Bedriftenes Møteplass 2016

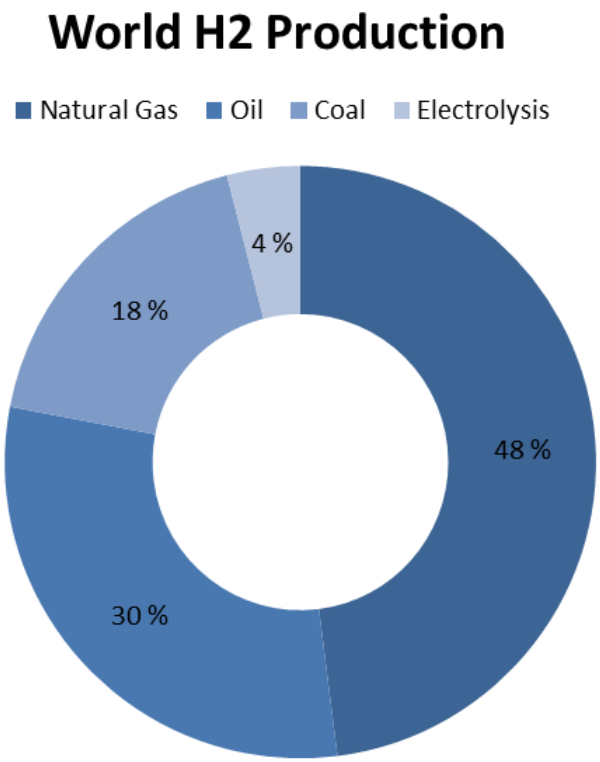
Nytt strømforbruk. Fra strøm til hydrogen, en ny lagringsmetode

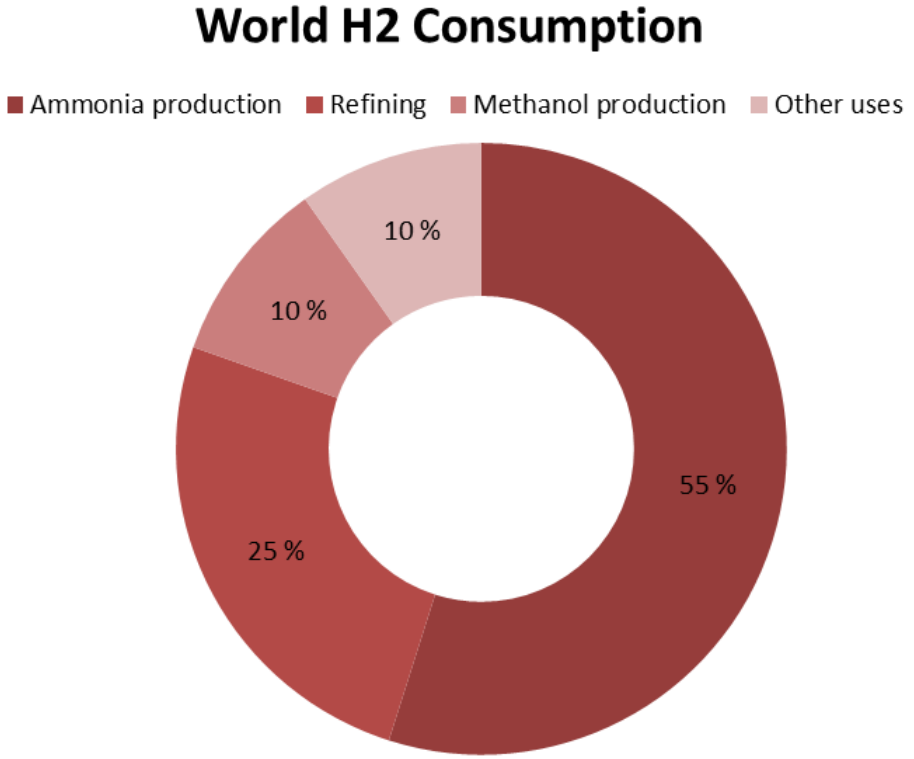
Magnus Thomassen, SINTEF Materialer og Kjemi

Oversikt

- Hvorfor hydrogen
- Litt om hydrogen fra elektrolyse
- Resultater fra forprosjekt. Vind-hydrogen på Raggovidda, Finnmark
- Veien videre

