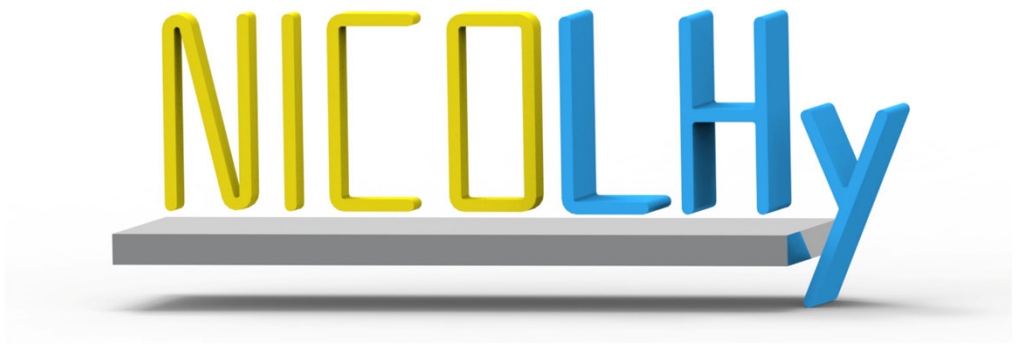

Novel Insulation Concepts for Large Scale Liquefied Hydrogen Storages

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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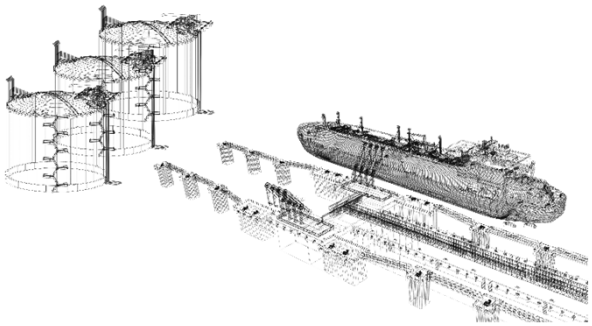
The Markets for LH2

Mobile energy intensive applications

Large-scale transport which requires also storage

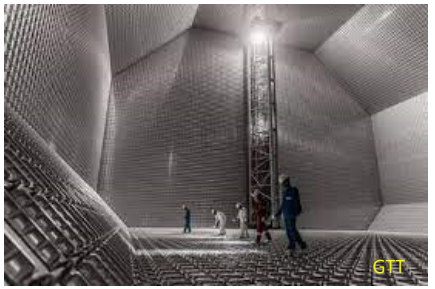


Large-scale and long-term storage

State of the Art 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

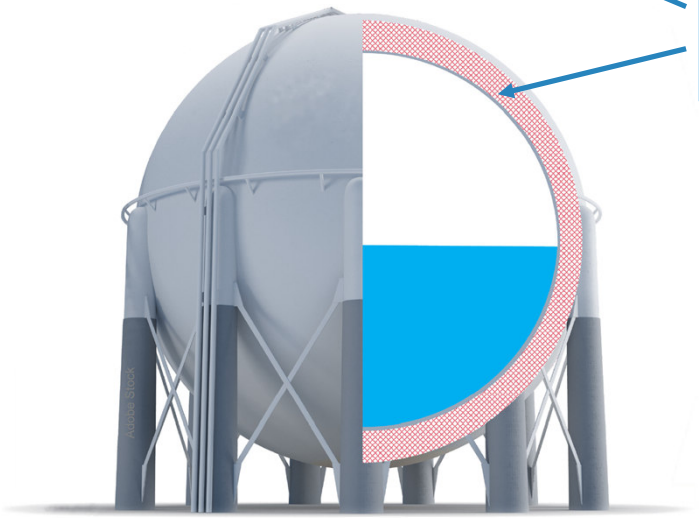
+ Two times the volume of an LNG tank is required to store the same amount of energy with LH2 +



