# BOR4STORE
## (303428)

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**http://www.bor4store.eu**

# PROJECT OVERVIEW

- Full name: Fast, reliable and cost effective Boron hydride based high capacity solid state storage materials
- Call topic: 2.4: SP1-JTI-FCH.2011.2.4: Novel H2 storage materials for stationary and portable applications
- Runtime: April, 1st, 2012 – September, 30, 2015
- Budget: 4.07 Mio.€, FCH JU contribution: 2.274 Mio.€
- Consortium overview

Helmholtz-Zentrum Geesthacht
Centre for Materials and Coastal Research
ABENGOA HIDROGENO
Zoz Group
katChem
AARHUS UNIVERSITY
IFE
NIS Nanostructured Interfaces and Surfaces
EMPA Materials Science & Technology

- Purpose:
  - Development of improved solid state based hydrogen storage system (> 4wt.%, > 40 kg $H_2/m^3$)
  - integration with ca. 1 kW SOFC, use of off-heat of SOFC
    $\Rightarrow$ lab prototype of net independent power supply
- Stage of implementation: 70%

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# PROJECT TARGETS AND ACHIEVEMENTS

| Status before project | MAIP target | Project Target | Current status/ achievements | Expected final achievement |
|---|---|---|---|---|
| Capacity of several tons of hydrogen (exact number secret) in metal hydride tanks demonstrated in German FC powered submarines before 2010.<br>Cost > 5000 € / kg of stored hydrogen | Potential for cost below 500 €/kg of stored hydrogen | Capacity 1 kg of hydrogen<br><br>potential for cost below<br>500 €/kg = 5 M€/t | Materials cost ca. 3,500 – 7,500 €/kg of stored hydrogen<br><br>Tank system prototype under construction | Use of Mg recycling alloys (waste, 0€) demonstrated.<br><br>Route for synthesis from Elements under investigation. |
| 50 g of storage material,<br>> 80 kg $H_2/m^3$<br>> 8 wt.%<br>Cycling stability unknown | Storage materials with capacities ≥ 6 wt.%, ≥ 60 kg $H_2/m^3$ | capacities > 80 kg $H_2/m^3$ and > 8 wt.%<br>Loss of capacity <10% over 500 loading cycles | Ca. 100 kg $H_2/m^3$<br>9 – 10 wt.% on materials basis<br>< 7% capacity decrease after 1000 cycles (extrapolated in lab sample) | 10 kg of storage material with same capacity,<br>< 5% capacity decrease for 500 cycles in tank |

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# PROJECT TARGETS AND ACHIEVEMENTS

| Status before project | AIP target | Project Target | Current status/ achievements | Expected final achievement |
|---|---|---|---|---|
| Release temperature of boron hydrides >350°C | reversibly releasing hydrogen at operating temperatures compatible e.g. with PEM FC, HT PEM FC or SOFC / MCFC | Release temperature ≤ 450°C (compatible with SOFC) | Release temperatures depending on compound 250 – 450°C | Suitable for operation with SOFC |
| Loading time >> 1 h | appropriate hydrogen loading and unloading kinetics for the envisaged application | Loading time < 1 h | Loading time < 1 h in materials testing, loading time of storage tank tbd. | Loading time < 1 h in storage tank (under construction) |
| Intermetallic hydride based storage systems >40 kg $H_2/m^3$ < 2 wt.% | Small scale prototype storage systems with significantly improved storage capacity compared to compressed gas storage (≥ 40 kg $H_2/m^3$, ≥ 4 wt.%, ) | Capacity > 40 kg $H_2/m^3$ > 4 wt.% | Storage system under construction | tbd. |

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# PROJECT TARGETS AND ACHIEVEMENTS

- Scientific understanding of boron based hydrogen storage materials (>8wt.%)
  - reaction mechanisms
  - additives
  - confinement
- Selection of reversible storage material with >80 kg $H_2/m^3$ / >8 wt.% capacity
  - Li-RHC ($LiH + MgB_2 \Leftrightarrow LiBH_4 + MgH_2$)
- Routes for cost effective materials synthesis
  - use of waste alloys (e.g. Mg alloy waste)
  - less pure raw materials
  - synthesis from the elements