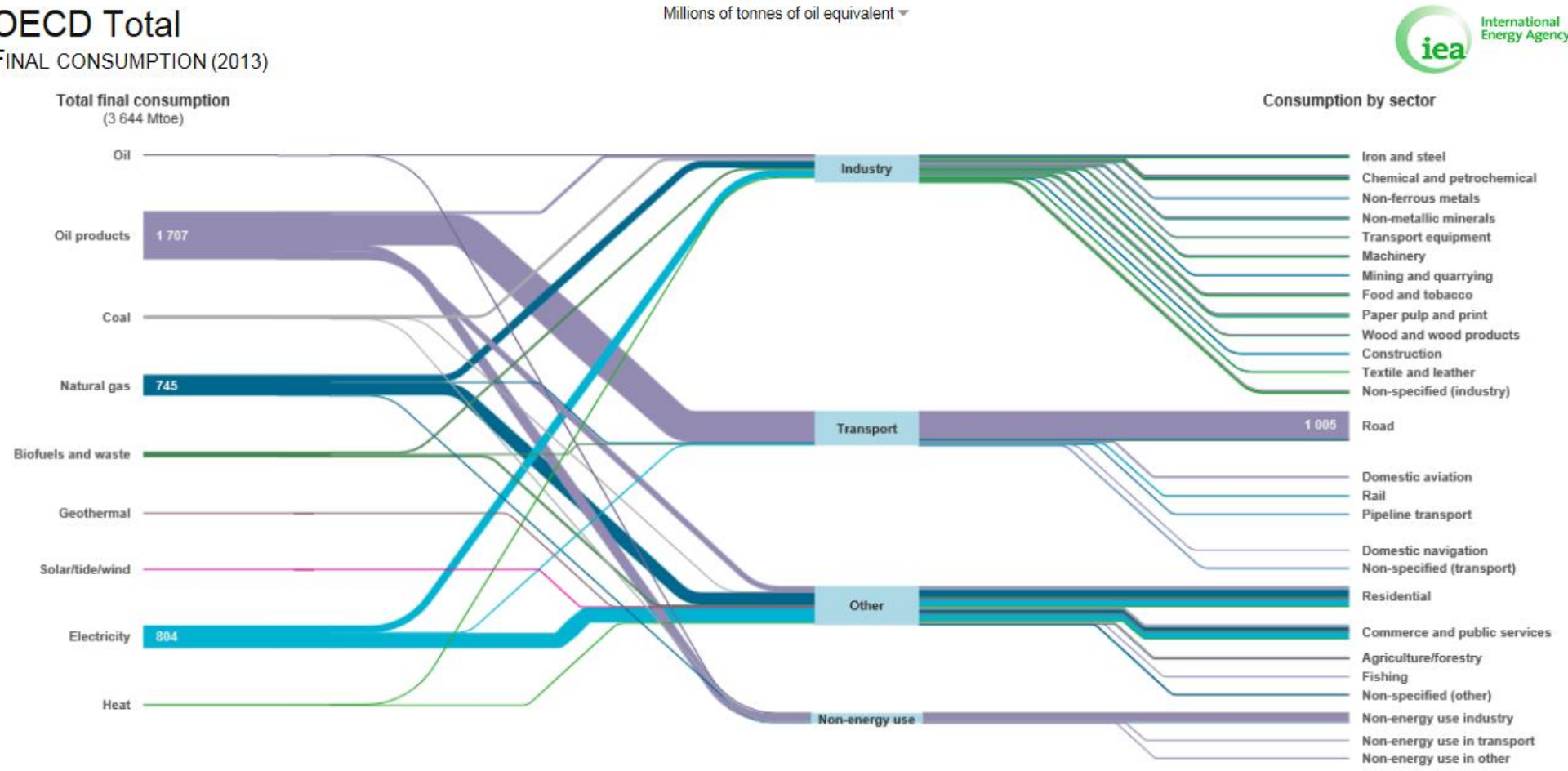
Hydrogen





50 Millioner tonn pr år

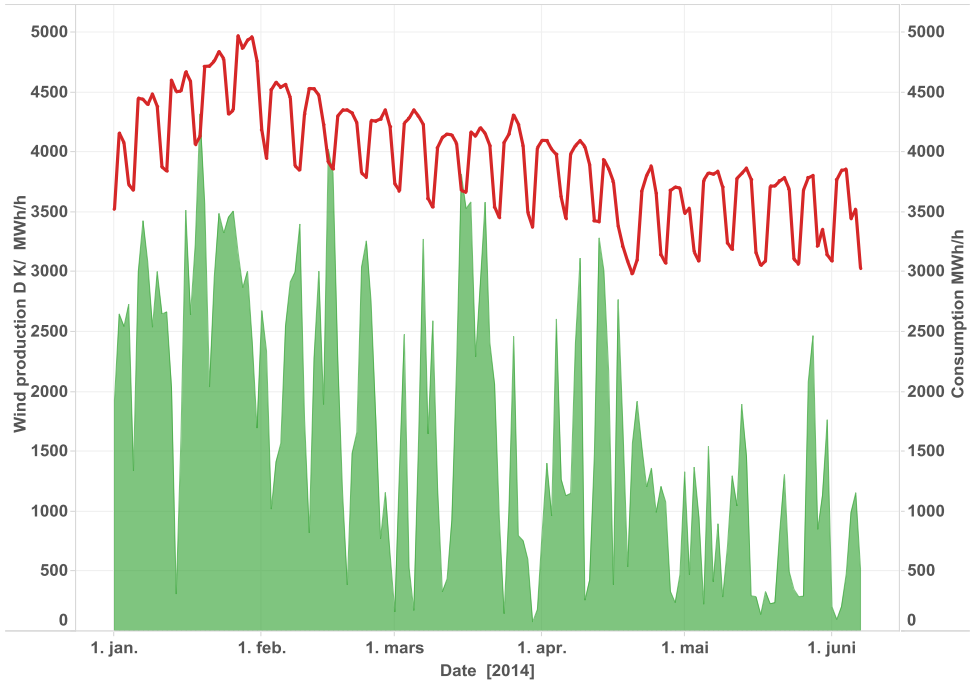
Hvorfor hydrogen?



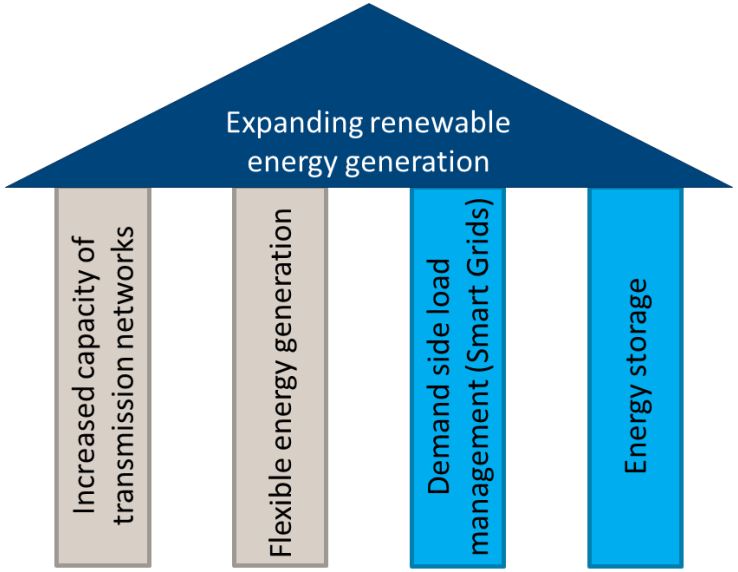
Hvorfor hydrogen?

- *Styrket forsyningssikkerhet*
- *Lønnsom fornybarproduksjon*
- *Mer effektiv og klimavennlig bruk av energi*
- *Næringsutvikling og verdiskaping gjennom effektiv utnyttelse av lønnsomme fornybarressurser.*

