Research on energy storage at NTNU and SINTEF

Battery and hydrogen technology

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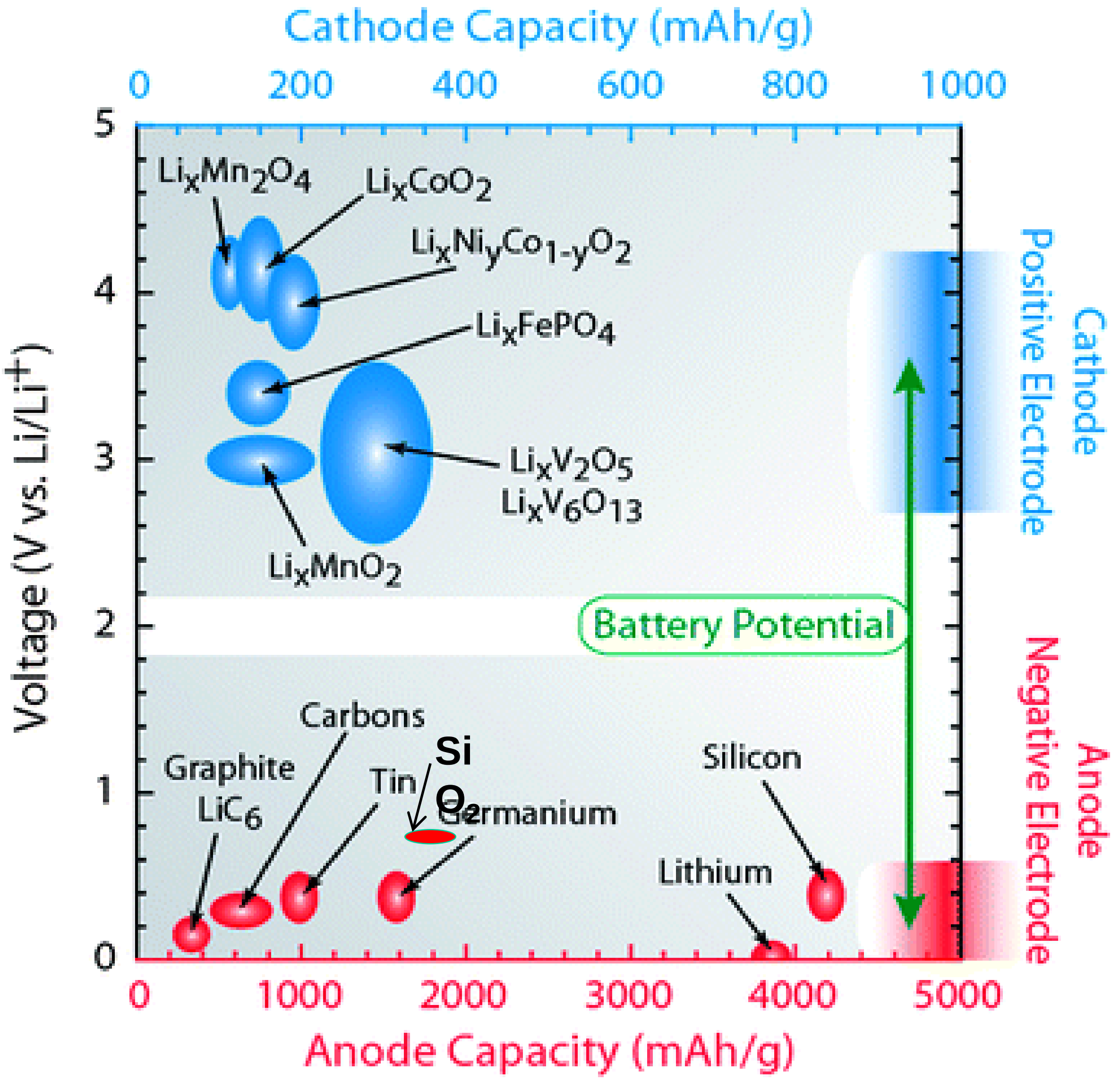
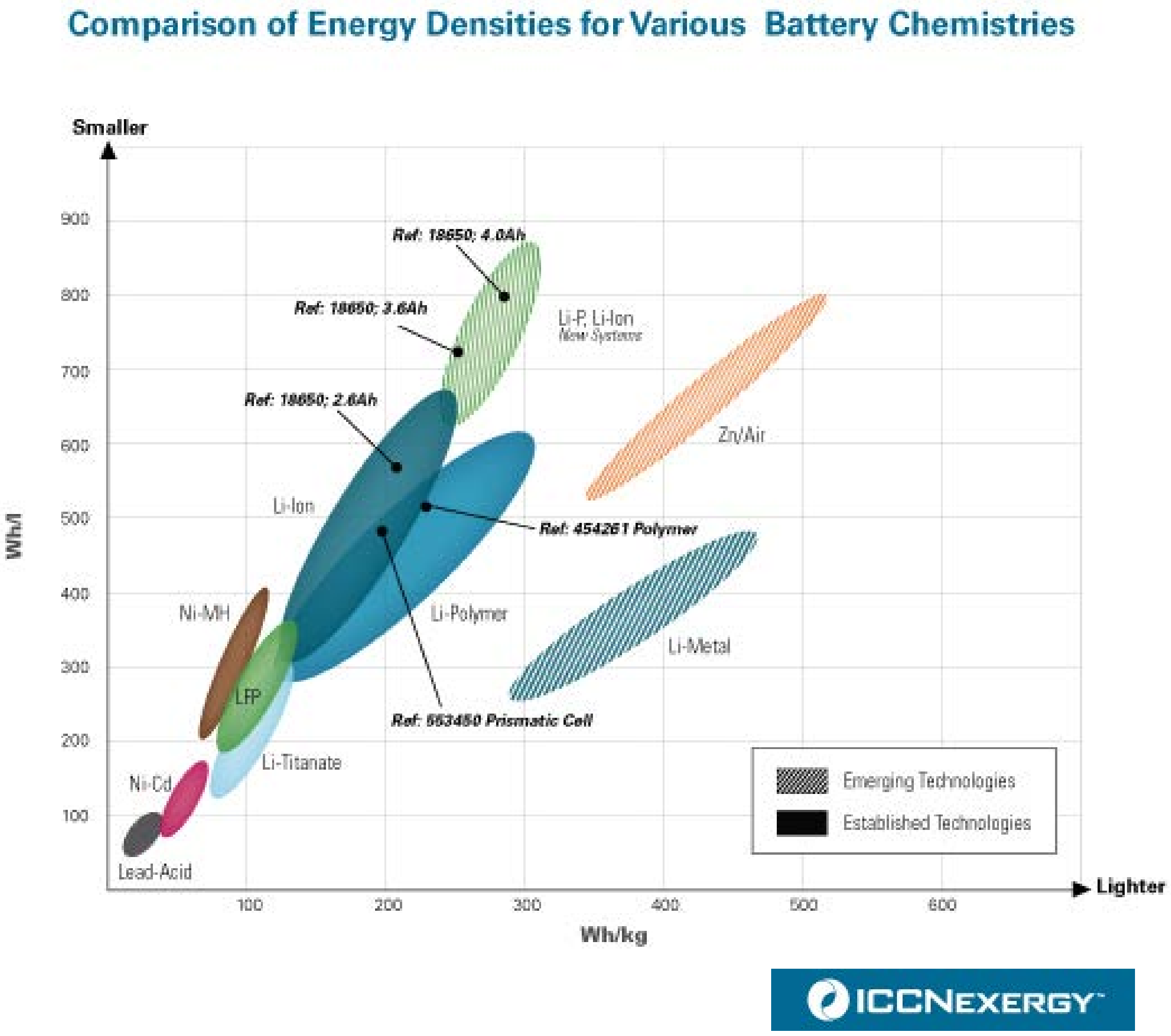
Department of Materials Science and Engineering

