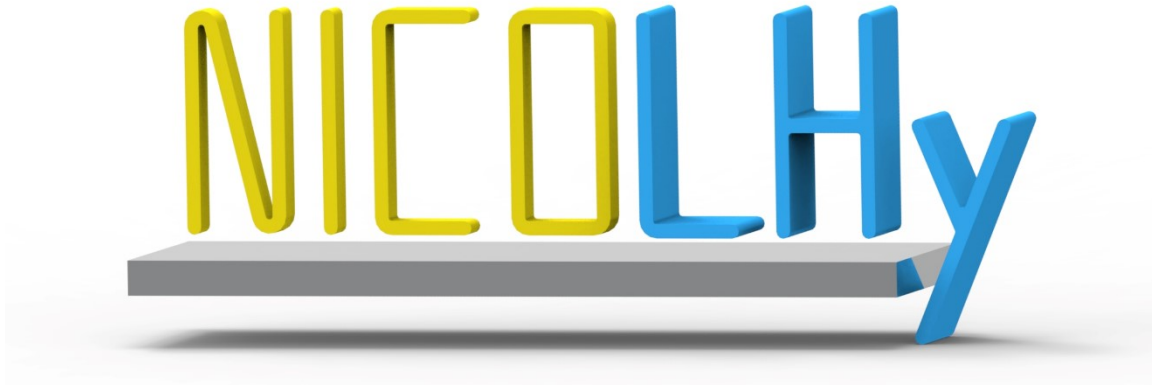

Large Scale Energy Transportation and Storage with Hydrogen

Robert Eberwein

Clean Hydrogen Partnership

BAM Bundesanstalt für Materialforschung und -prüfung

ALMA MATER STUDIORUM UNIVERSITÀ DI BOLOGNA

DLR

NTNU Norwegian University of Science and Technology

National Technical University of Athens

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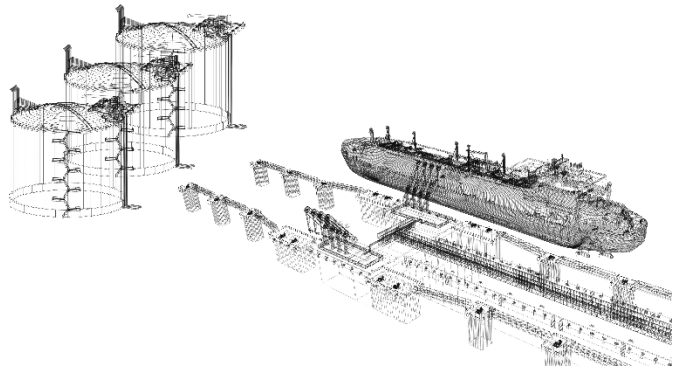
The markets for LH2

Mobile energy intensive applications

Large-scale transport which requires also storage



Large-scale and long-term storage

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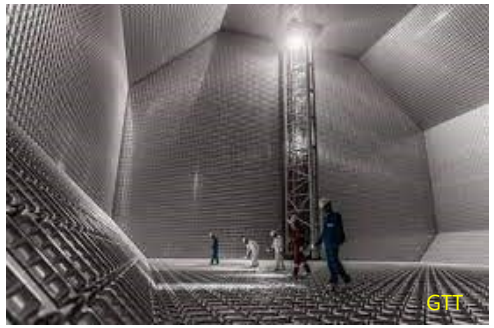
SoA and expected size

		LH2 Industry	LNG Industry
Ship tank	In application	1.250 m³	65.000 m³
	In design	40.000 m³	
Storage tank	In application	5.000 m³	180.000 m³
	In design or construction	40.000 m³	220.000 m³

+ Two times the volume of an LNG tank is required to store the same amount of energy with LH2 +



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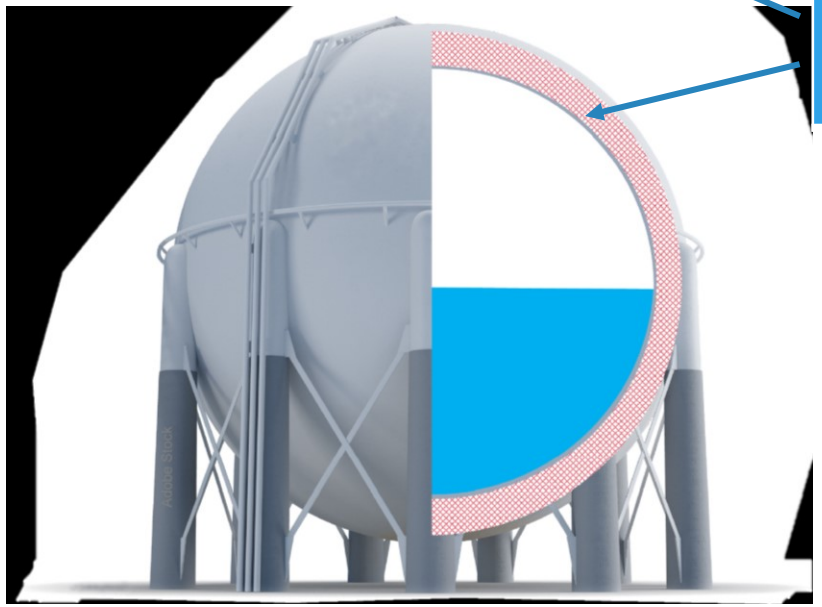
SoA storage technology