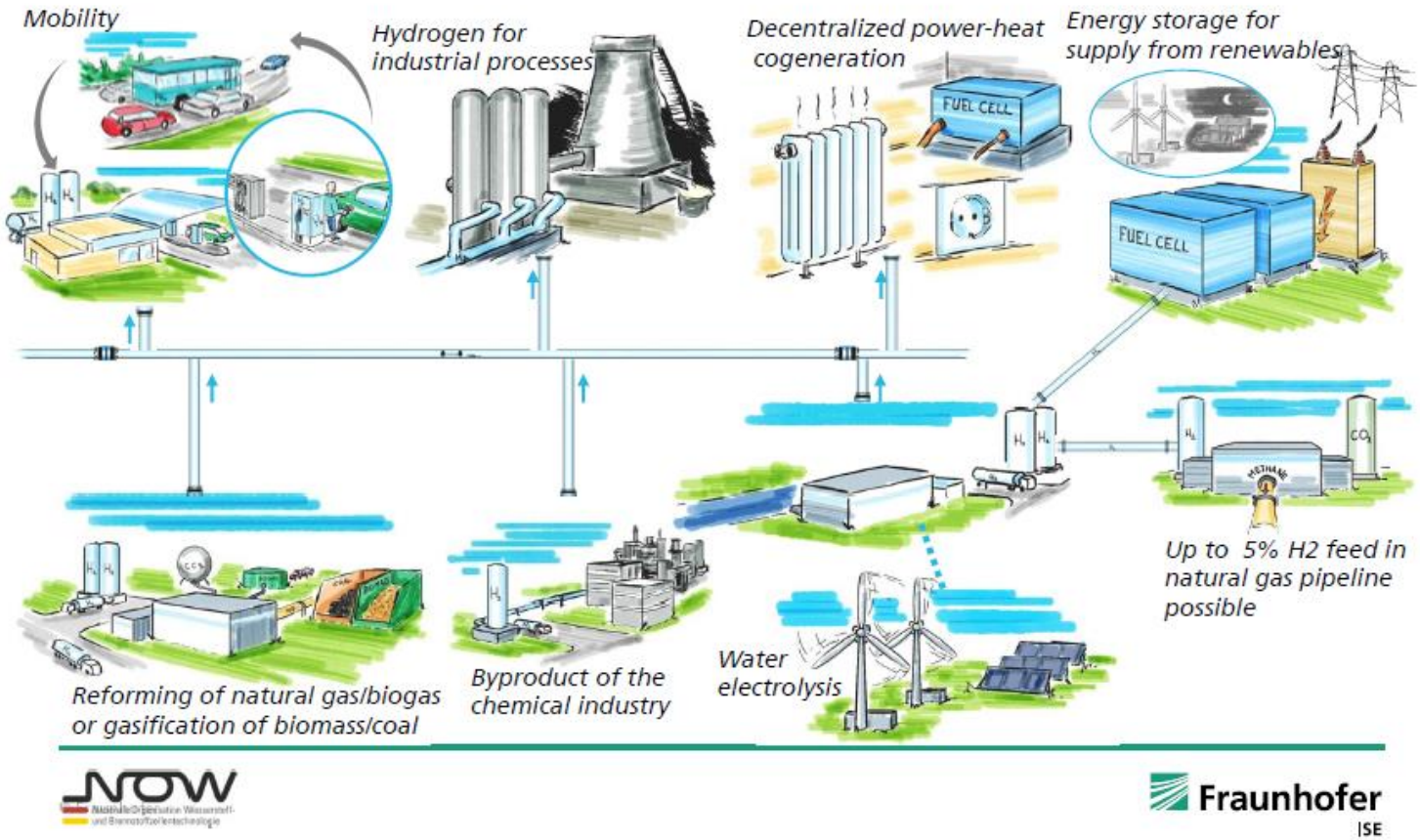
Styrket forsyningssikkerhet

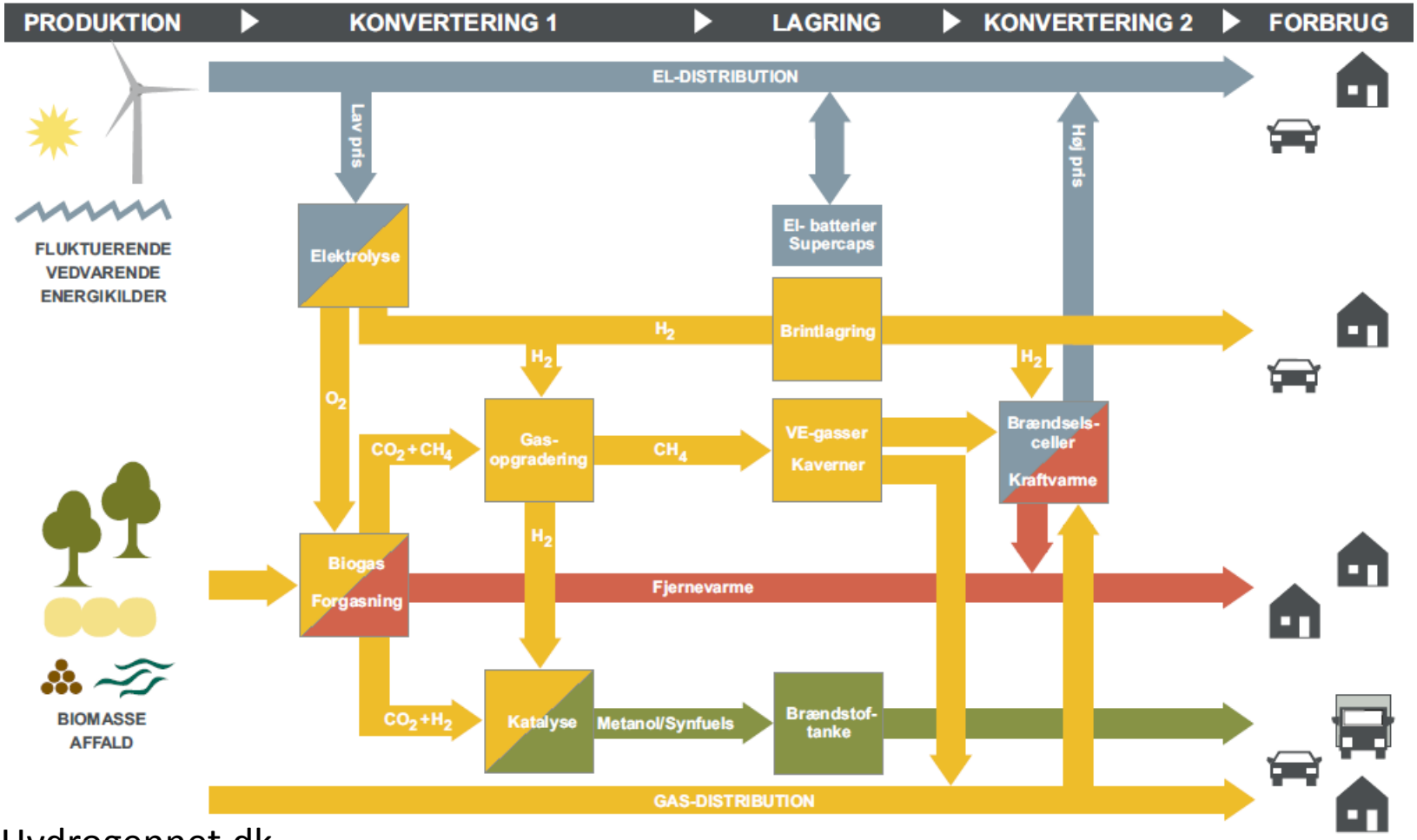


Energy consumption and wind power production in Denmark 2014

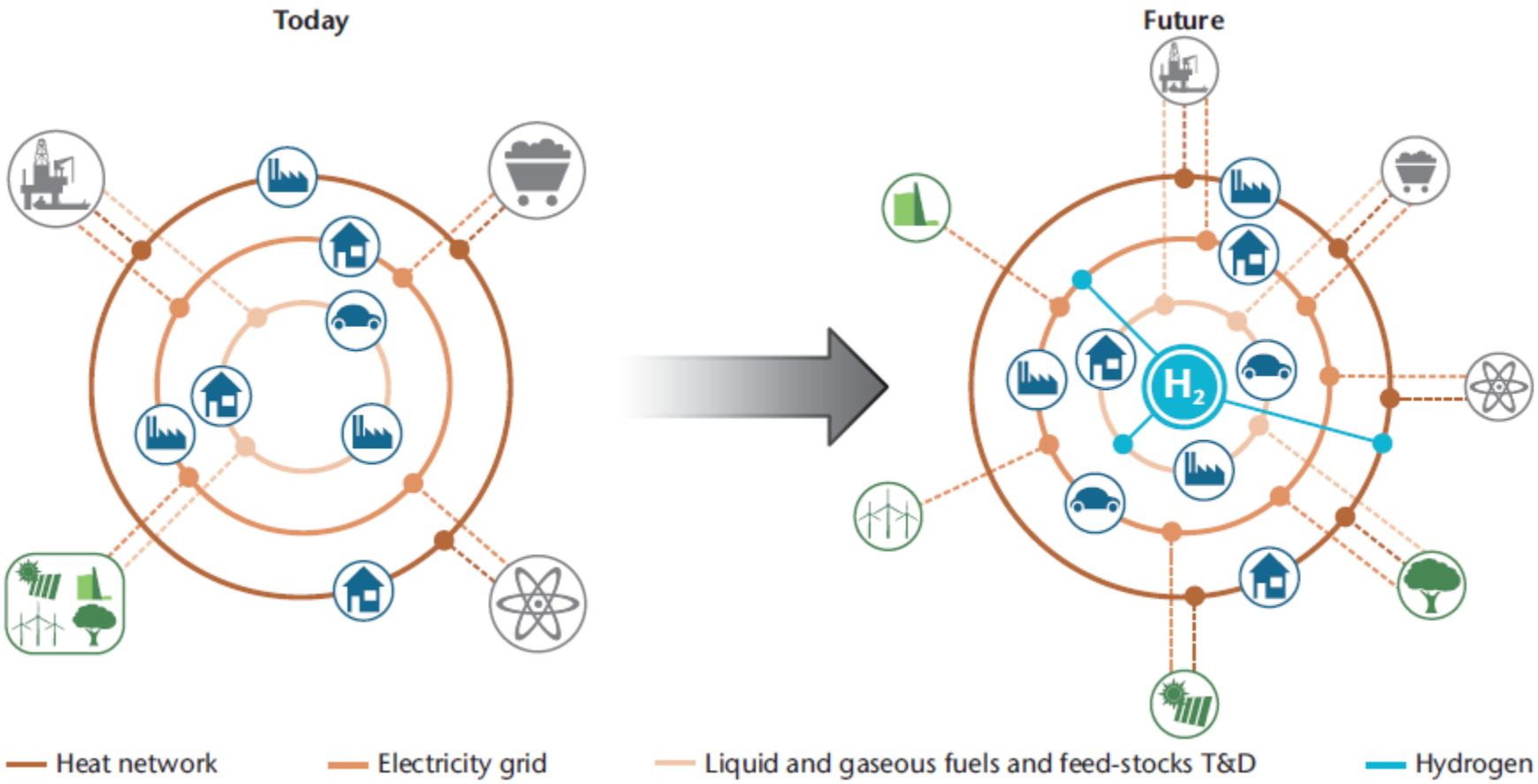


Mer effektiv og klimavennlig bruk av energi





Source: Hydrogennet.dk

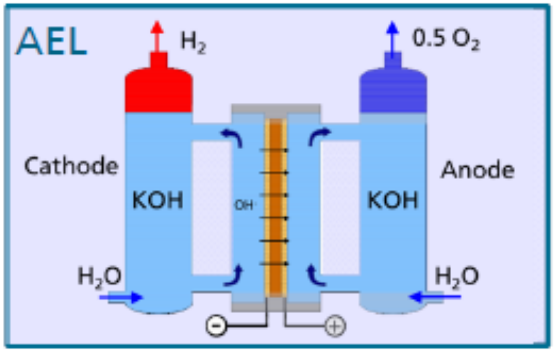

Today
Future
H_2
Heat network
Electricity grid
Liquid and gaseous fuels and feed-stocks T&D
Hydrogen

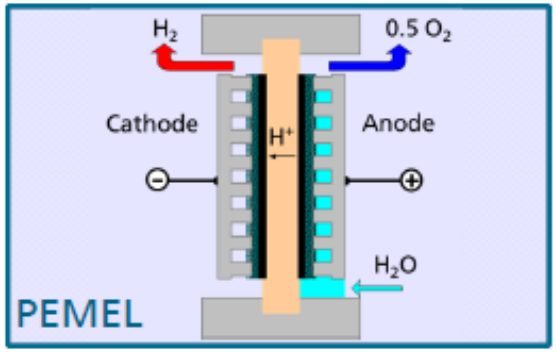
Næringsutvikling og verdiskaping gjennom effektiv utnyttelse av lønnsomme fornybarressurser.