Main topics

- Battery technology – status and challenges
  - Li-ion batteries
  - Mg-ion batteries
  - Metal-air batteries (Li-air and Zn-air)
- Hydrogen technology – status and challenges
  - Hydrogen for stationary and portable energy storage
  - Hydrogen storage options



Cathode Capacity (mAh/g)
0
200
400
600
800
1000
Voltage (V vs. Li/Li+)
5
4
3
2
1
0
LixMn2O4
LixCoO2
LixNiyCo1-yO2
LixFePO4
LixV2O5
LixV6O13
LixMnO2
Battery Potential
Positive Electrode
Cathode
Negative Electrode
Anode
Carbons
Graphite
LiC6
Tin
SiO2
Germanium
Silicon
Lithium
0
1000
2000
3000
4000
5000
Anode Capacity (mAh/g)



Comparison of Energy Densities for Various Battery Chemistries
Smaller
Wh/l
Lighter
Wh/kg
Ref: 18650; 4.0Ah
Ref: 18650; 3.6Ah
Ref: 18650; 2.6Ah
Li-P, Li-Ion
New Systems
Zn/Air
Li-Ion
Ref: 454261 Polymer
Ni-MH
Li-Polymer
Li-Metal
LFP
Ref: 553450 Prismatic Cell
Li-Titanate
Ni-Cd
Lead-Acid
Emerging Technologies
Established Technologies
ICCNEXERGY

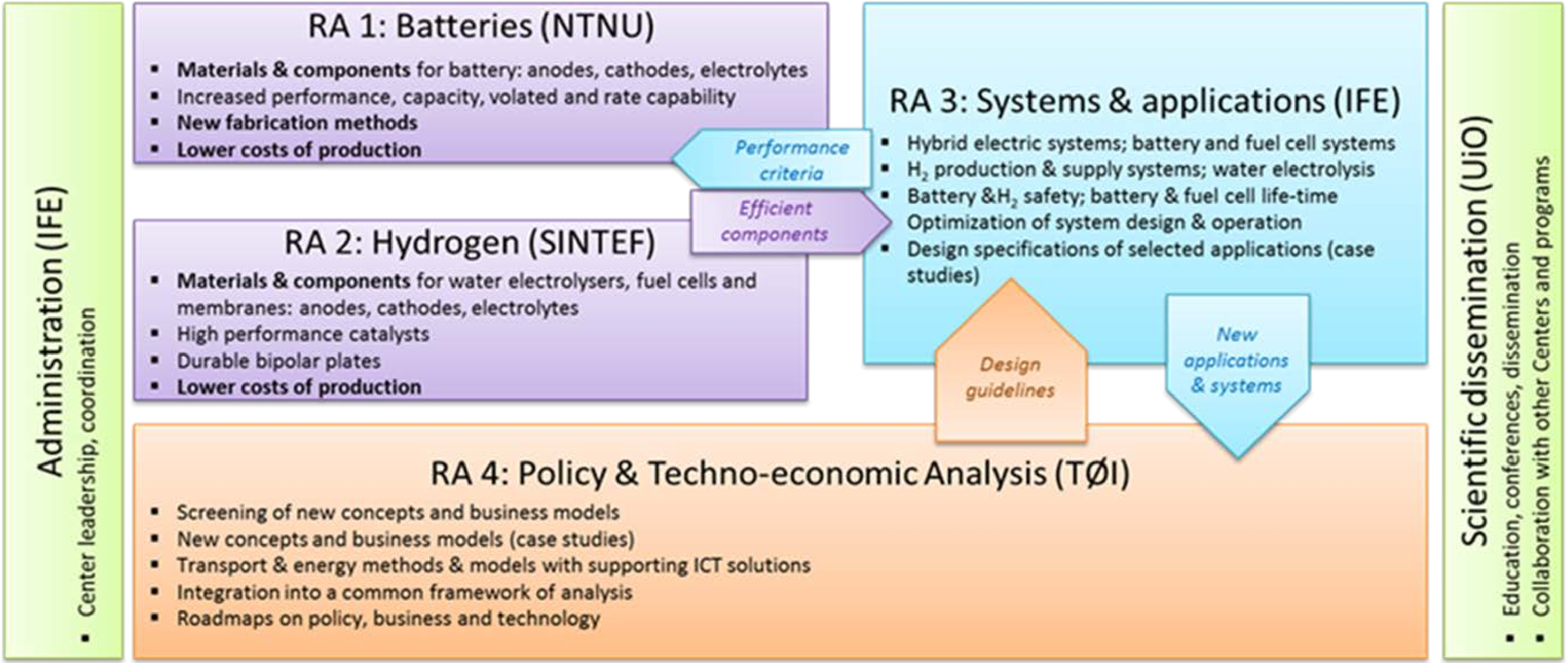
Batteries – current and previous projects

- Previous:
  - CARBATT (carbon anodes in Li-ion batteries)
  - SilcatBatt (cathodes in Li-ion batteries)
  - NanoMag (cathodes in Mg-ion batteries)
  - Enviro-Batt (anodes in Li-ion batteries)
  - 2 PhD projects funded internally by NTNU
- Current:
  - OPT-ELLiAIR (Li-air batteries)
  - SiBEC (Si anodes and full cell Li-ion batteries)
  - ADMIRE (Mg-ion batteries)
  - ZAS (EU project on Zn-air batteries)
  - 3 PhD projects funded internally by NTNU (2 on Li-ion and 1 on Mg-ion batteries)
  - FME MoZEES (battery and hydrogen technology)

Recently awarded projects:

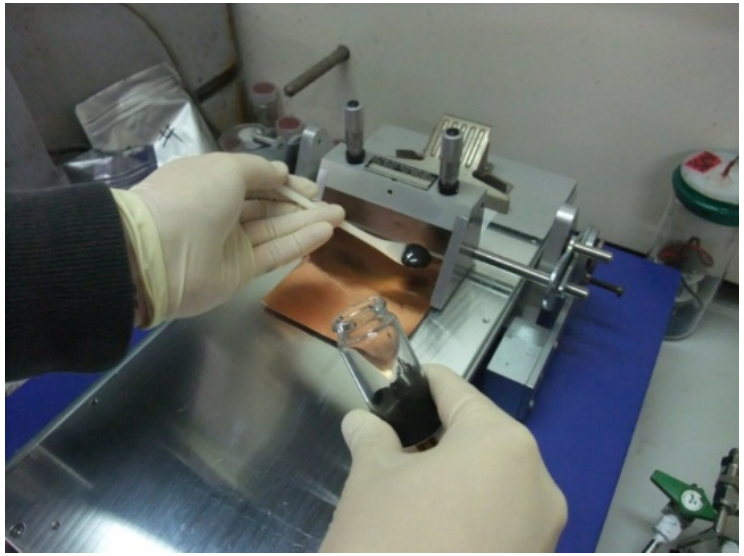
- Bio-Batt (Nano2021) – NFR-project on silica anodes
- Discovery project on silica anodes

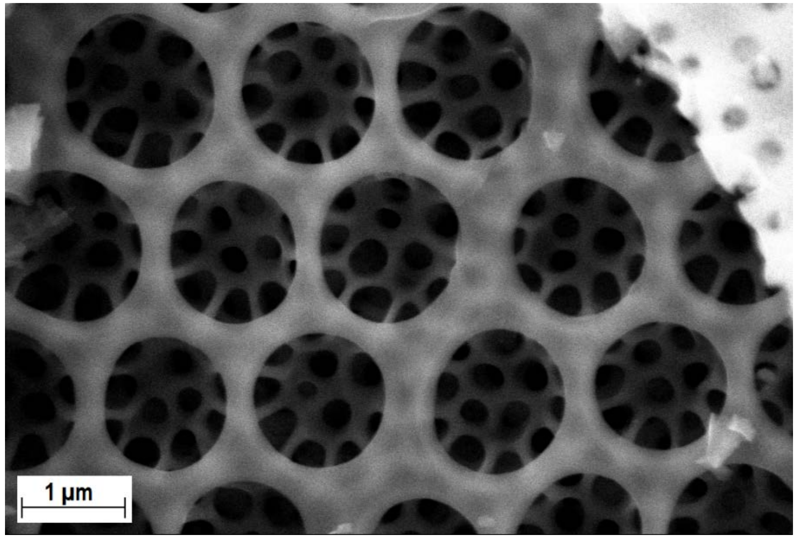
FME MoZEES


Administration (IFE)
▪ Center leadership, coordination
RA 1: Batteries (NTNU)
▪ Materials & components for battery: anodes, cathodes, electrolytes
▪ Increased performance, capacity, volated and rate capability
▪ New fabrication methods
▪ Lower costs of production
Performance criteria
Efficient components
RA 2: Hydrogen (SINTEF)
▪ Materials & components for water electrolysers, fuel cells and membranes: anodes, cathodes, electrolytes
▪ High performance catalysts
▪ Durable bipolar plates
▪ Lower costs of production
RA 3: Systems & applications (IFE)
▪ Hybrid electric systems; battery and fuel cell systems
▪ H_2 production & supply systems; water electrolysis
▪ Battery &H_2 safety; battery & fuel cell life-time
Optimization of system design & operation
▪ Design specifications of selected applications (case studies)
Design guidelines
New applications & systems
RA 4: Policy & Techno-economic Analysis (TØI)
▪ Screening of new concepts and business models
▪ New concepts and business models (case studies)
▪ Transport & energy methods & models with supporting ICT solutions
▪ Integration into a common framework of analysis
▪ Roadmaps on policy, business and technology
Scientific dissemination (UiO)
▪ Education, conferences, dissemination
▪ Collaboration with other Centers and programs

Bio-Batt

- Using diatom frustules (silica) as anode material in Li-ion batteries
- Water soluble alginate binders makes this solution much more environmetally friendly