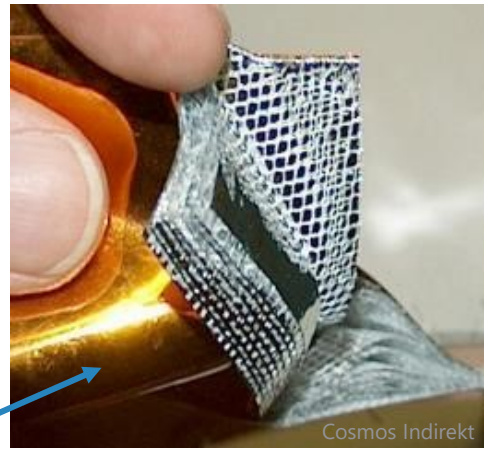
Small-scale tank

Large-scale tank

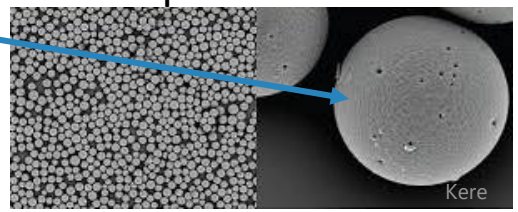


Double wall + **Vacuum** + **Fill material**

MLI



Microspheres



Perlites

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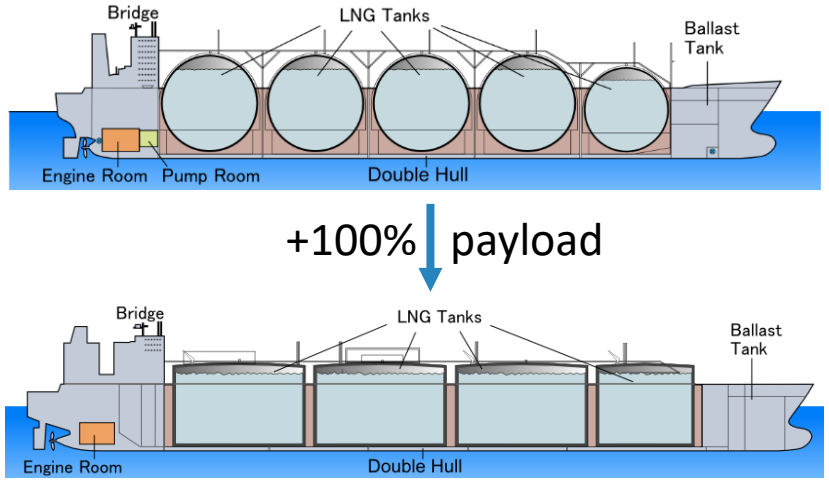
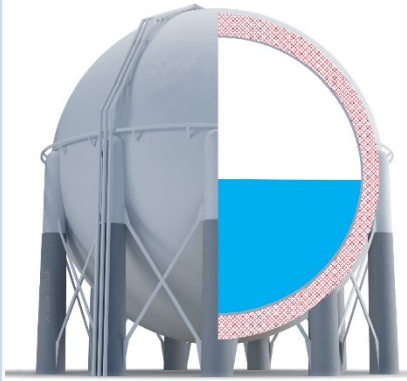
SoA evaluation

Advantages	Disadvantages

✓ Lowest surface / volume ratio
✓ proved manufacturability and process chain
✓ In use since > 50 years
	❖ Bad to install in technical applications
	❖ Bad Process chain within production:
	  ❖ Time intensive (>36 Month)
	  ❖ Difficult for automation and parallelization or processes
	  ❖ High manpower fluctuations
	  ❖ Quality assurance is limited
	❖ In case of an insulation failure:
	  ❖ Non multi-failure tolerance
	  ❖ Payload is lost
	  ❖ Long service time
	❖ Upscaling is expensive as known from LNG industry