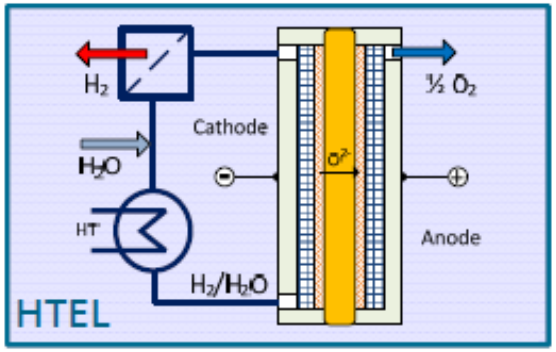
Lønnsom fornybarproduksjon

Hydrogen fra elektrolyse

Technology	Temp. Range	Cathodic Reaction (HER)	Charge Carrier	Anodic Reaction (OER)
Alkaline electrolysis	40 - 90 °C	$2H_2O + 2e^- \Rightarrow H_2 + 2OH^-$	OH^-	$2OH^- \Rightarrow \frac{1}{2}O_2 + H_2O + 2e^-$
Membrane electrolysis	20 - 100 °C	$2H^+ + 2e^- \Rightarrow H_2$	H^+	$H_2O \Rightarrow \frac{1}{2}O_2 + 2H^+ + 2e^-$
High temp. electrolysis	700 - 1000 °C	$H_2O + 2e^- \Rightarrow H_2 + O^{2-}$	O^{2-}	$O^{2-} \Rightarrow \frac{1}{2}O_2 + 2e^-$

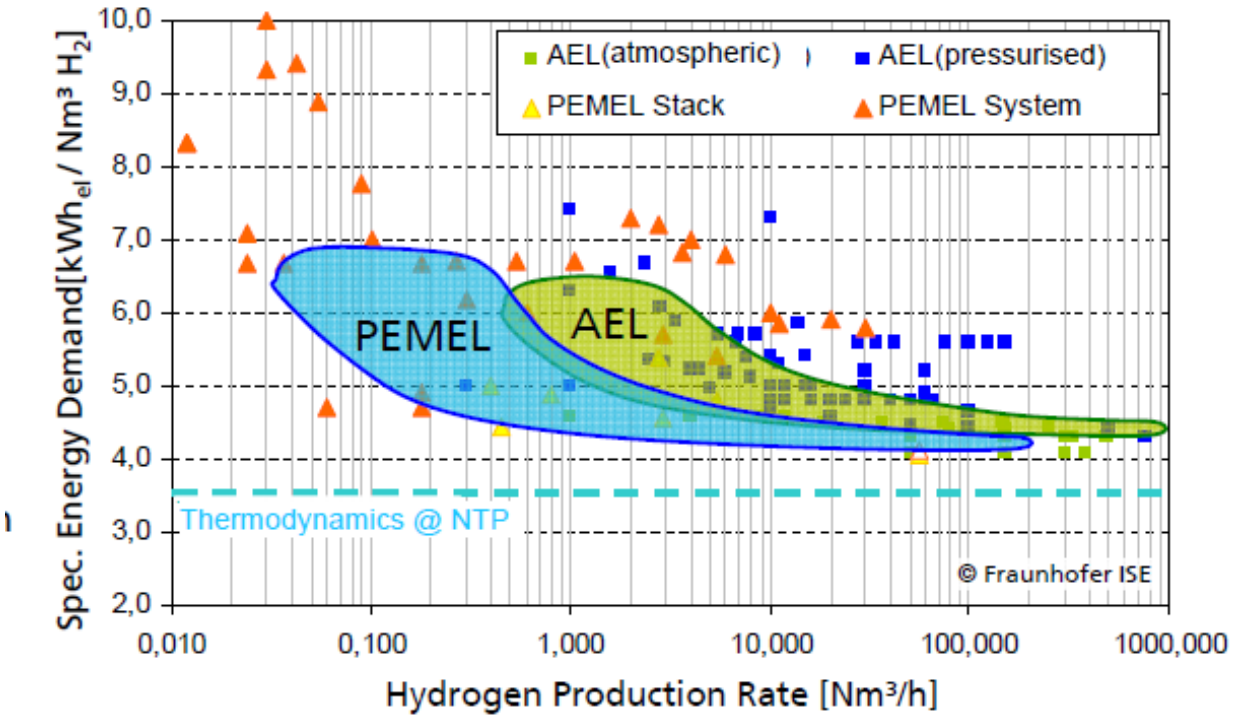






Performance and efficiencies of water electrolysis

- Higher operating pressure
- Higher power density
- Dynamic operation
- Reduction of energy consumption is possible



Dagens elektrolysører

Alkalisk elektrolyse
2 MW, 13.5m x 4 m
Velprøvd teknologi

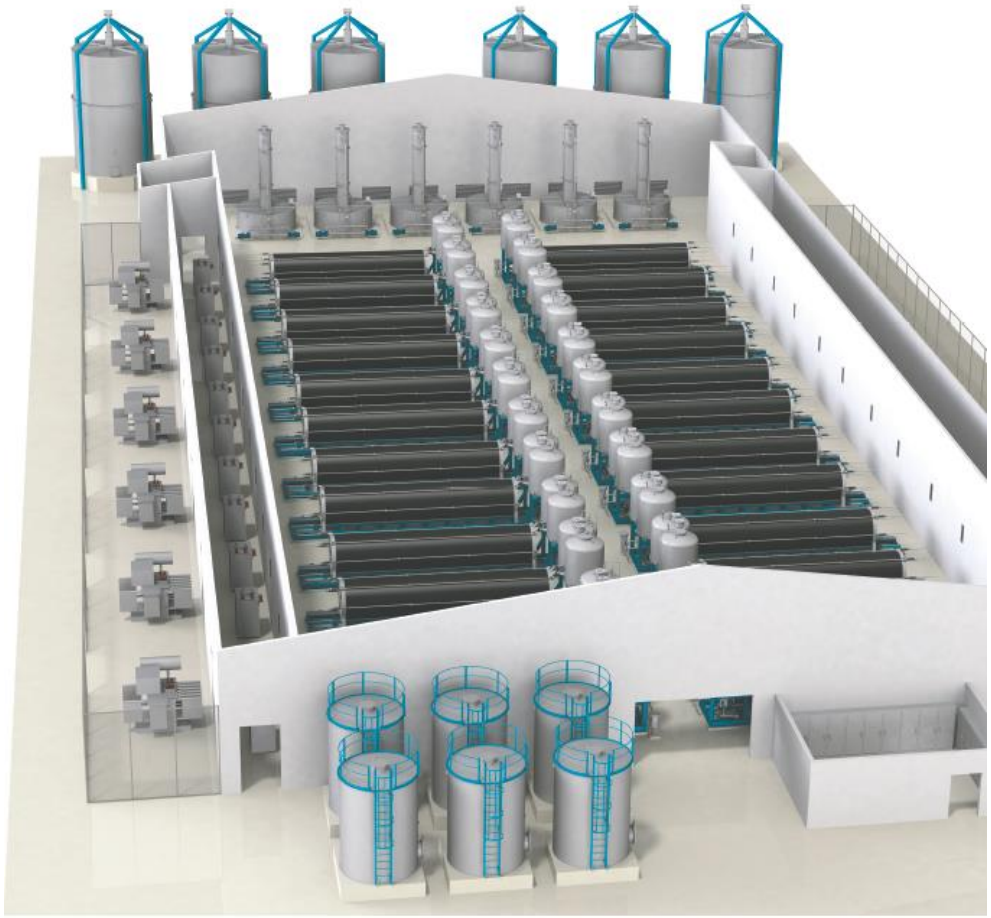
PEM elektrolyse
1.5 MW, 0.8m x 0.55 m
Et par år på markedet