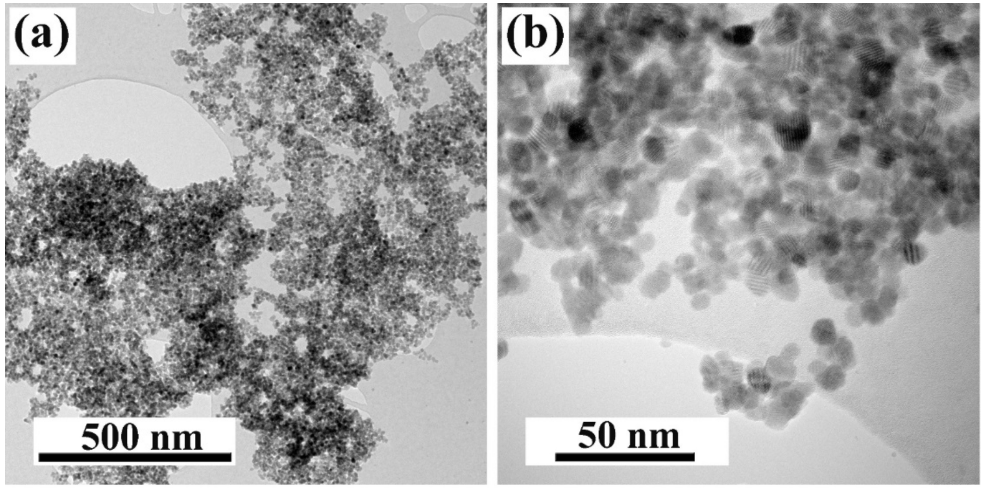


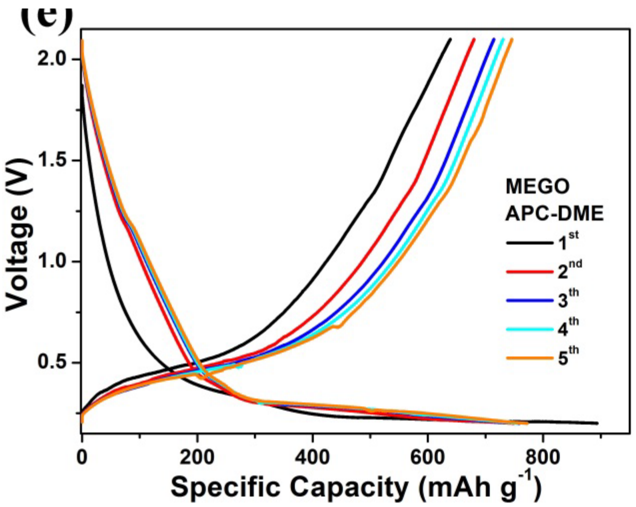
SiBEC

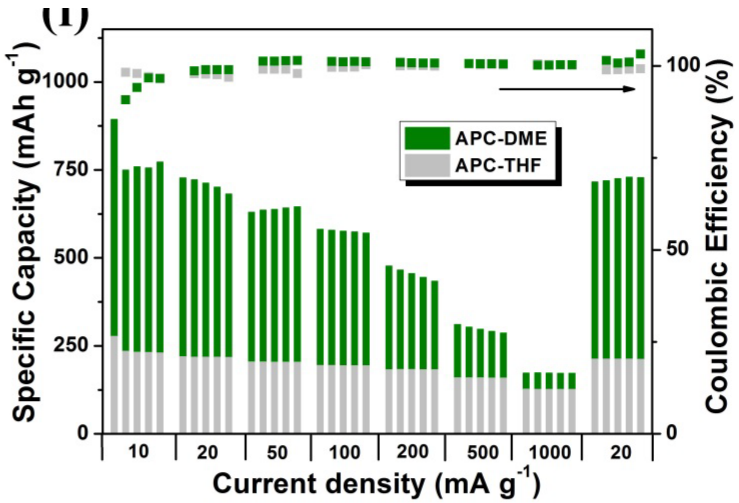
- Collaboration between NTNU, IFE, SINTEF, Elkem, FMC Biopolymer and CerPoTech
- Total budget 20 MNOK
- Develop anodes for Li-ion batteries using Si from Elkem and alginate binders from FMC Biopolymer
- Fokus on full cell testing using commercially available cathodes with the Si anodes

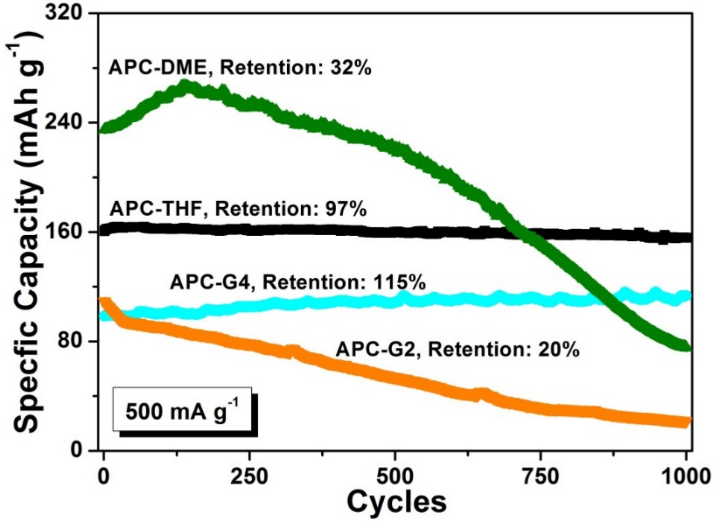
NanoMag

- New cathode material for Mg-ion batteries
- Stable cycling at high capacities and high current rates
- Low operating voltage









Challenges and opportunities

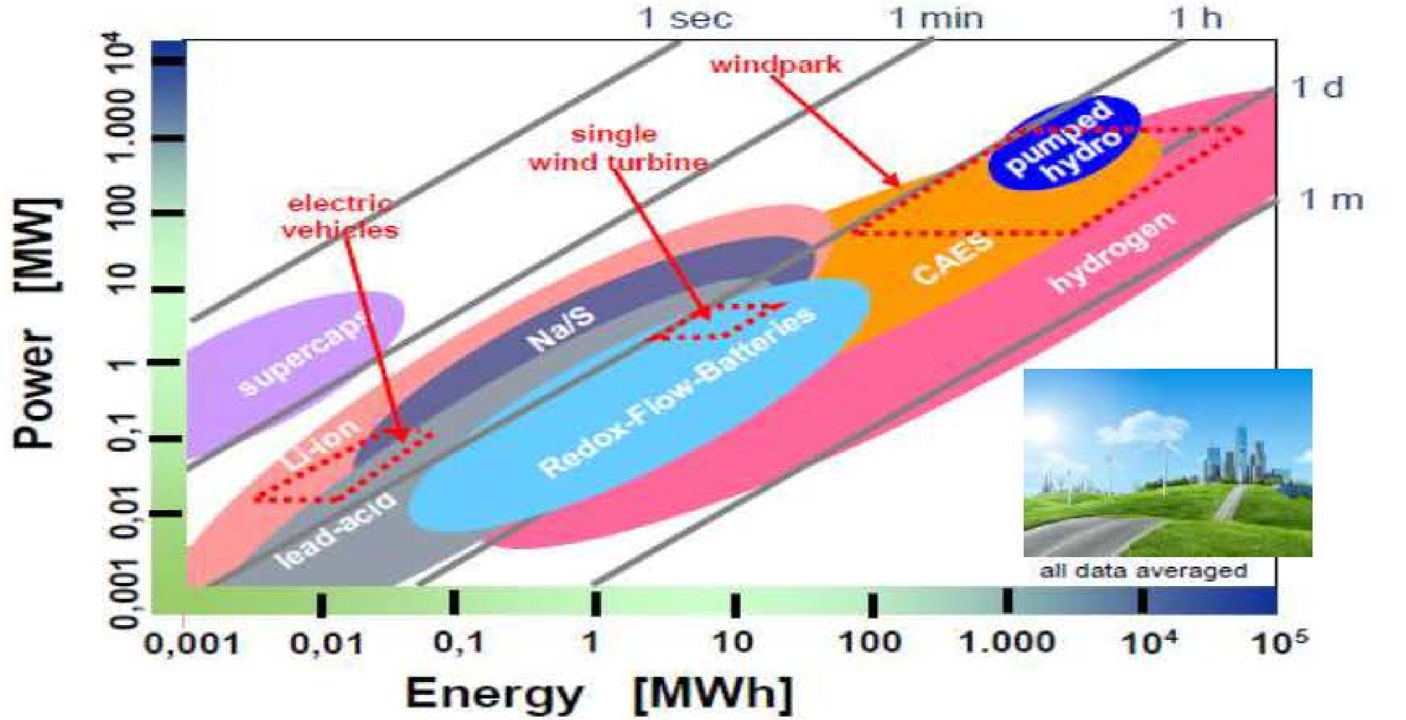
- Li-ion batteries
  - Established technology and extremely competitive
  - Hard to find a niche
  - What can we do:
    - Environmetal aspects (CO_2 footprint for production)
    - Must join forces and work cross disciplinary – both academia and industry (i.e MoZEES)
    - Target specific applications (i.e. maritime sector)
    - Use local natural resources and work with Norwegian industry
- Mg-ion batteries and metall-air batteries
  - Theoretical capacities exceed those of Li-ion technology
  - Less research worldwide – easier to make significant improvements
  - Materials development is key issue
  - Understand fundamental aspects