Adobe

NASA

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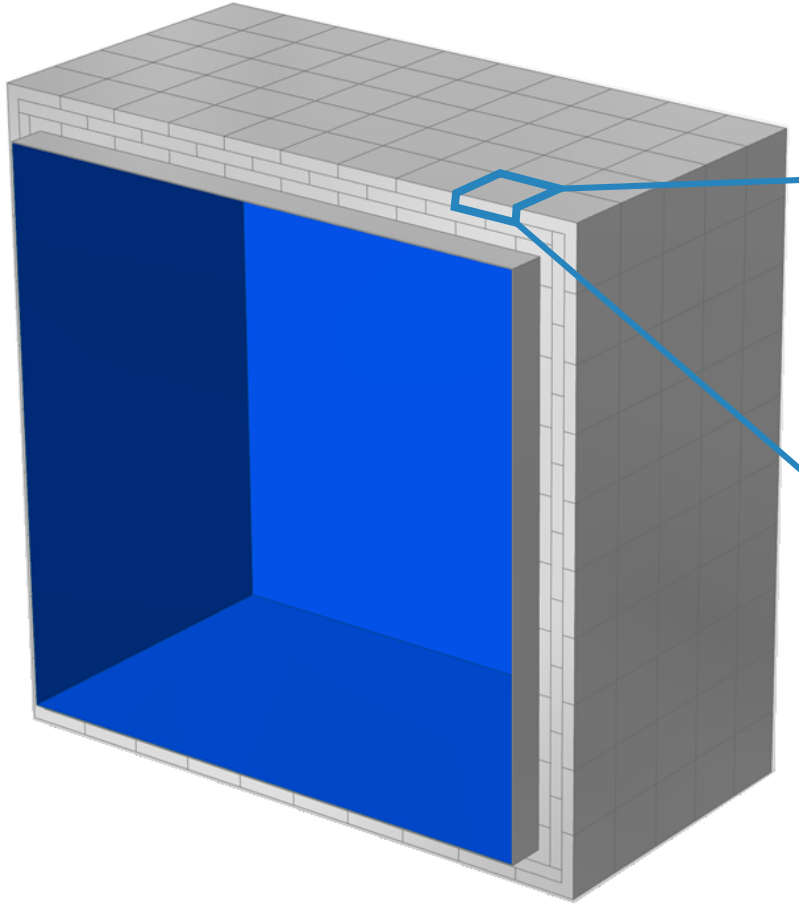
Tank insulated by Vacuum Insulation Panels (VIP)



Gas-tight outer membrane

High porous core material

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VIP advantages

Insulation

- ✓ Industrial manufacturing in an industrial environment,
- ✓ Excellent quality control during the manufacturing process,
- ✓ Automation of manufacturing and quality control,
- ✓ Lower vacuum requirements of VIP (1 to 10^2 Pa) than e.g. MLIs (10^{-5}Pa),
- ✓ Parallelization of tank constructions.

Tank

- ✓ Flexibility in the selection of the tank shape due to the inherent stability of the insulation,
- ✓ Reduction of construction time and increase of plannability,
- ✓ Improved planning of manpower requirements during tank installation,
- ✓ Increased fault tolerance of the entire insulation system due to the high number of partial insulation elements (VIPs).

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Technology Readiness Level (TRL) of VIP applications

Building industry (TRL9)

Transport of:

- Covid vaccines (TRL9)
- Human organs (TRL9)
- Large goods (TRL6)

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Barriers and scope

Recent construction principles for VIP‘s don‘t fulfill the requirements:

- Temperature resistents up to – 253°C,
- Long-life performance,
- Handling of thermal displacements,
- Safety?

Need for research and new design principles to apply VIP‘s on LH2 storages with capacities of 40.000 m³ to 200.000 m³ LH2

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Project structure

Stakeholder Advisory Board
- Industry, policymakers, standardization bodies,

(WP6)

Knowledge
- State of the art
- Projects (past & ongoing)
- Industry
- Novel insulation concept proposal

(WP1)

Project Coordination

(WP7)

Insulation design
- Material selection
- Thermo-mechanical evaluation
- Performance modelling

(WP2)

Proof of concept
- Material testing
- Accident scenario testing (fire)

(WP3)

Risk analysis
- Hazard identification
- Risk analysis & safety barriers

(WP4)

Sustainability
- Circularity, sustainability, scalability
- Techno-economic analysis
- Gap analysis

(WP5)

Implementation
- Novel insulation concept
- Design guidelines
- RCS recommendation

(WP1)

Patents
Regulations
Standards

(WP6)

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Risk analysis
Identification of reference hazardous scenarios