Elektrolyse – en velprøvd og Norsk teknologi

Glomfjord – 135 MW
~ 3 tonn/h

50 MW H_2 PLANT

12 000 Nm^3/hour - 26 000 kg/day



More than 500 MW of H_2 plants delivered since 1927

NEL HYDROGEN

POWER TO GAS

Demonstration Projects and H2 Filling Stations in Germany

Photo: © Thüga
Power to Gas Pilot Project

Photo: © EnBW
H2 Filling Station

Photo: © E.ON
Power to Gas Pilot Project

Photo: © Total
H2 Filling Station

Power to Gas
- in Planning
- in Construction
- in Operations

H2 Filling Station
- in Planning
- in Construction
- in Operations

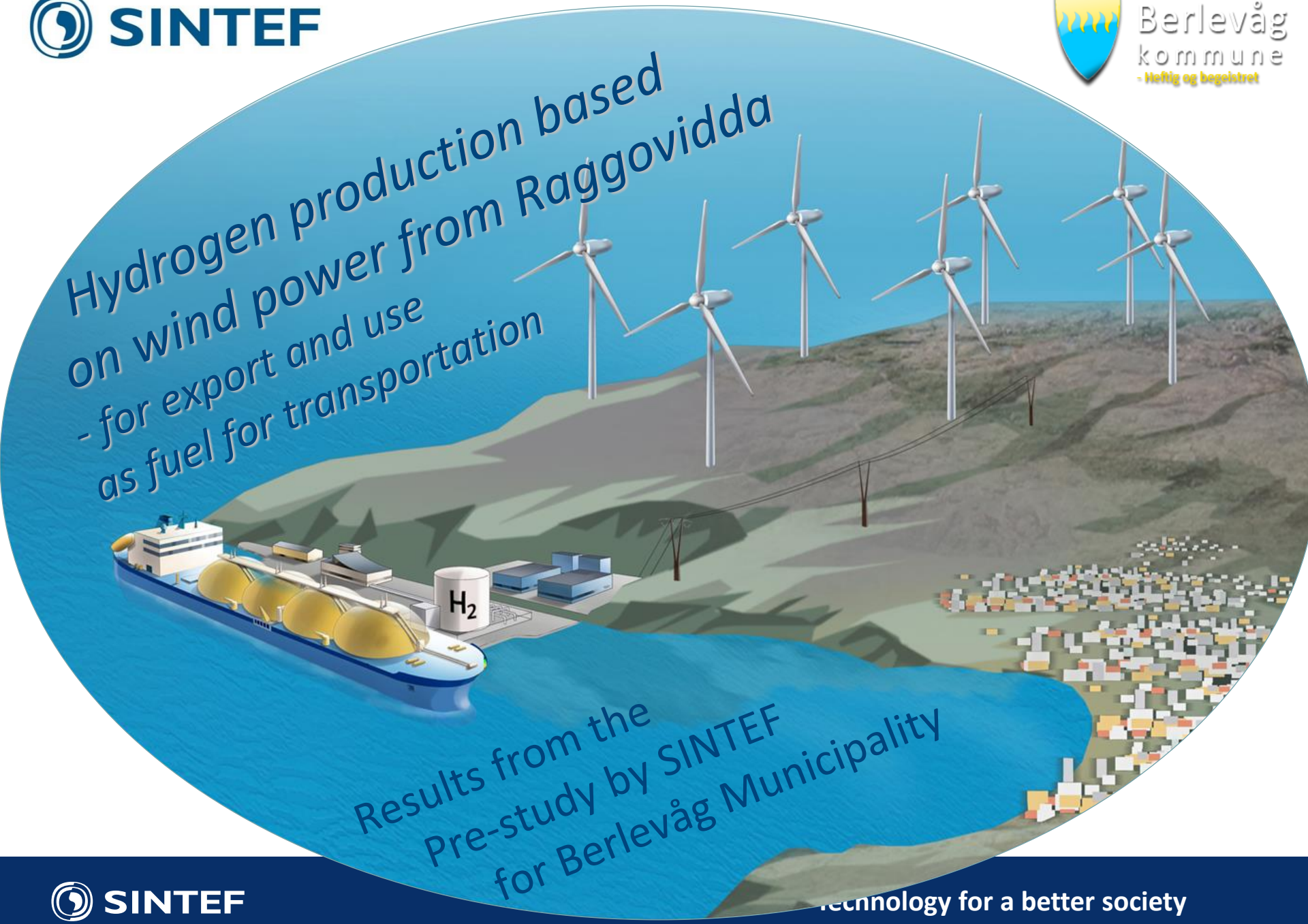
Sources: NOW/DENA

Borders
- (Federal) State Capital
- City-State

SINTEF

Berlevåg kommune
- Heftig og begeistret

Hydrogen production based on wind power from Raggovidda - for export and use as fuel for transportation



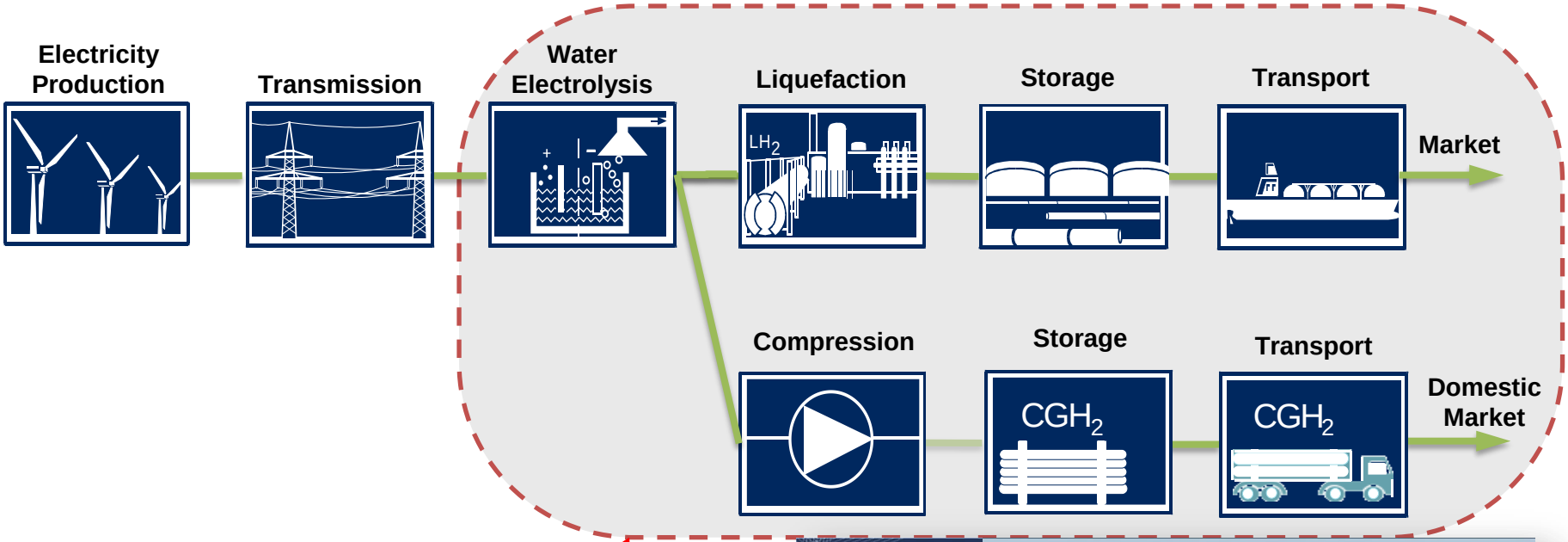
Results from the Pre-study by SINTEF for Berlevåg Municipality

Objective of Pre-study

- ***To assess the prospects of making a sustainable business case for hydrogen production based on the vast wind energy resources at Varangerhalvøya and especially in Berlevåg.***

- Sub-goals:
  - *To provide an overview of state of the art for relevant hydrogen technologies*
  - *To estimate hydrogen cost based on wind energy in Finnmark*
  - *To recommend a step-wise approach to realise increased exploitaion of the regional wind potential in Finnmark.*

Extent of pre-study



Estimates for H_2 delivered to market

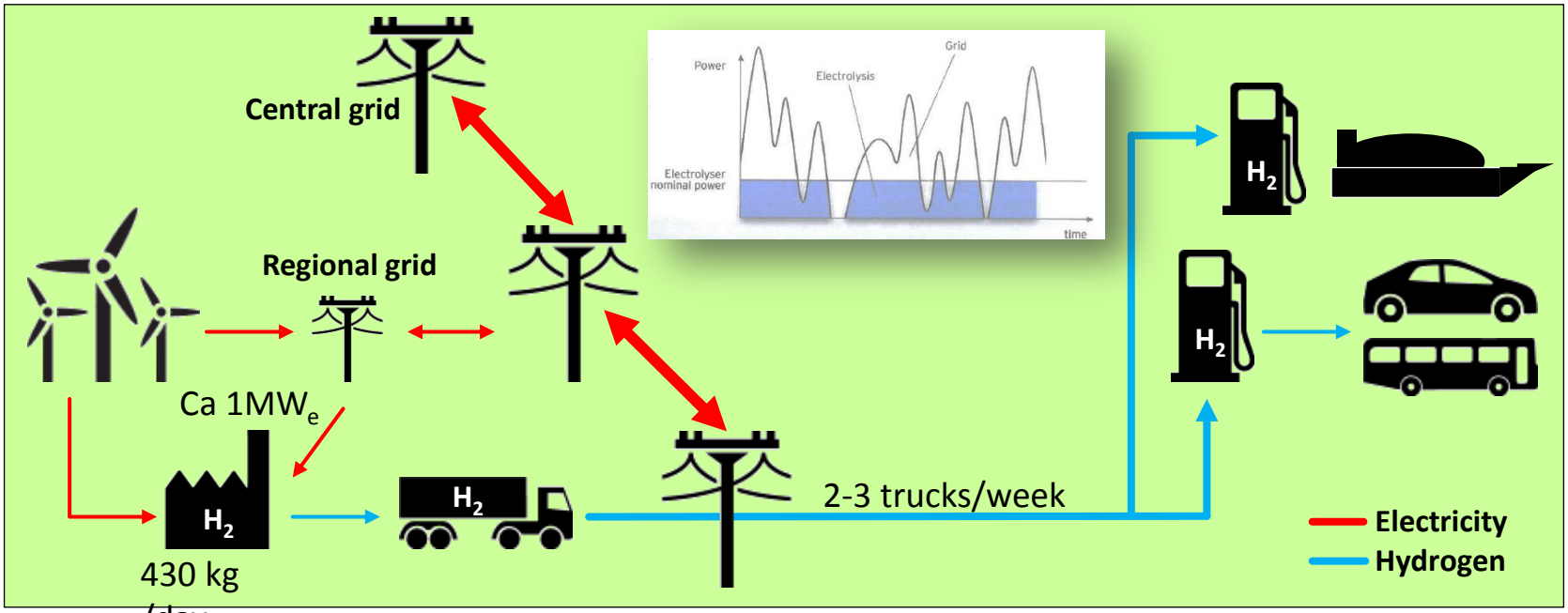
H_2 Cost Estimates from Raggovidda

- Key factors
  - *Production volume*
  - *Annual operational hours of (L)H_2 plant*
  - *Electricity cost, sensitivity 50 ± 30 øre/kWh (7,5 ± 4,5 Yen/kWh)*
  - *Transport and distance to market*