Large Scale Energy Storage

Options to address `grid storage´ are limited

SIEMENS

segmentation of large-scale (electrical) energy storage



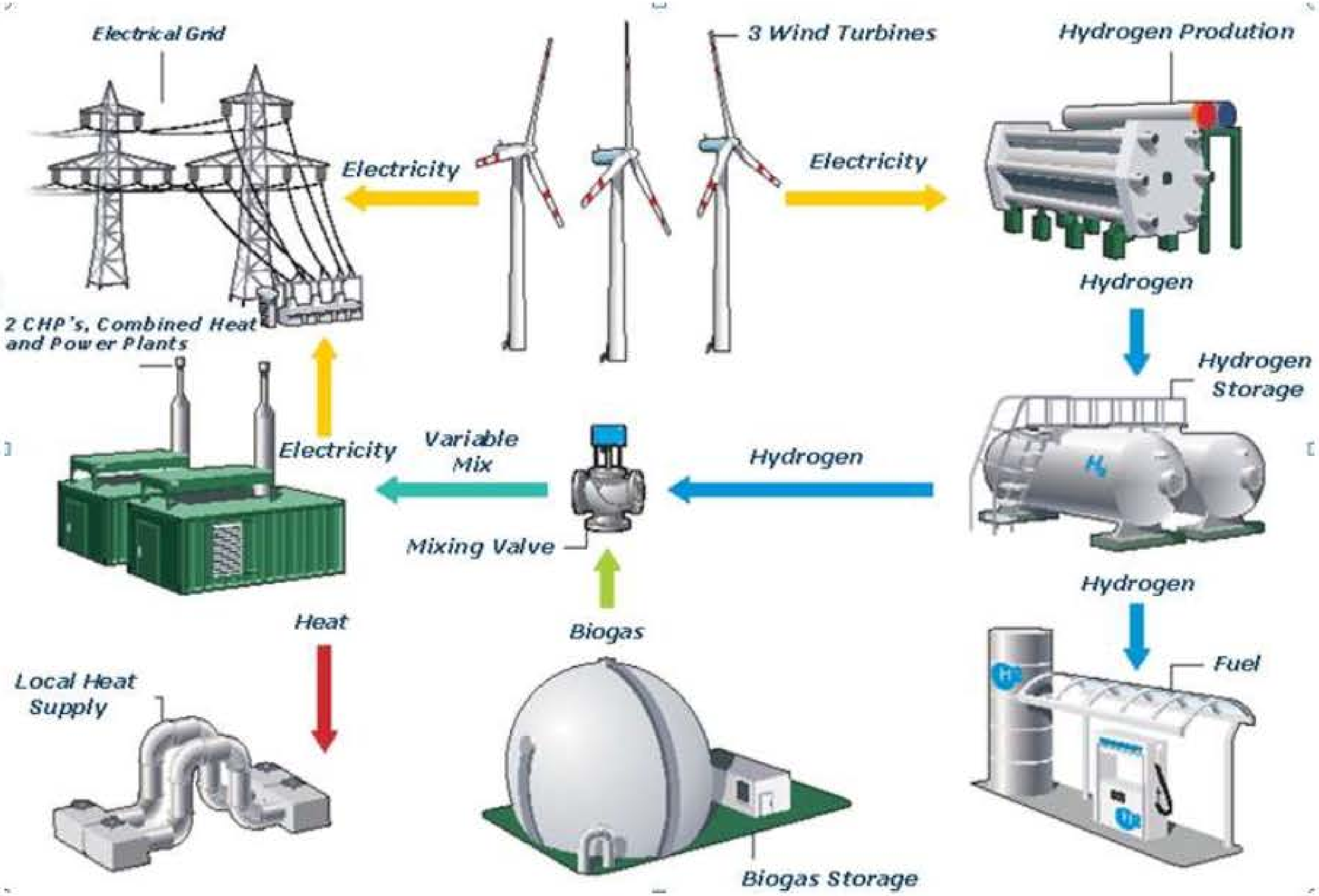
key statements:

- Battery storage applications are limited in the hour range
- Energy storage >100 MW can only be addressed by Pumped Hydro, Compressed Air (CAES) and Hydrogen
- The potential to extend pumped hydro capacities is very limited
- CAES has limitations in operational flexibility and capacity

Hydrogen is the only option to cover energy capacities > 10 GWh

Hydrogen Storage – Hybrid Power Plant

- Enertrag, Vattenfall, Total are developing a wind-hydrogen hybrid power plant
- Wind farm with direct coupling to electrolyzer
- Hydrogen storage
- Utilization of hydrogen in small scale CHP and for external use