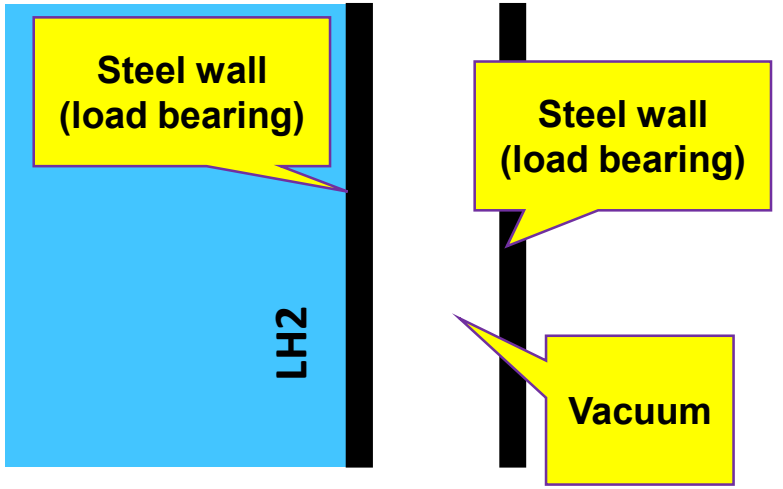
Reference schemes

CONVENTIONAL SYSTEM

SHAPE: Spherical tank

SIZE: 4'700 m^3 (approx. D=22m)

INSULATION SYSTEM: vacuum gap

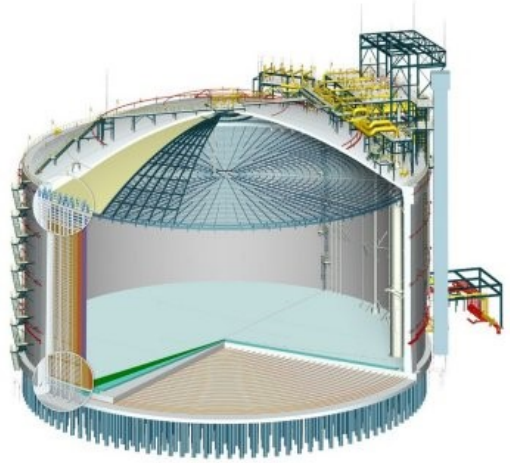


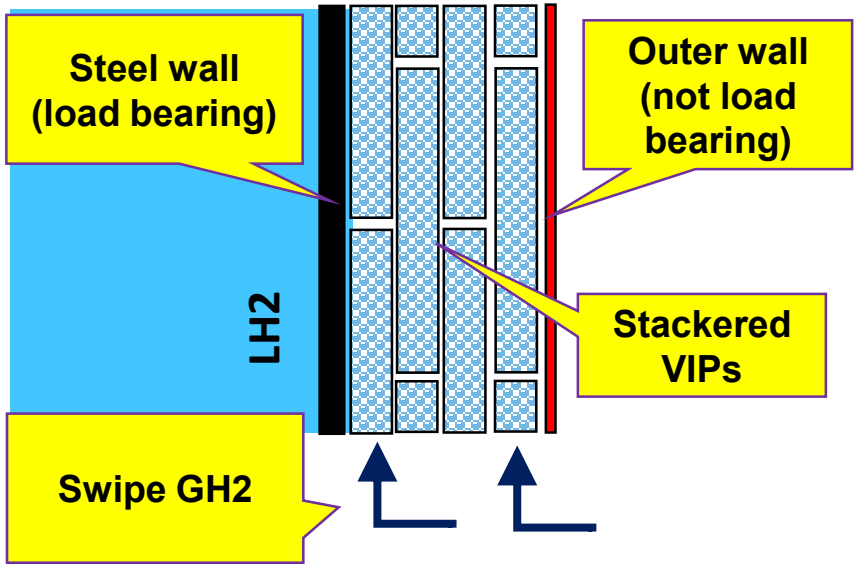
"NOVEL" SYSTEMS

SHAPE: Cylindrical vertical axis

SIZE: 200'000 m^3 (D=75m, H=60m)

INSULATION SYSTEM: stackered VPIs





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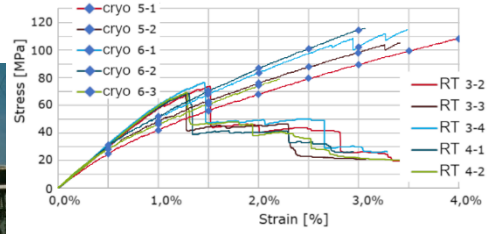
Reference projects