- Cost Estimates for 4 Cases:

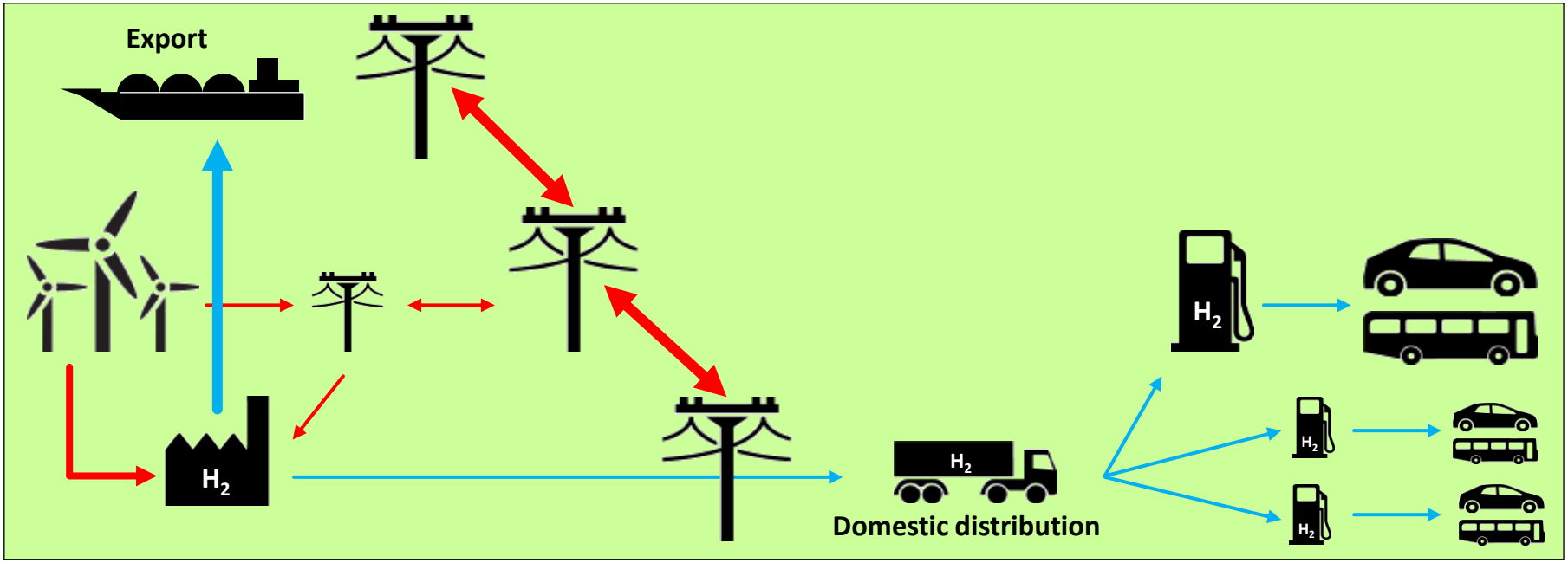
– *Pilot scale, domestic marked,*	*430 kg/day*	*~1 MW*
– *Small scale, export,*	*10 000 kg/day*	*~30 MW*
– *Raggo concession scale, export*	*50 000 kg/day*	*~155 MW*
– *Full scale, export,*	*770 000 kg/day*	*~2 000 MW*

Pilot scale project 2016-2019



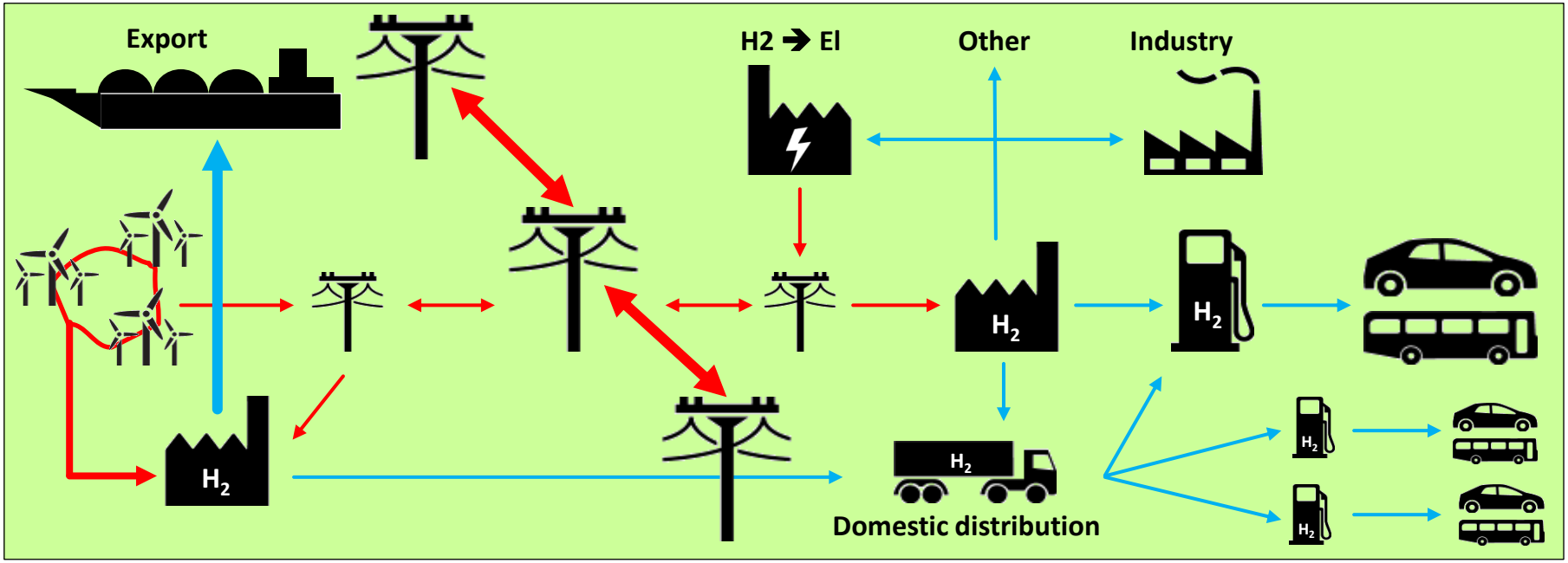
- Continuous H_2-production ~ 1 MW (~ 1000 FCEVs / 20 FC buses / boats)
- Objective: Test and get acquainted to technology in smaller (down-sized) scale
- Assess export options (prerequisites for profitable scale-up)
- Identify potential end-users of oxygen (O_2) (Fish farming?)

