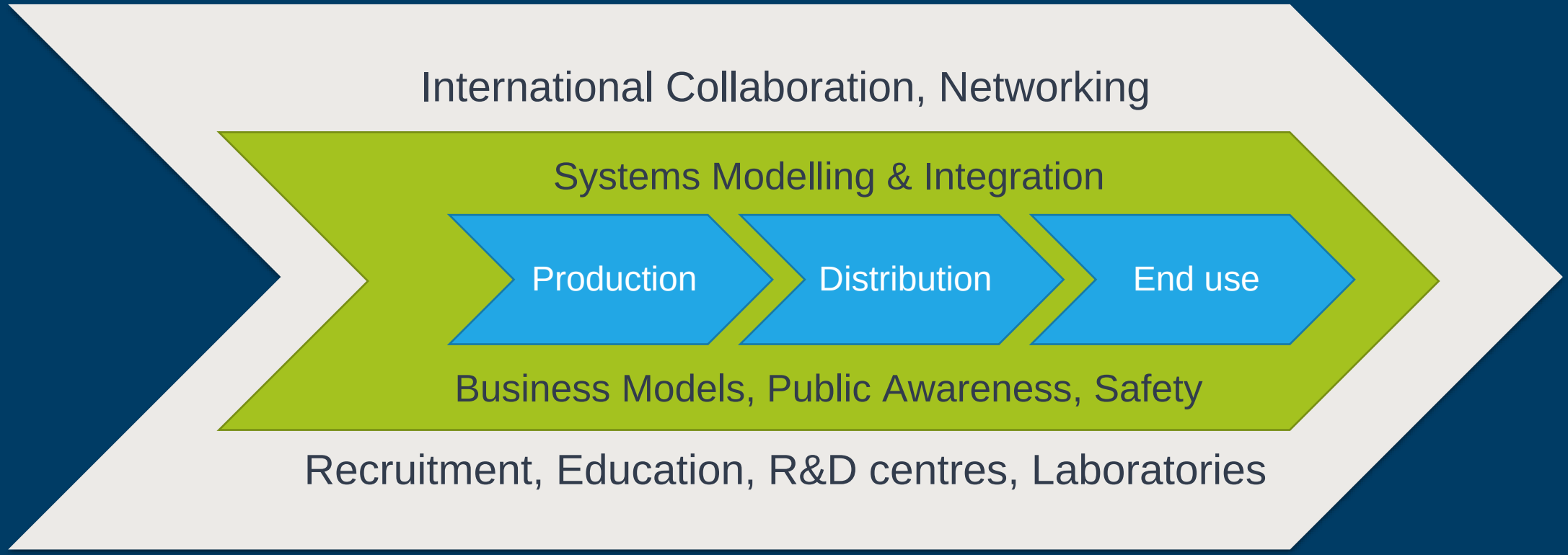
Clean Hydrogen Partnership

WATERBORNE

CLEAN AVIATION

PROCESSES4PLANET

Hydrogen value chain, SINTEF's engagement



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