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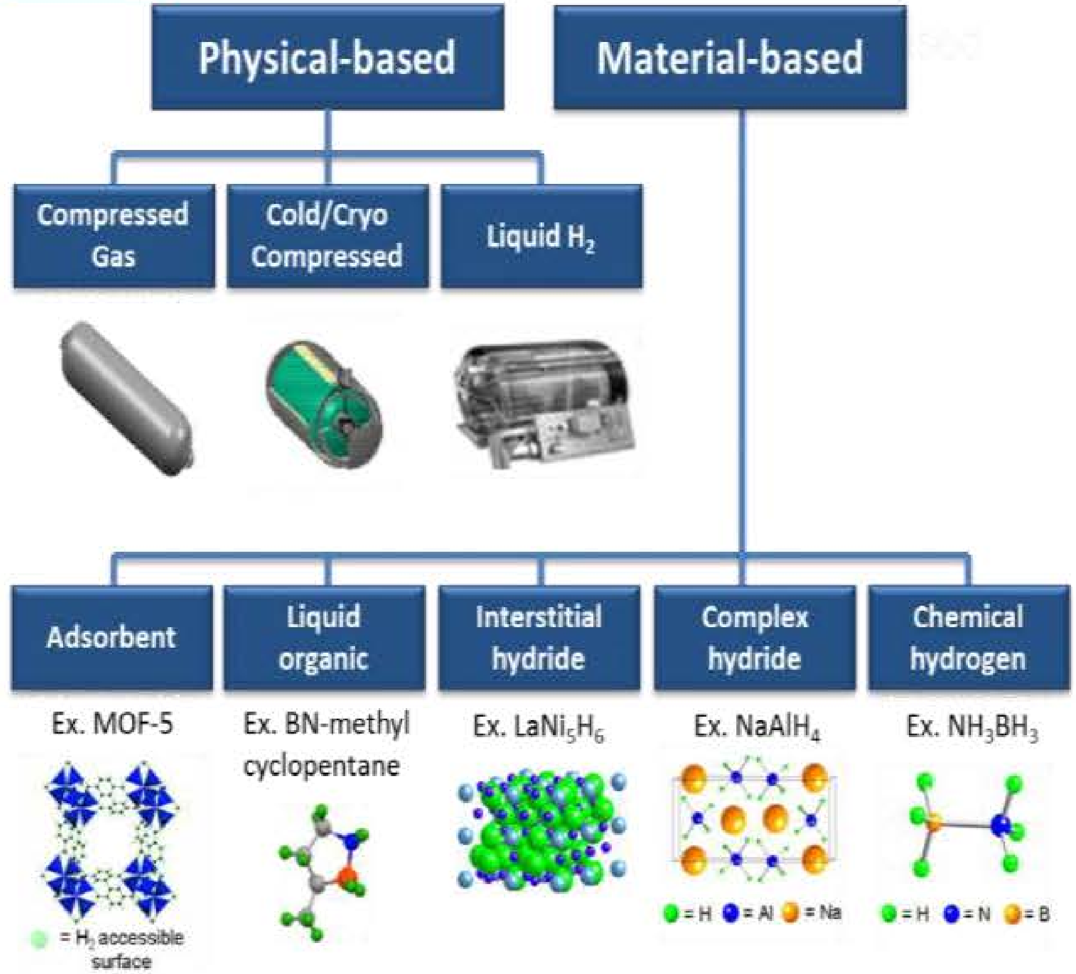
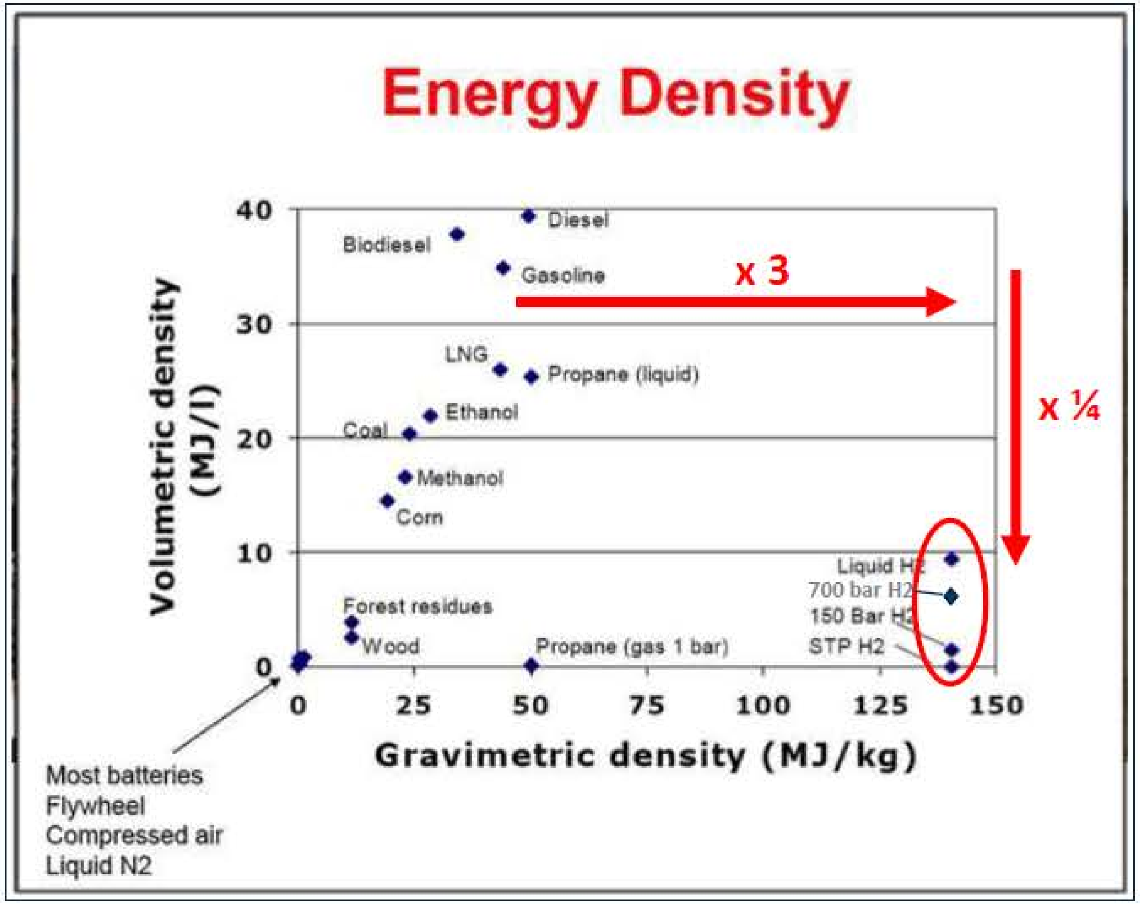
VATTENFALL