State of the Art Storage Technology

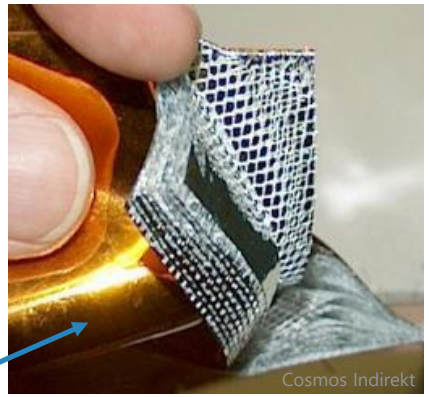
Small-scale tank

Large-scale tank

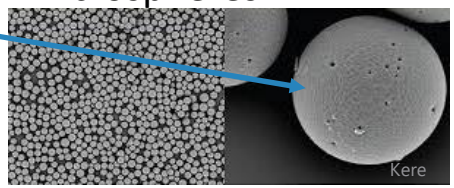


Double wall + **Vacuum** + **Fill material**

MLI



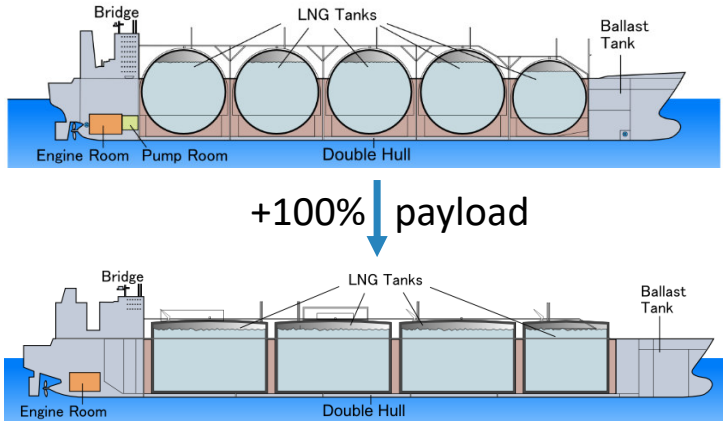
Microspheres

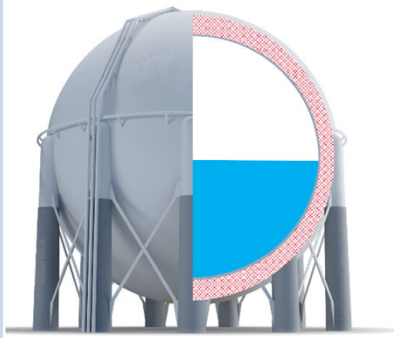


Perlites

State of the Art Evaluation

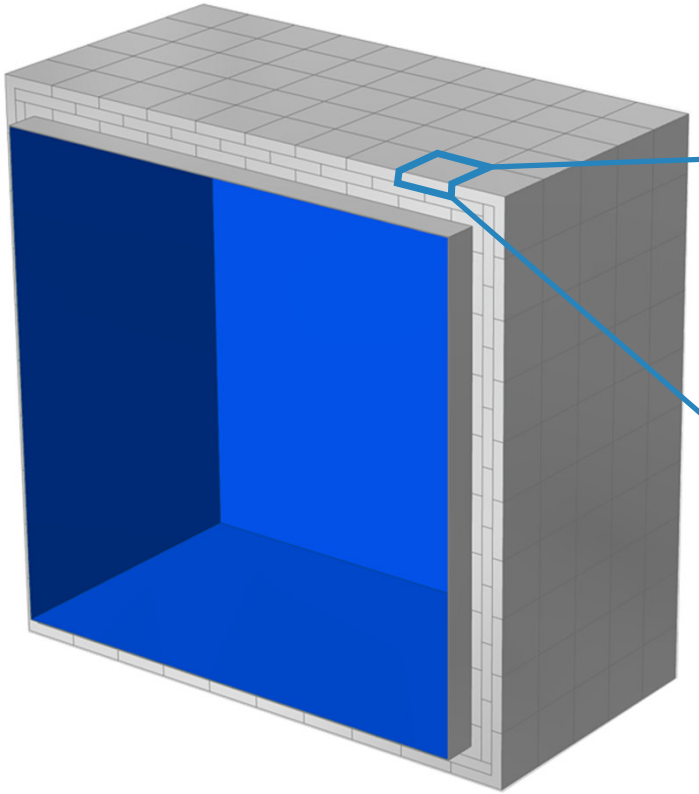
Advantages	Disadvantages
✓ Lowest surface / volume ratio ✓ proved manufacturability and process chain ✓ In use since > 50 years	❖ Low useable volume compared to prismatic shapes ❖ Process chain within production: ❖ Difficult for automation and parallelization of processes ❖ High manpower fluctuations ❖ Quality assurance is limited ❖ Time intensive (>36 Month) ❖ In case of an insulation failure: ❖ Non multi-failure tolerance ❖ Payload is lost ❖ Long service time ❖ Due to 2 pressure vessels, upscaling is not directly associated with a reduced material demand