Small scale demo project (2020-2024)



- Dynamic H_2-production ~ 30 MW (25 000 FCEVs / 500 buses)
- Additional sales of O_2,
- Assess distribution in regional µ-grids for hydrogen(town gas)

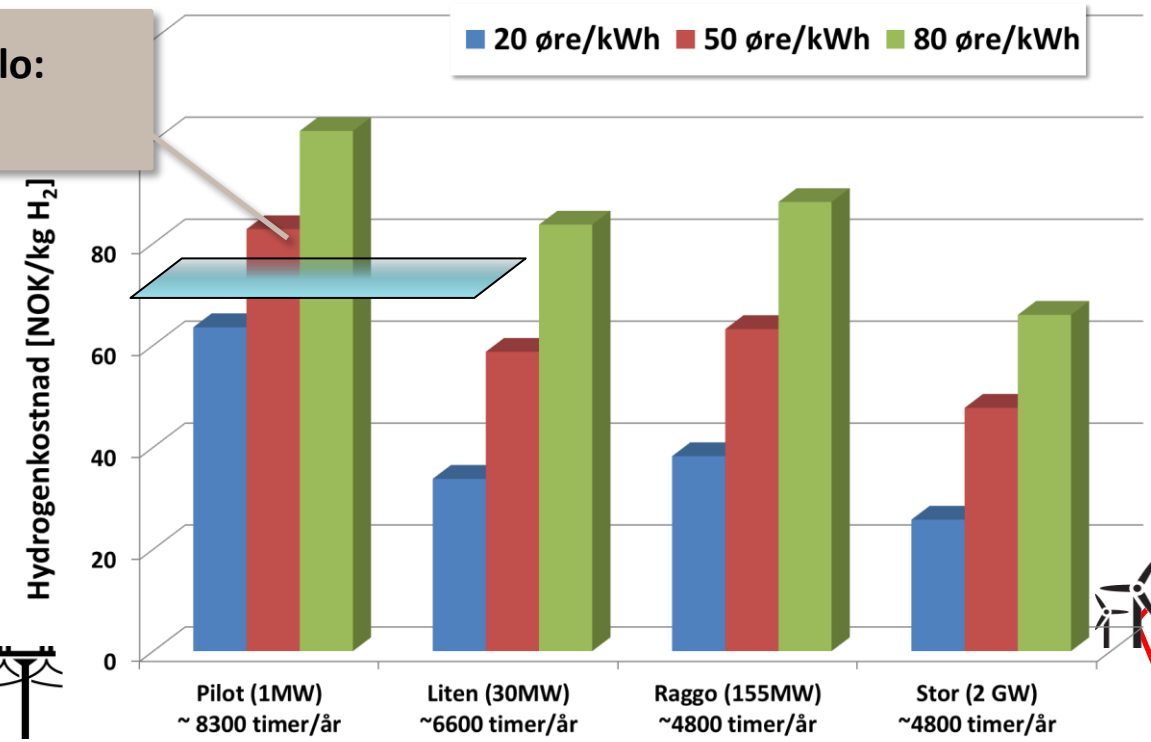
Full scale demo project (2025→)

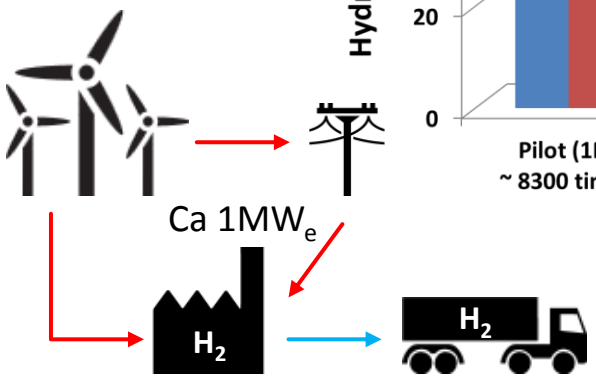


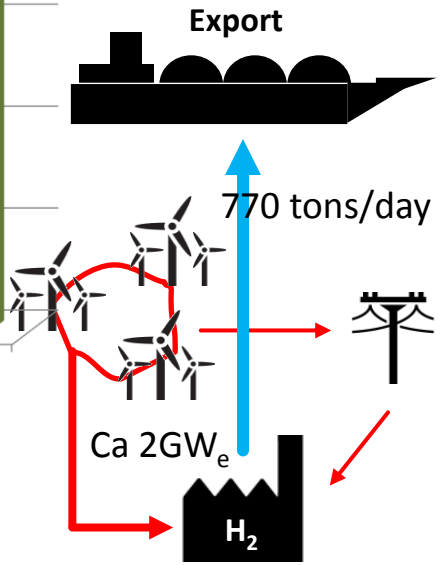
- Full scale H_2-produksjon / Dynamic operation / ~ 2000 MW (3 million FCEVs)
- Use of hydrogen as fuel for transport, grid balancing and export

Cost estimates

Nozzle price in Oslo:
72 kr/kg + MVA



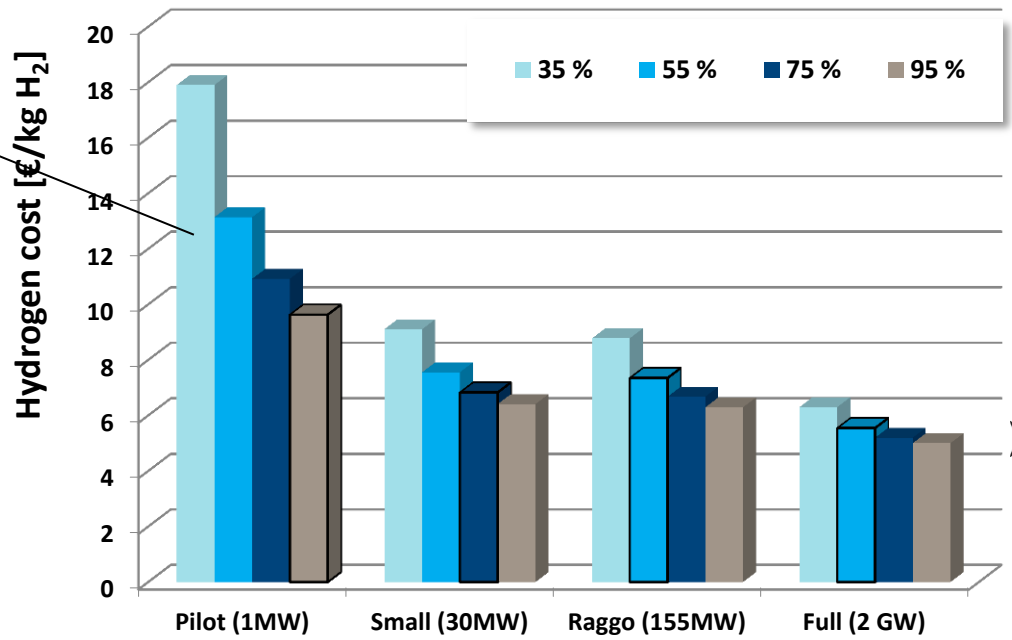


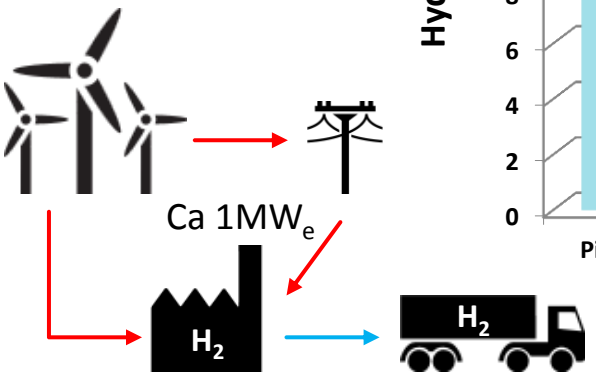


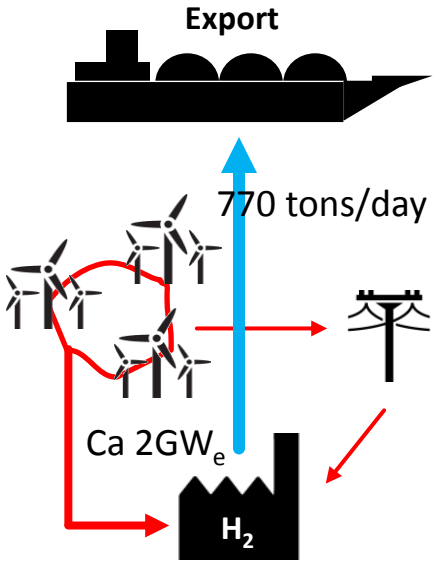
Plant annual operational hours

Average from Norwegian Wind parks

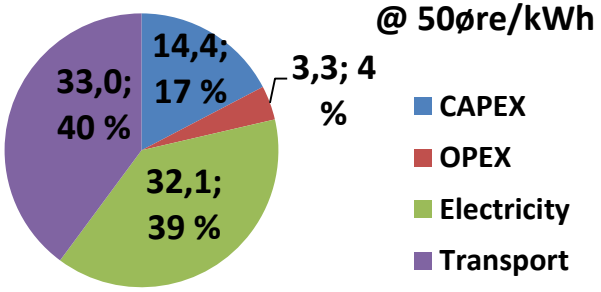
Hydrogen cost @ annual plant utilisation (%) at 50 øre/kWh (58,14€/MWh)