Hydrogen storage technologies



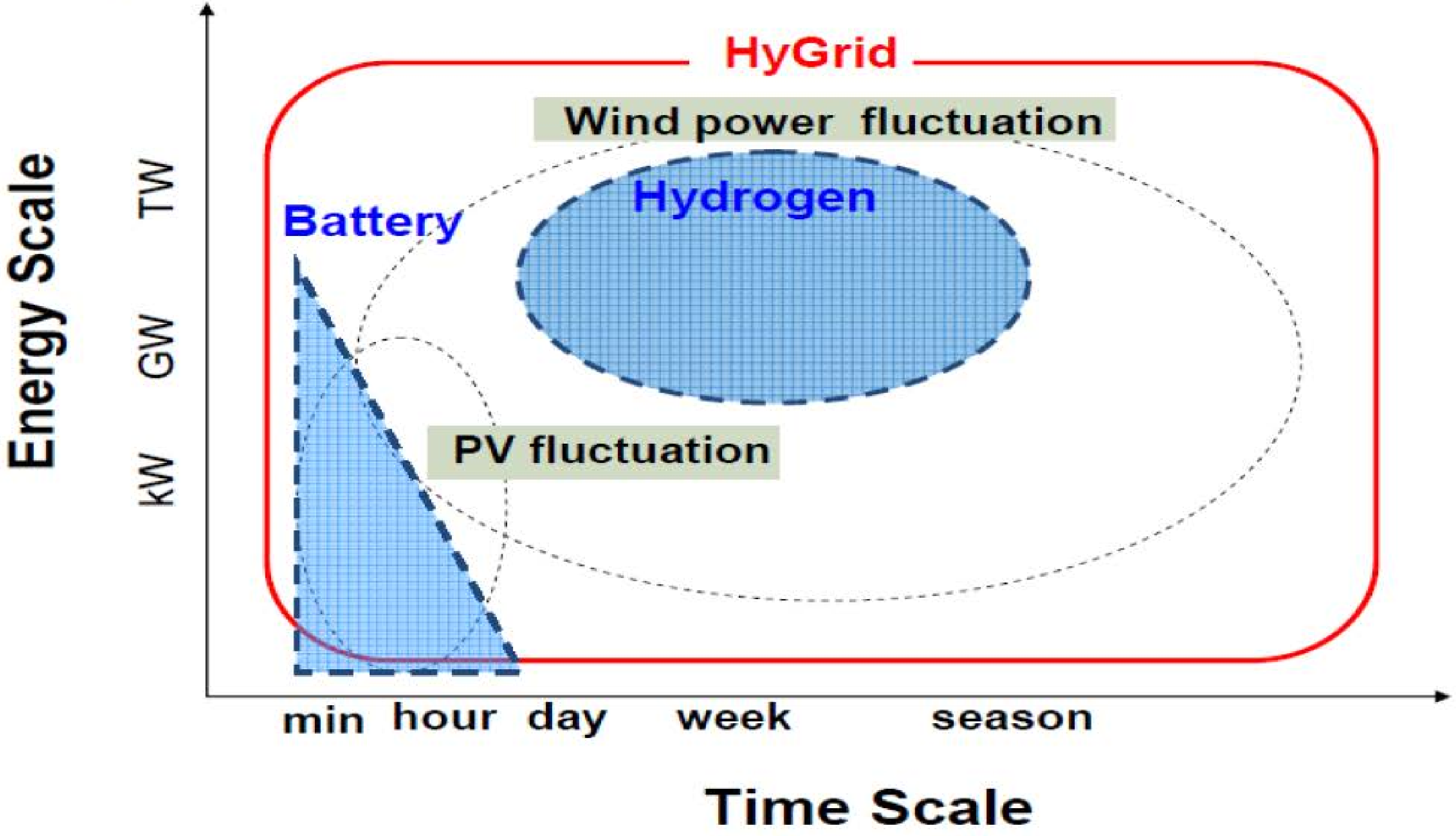


SINTEF

HyGrid basic concept

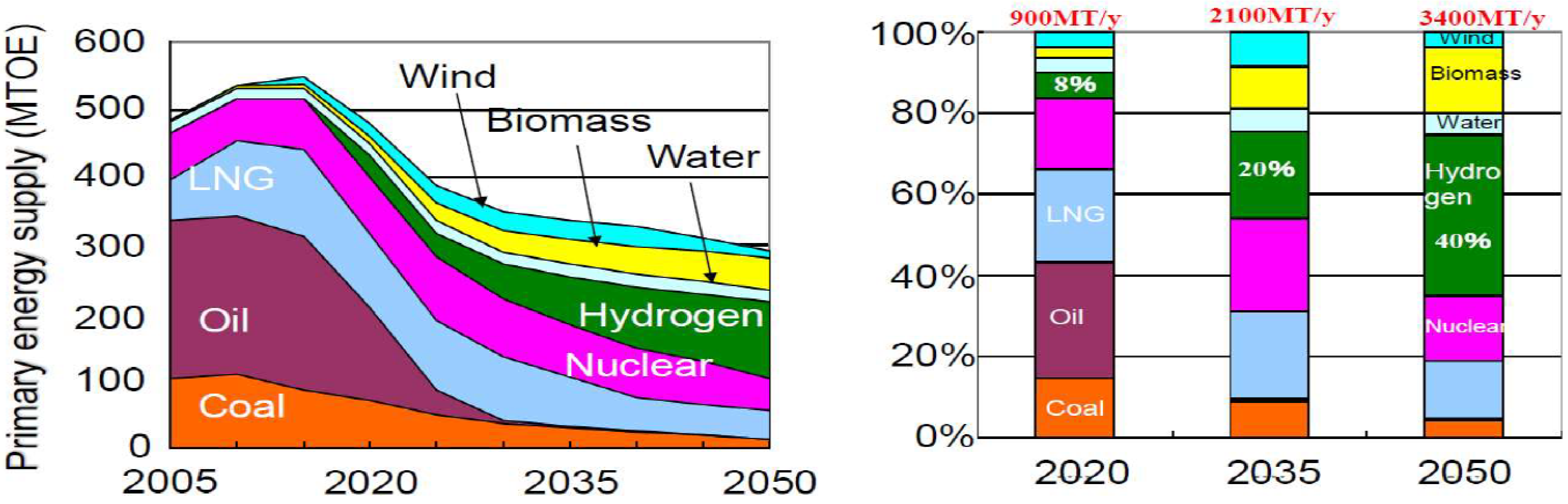
Kawasaki

HyGrid is absorbing
larger energy scale and longer fluctuation



Future Hydrogen Supply

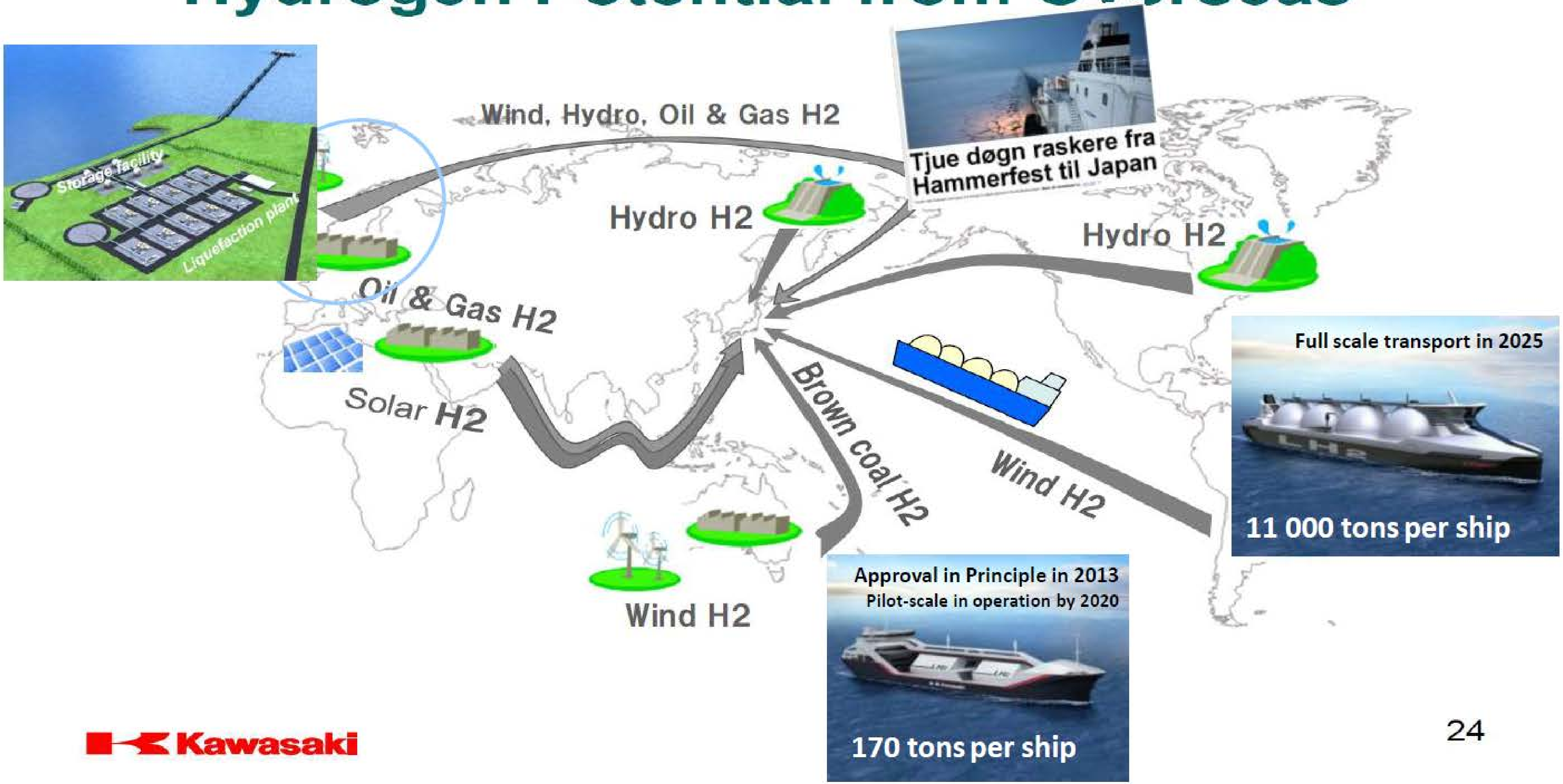
Prediction of hydrogen supply (primary energy supply)