Adobe


NASA

Tank Insulated by Vacuum Insulation Panels (VIP)



Gas-tight outer membrane

High porous core material

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),

Tank

- ✓ Parallelization of tank constructions.
- ✓ 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).

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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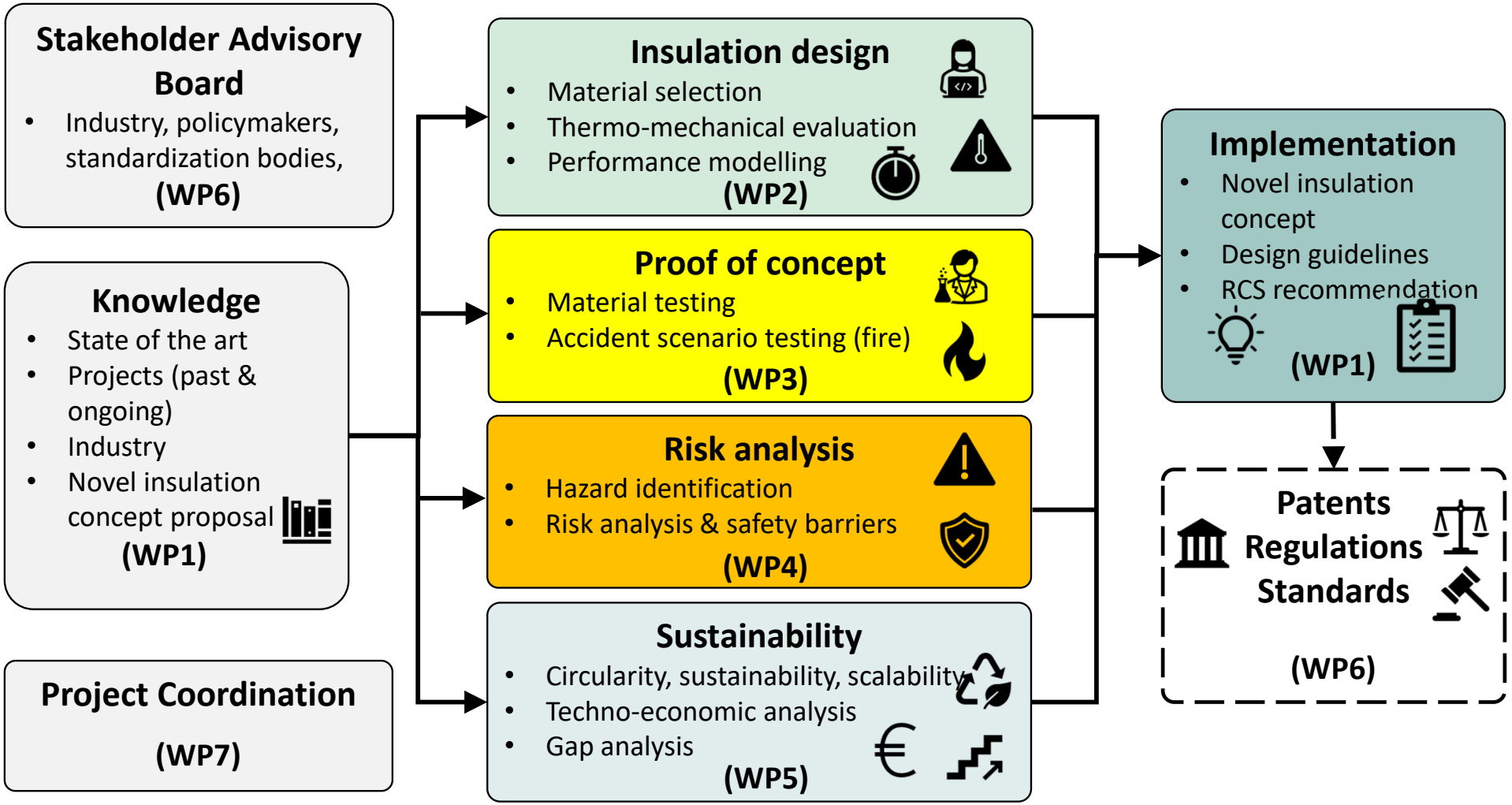
Project Structure