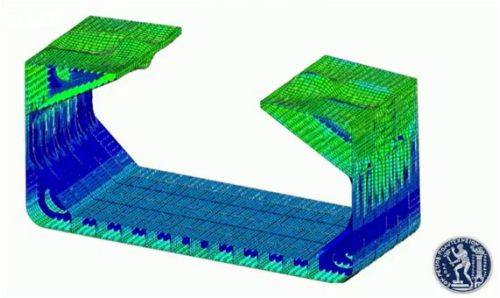
NICOLHy

EQHHP



LVHYS

STL
SHIPBUILDING TECHNOLOGY LABORATORY



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Thanks for your attention

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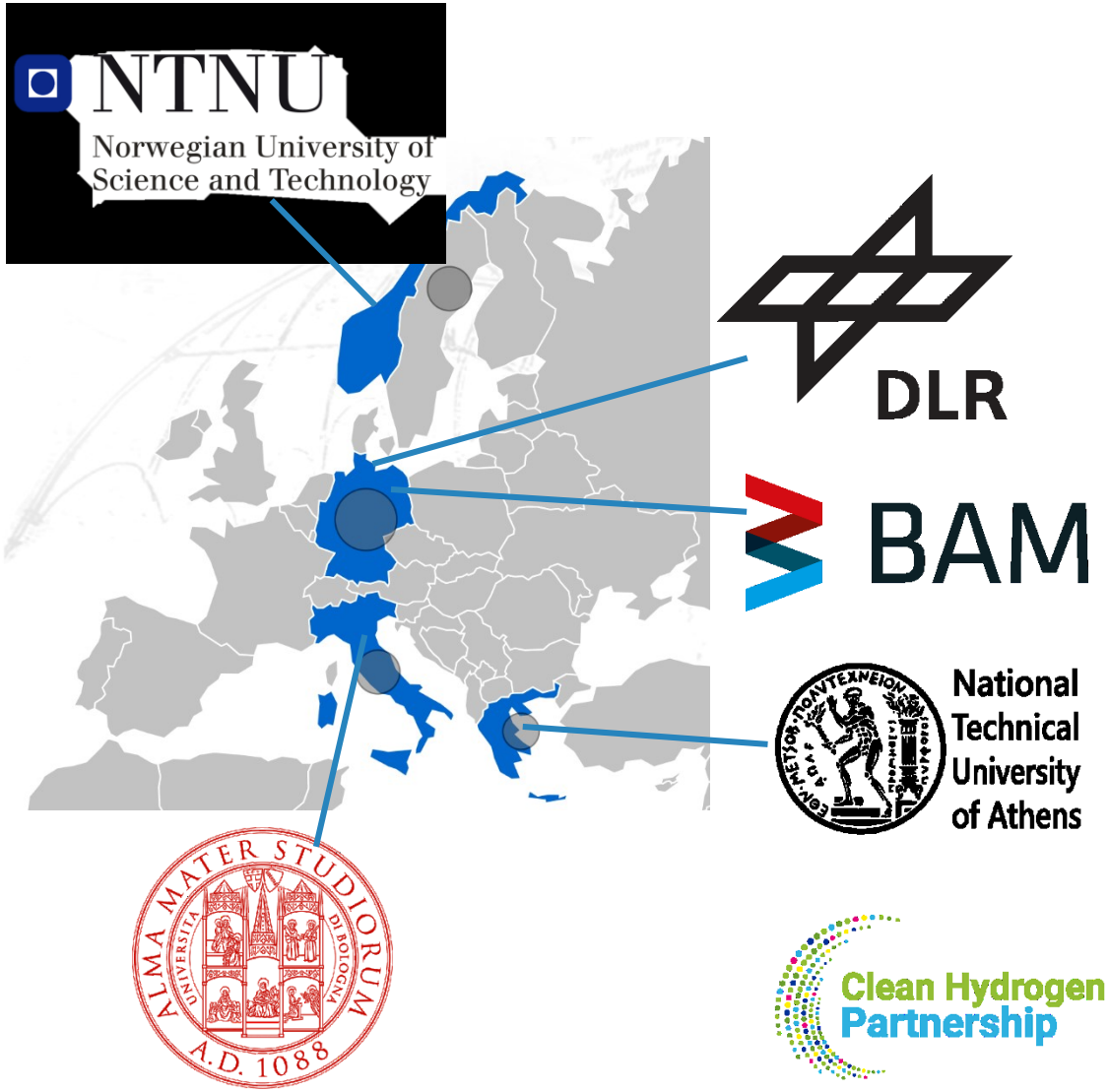
Project consortium

Partner	✓ BAM ✓ UniBo ✓ DLR ✓ NTNU ✓ NTUA

[redacted]



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