- In 2020 introduction of hydrogen (hydrogen cost: CIF25 yen/Nm^3)
- Switching to CO_2-free fuels is necessary by 2050
- This switch is necessary even if the hydrogen cost is 35 yen /Nm^3 or 45 yen/Nm^3
- Supply for power generation is introduced earlier than that for heat

Kawasaki

Hydrogen Potential from Overseas



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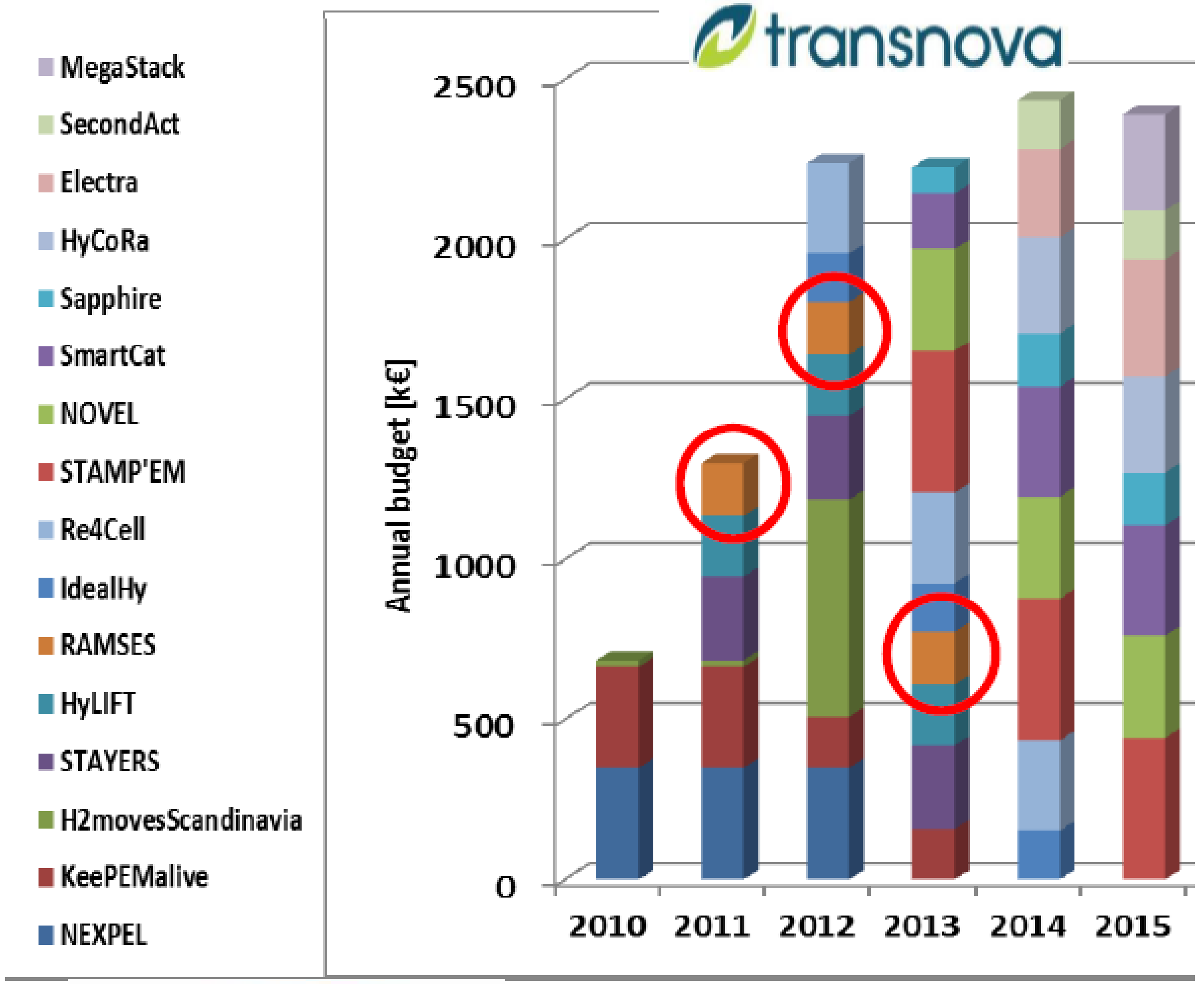
SINTEF's FCH JU-projects & partners

National top-financing: Norges forskningsråd — *The Research Council of Norway*

transnova



HELION HYDROGEN POWER
fumatech
Shell
Linde
IRD Fuel Cell Technology
seasonve
Solvay Solexis
SOLVAY
Höganäs
Nedstack PEM FUEL CELLS
STILL
SolviCore Fuel Cell Technologies
ITM POWER
BAIKOWSKI
COPRECI
H2 Logic Hydrogen Fuel Cell Motive Power Solutions
DAIMLER
MULAG
Miba
Fronius
elringklinger
New Energy World JU — fuel cells & hydrogen for sustainability
TEER COATINGS LTD innovation and experience
JM Johnson Matthey Fuel Cells — the power within

Hydrogen – challenges and opportunities

- Norwegian industry may provide technology
  - Large scale H_2-production as reactant for fertilizer production (Hydro, NEL Hydrogen)
  - «Low cost» hydrogen → based on «stranded wind» resources
  - Hexagon Raufoss, composite tanks for efficient transport, 1 tonnes H_2/unit

Adresseavisen

Ny bil, men eieren får ikke fylt drivstoff på den

Steffen Møller-Holst har kjøpt en bil som går på hydrogen. Problemet hans er at det ennå ikke er mulig å fylle dette drivstoffet noe sted i Midt-Norge.

Battery and hydrogen technology go hand in hand

- Collaborative efforts
- Academia and industry must join forces
- Use local resorces and Norwegian industry
- Cross disciplinary efforts
- Environmental aspects of production processes (particularly batteries)
  - Reduce CO_2 footprint
- Target markets relevant for Norway (i.e. marine transport)
- Combine battery and hydrogen storage options and take advantage of their different system properties