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New Technics, New Scale, New Risks?

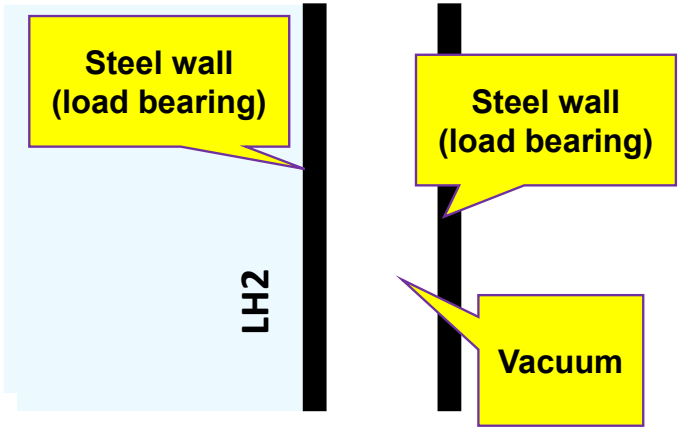
Reference schemes

CONVENTIONAL SYSTEM

SHAPE: Spherical tank

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

INSULATION SYSTEM: vacuum gap

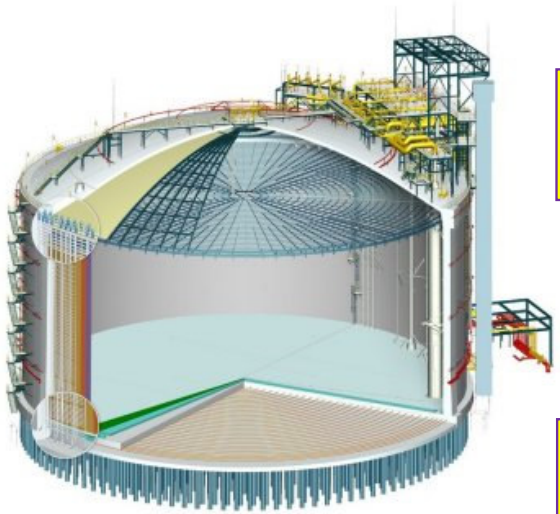


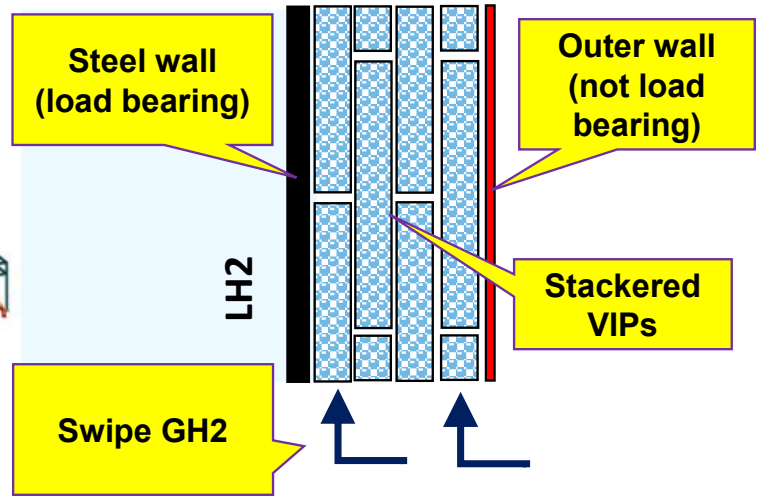
"NOVEL" SYSTEMS

SHAPE: Cylindrical vertical axis

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

INSULATION SYSTEM: stackered VIPs