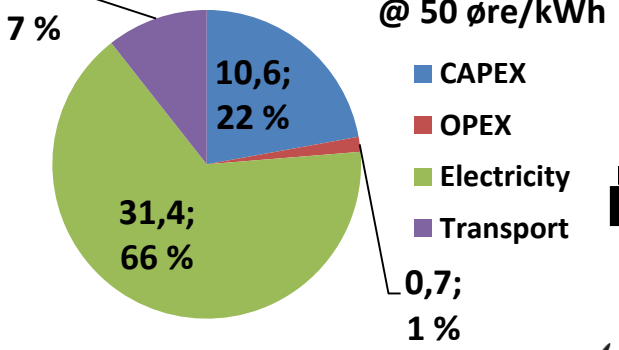


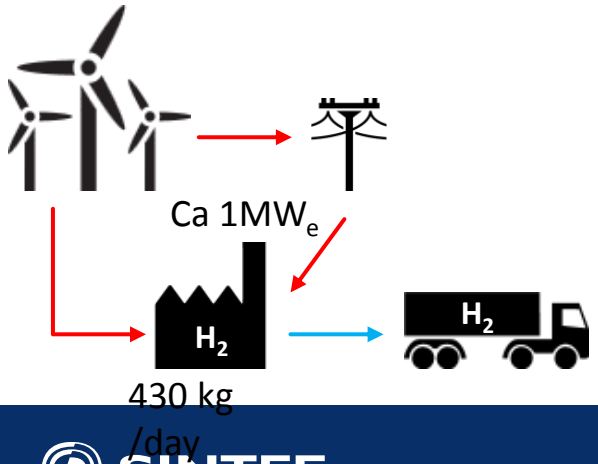


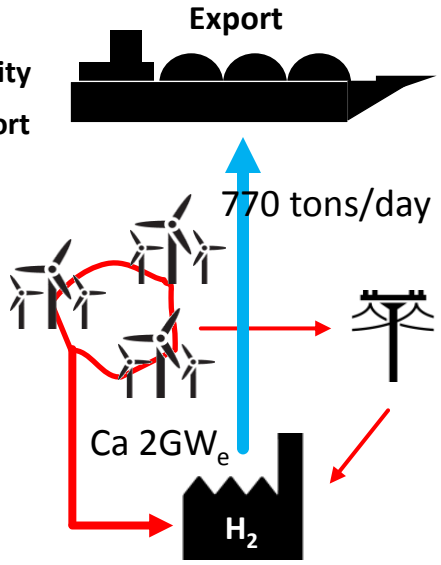


Cost distribution



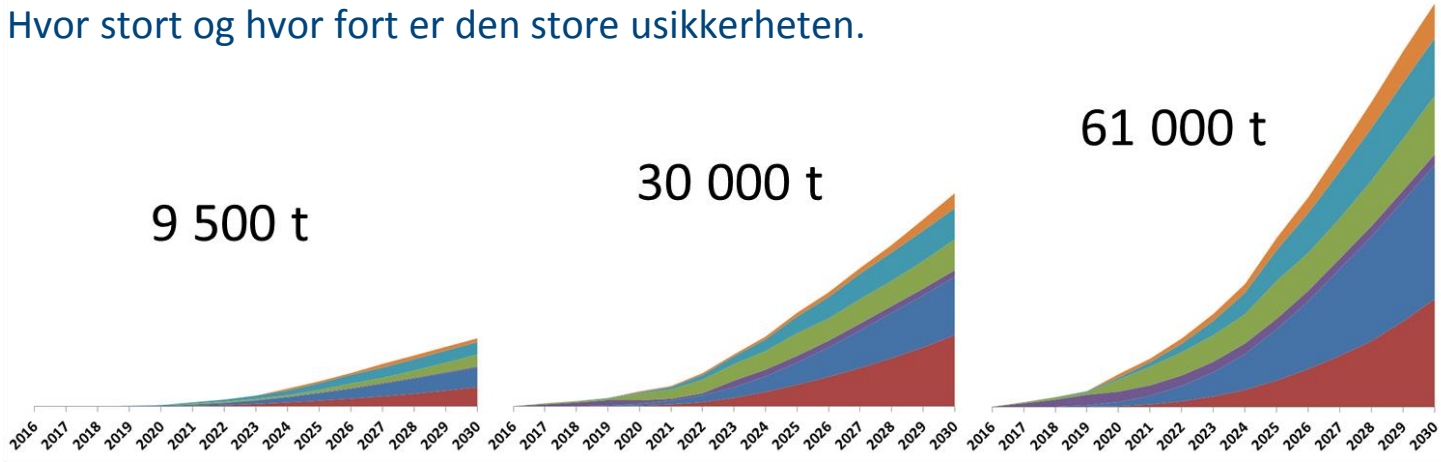






Konklusjoner

- H_2- produksjon kan legge til rette for økt utnyttelse av vindenergi
- Teknologi for H_2-produksjon og eksport er tilgjengelig
  - Norsk industri kan levere både hydrogen og teknologi
- H_2 kostnader avhenger av flere faktorer
  - Strømkostnader og produksjonsvolum. Distanse til markedet.
- Markedet for H_2 som drivstoff, men også som innsatsfaktor I industrien vil øke
  - Hvor stort og hvor fort er den store usikkerheten.



"Hyper" (Research Council, ENERGIX Programme)

- Project responsible: SINTEF Energy Research
- Competence building ("KPN") project co-funded by industry partners (2016–2019, 20 MNOK budget)
- Large-scale hydrogen production and liquefaction in Norway
- Fossil (gas) and renewable primary energy sources

SINTEF

The Institute of Applied Energy

Statoil

NTNU
Kunnskap for en bedre verden

Kawasaki

Mitsubishi Corporation

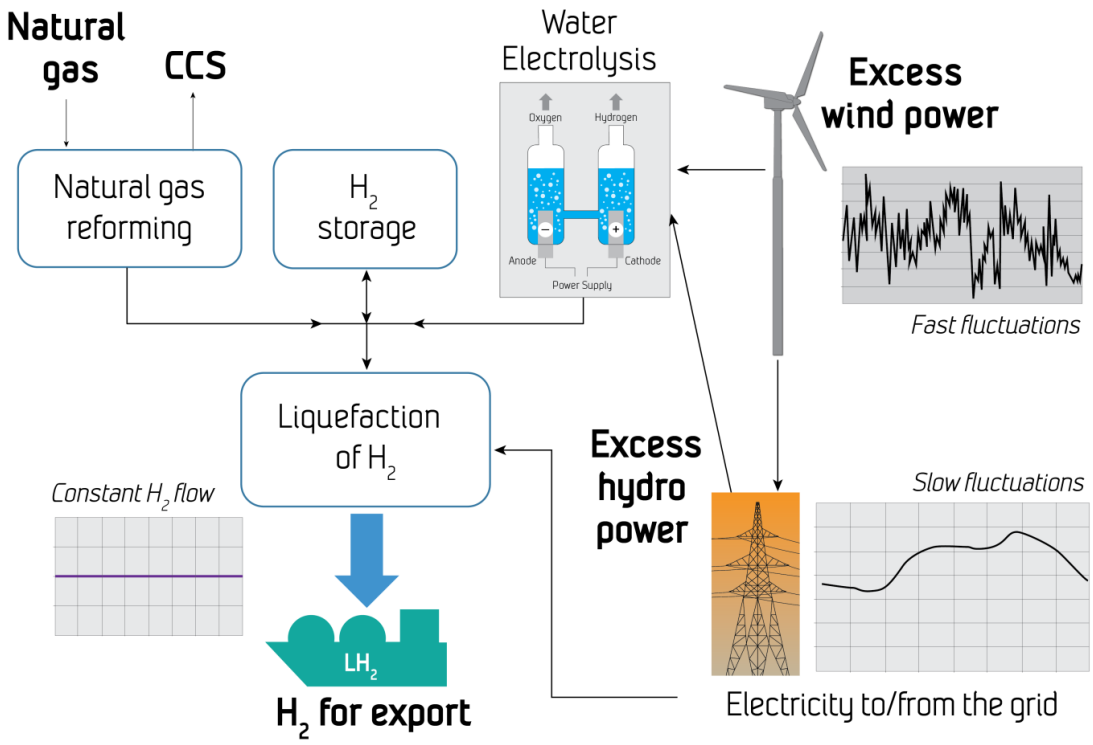
A Member of The Linde Group
KRYOTECHNIK

NEL HYDROGEN

Hyper project description (brief)

System under investigation in Hyper: Combining hydrogen production from fossil and renewable energy.

Knowledge gaps to be closed in all aspects of the production system.



Takk for oppmerksomheten !