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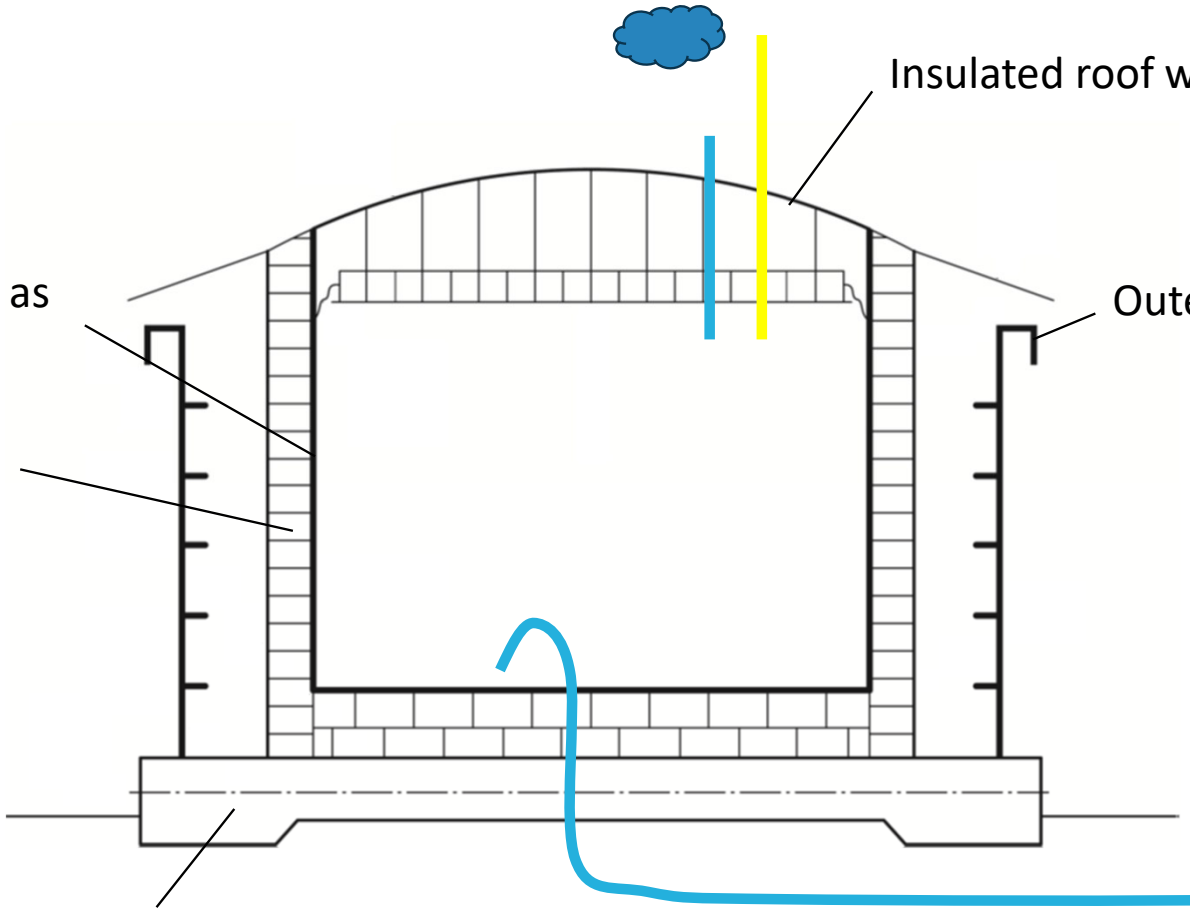
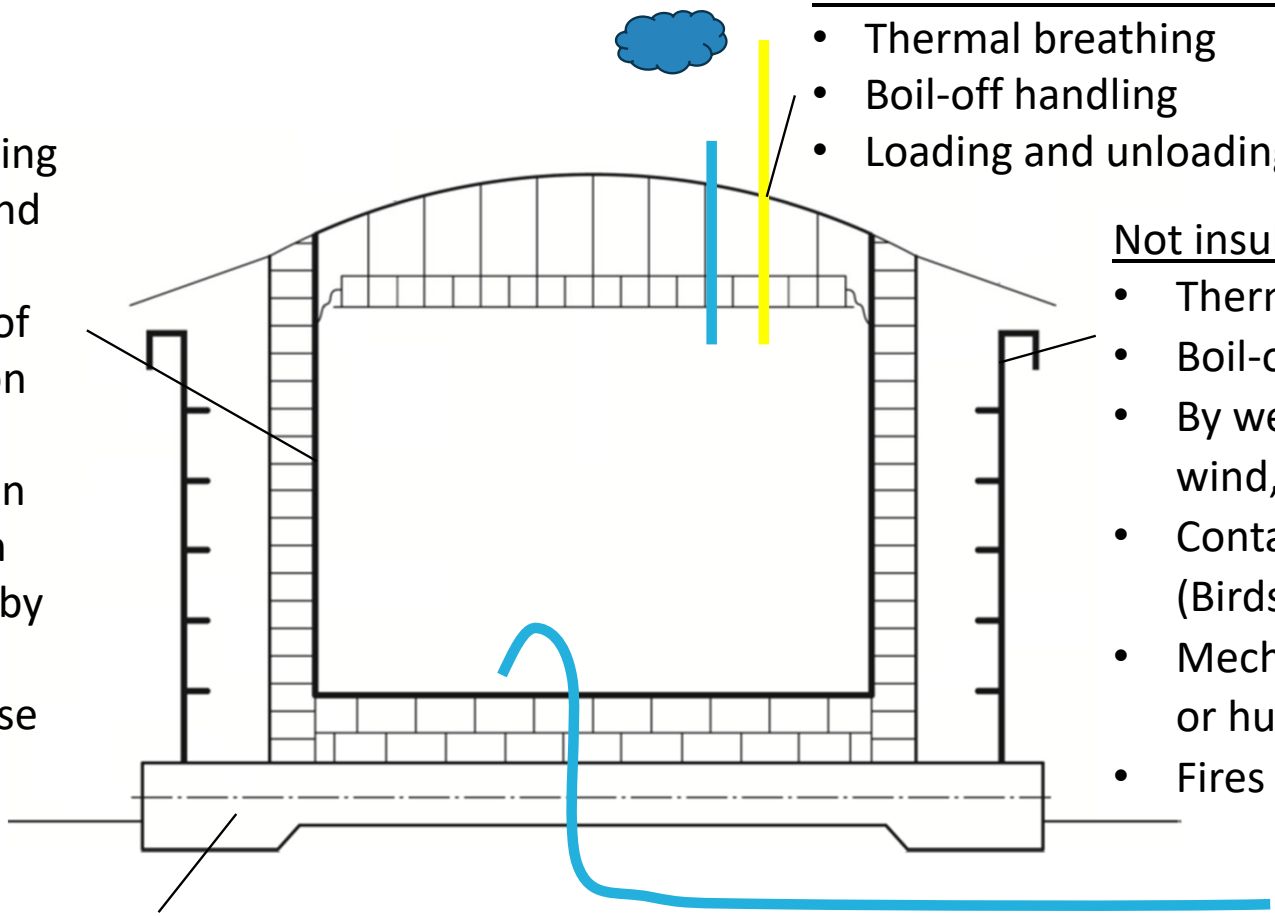
LH2 Tank Design Oriented to EN 14620



Safety Questions

Insulated roof with tubes
- Thermal breathing
- Boil-off handling
- Loading and unloading procedures

Wall + Insulation
- Thermal breathing while loading and unloading
- Consequences of partial insulation degradation
- Liquefied oxygen (LOX) formation
- Contamination by dust or animals
- Behaviour in case of a fire



Not insulated outer walls behavior:
- Thermal shocks
- Boil-off handling
- By weather conditions (water, wind, sun, moisture, air)
- Contaminations by dust, animals (Birds, insects)
- Mechanical damage by animals or humans
- Fires

Consequences of a heaters damage

Behaviour of tubes connected to the insulation

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Thank you for your attention

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NICOLHy project No. 101137629 is funded by the European Union.