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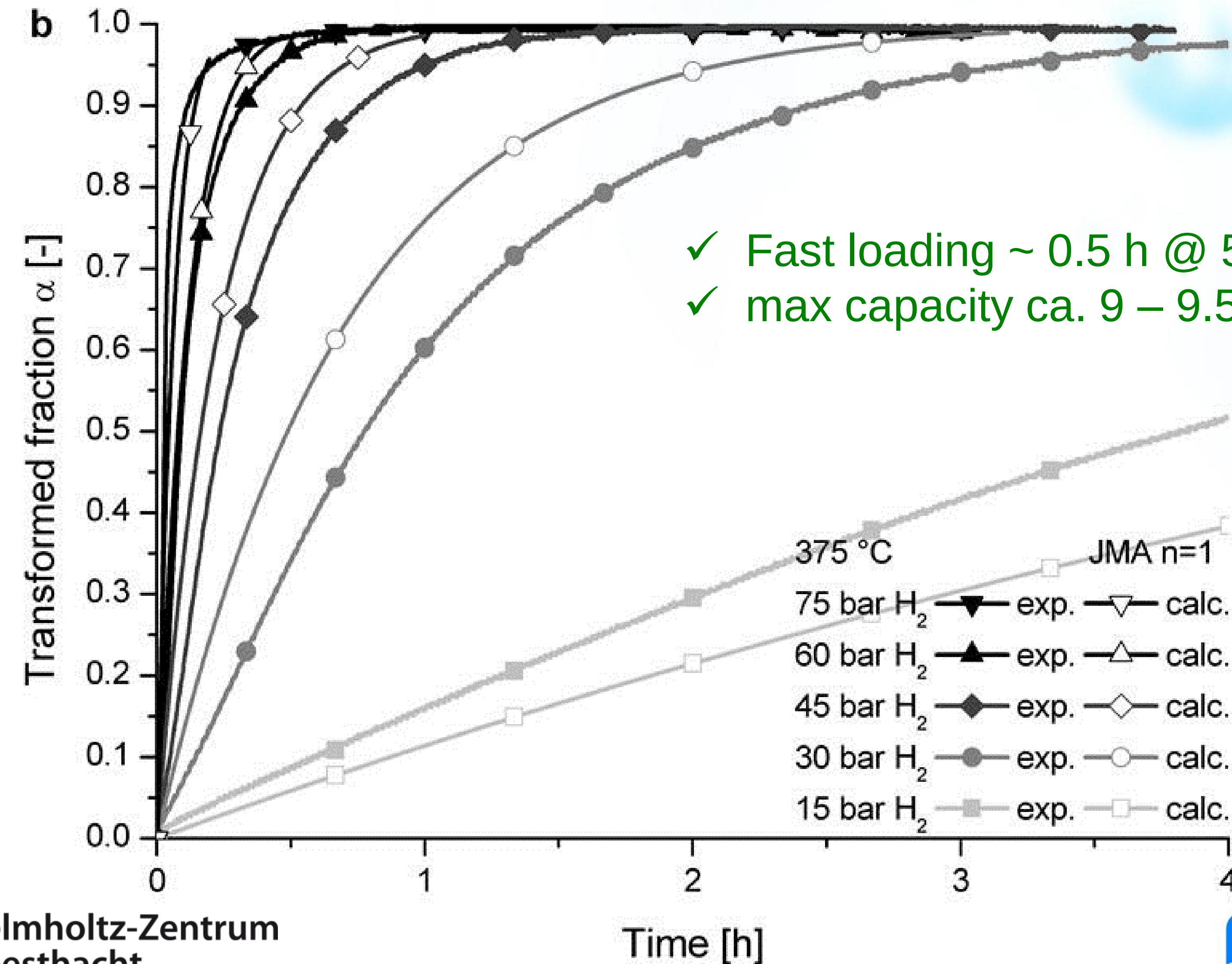
# Loading behaviour of Li-RHC




✓ Fast loading ~ 0.5 h @ 50 – 60 bar
✓ max capacity ca. 9 – 9.5 wt.%

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# Li-RHC tank system test

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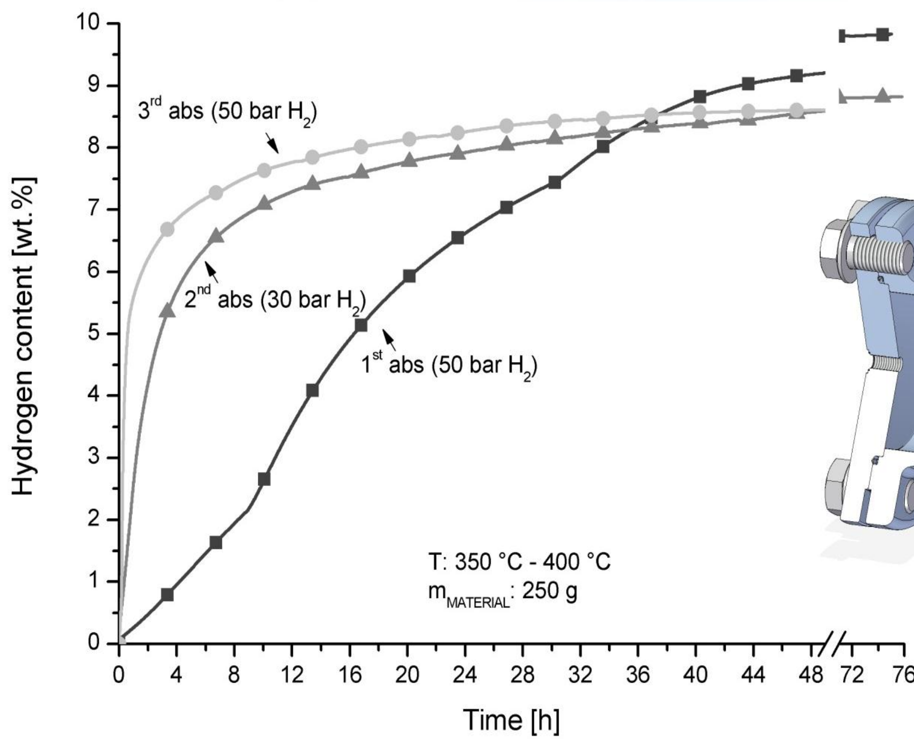


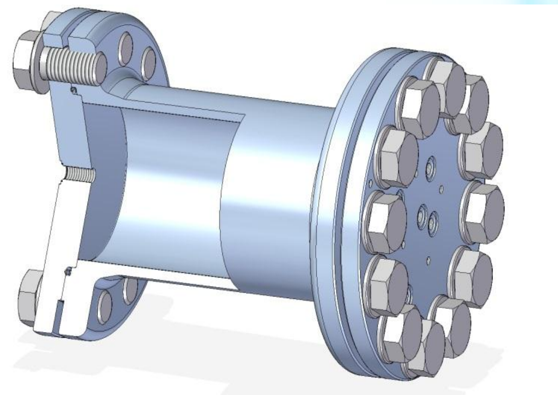

- ✓ First single module high capacity solid state tank based on $LiBH_4/MgH_2$
- ✓ Reversible hydrogen storage capacity of >8.5 wt.% after 3 cycles
- ✓ Improved sorption rate and capacity with further increasing number of cycles

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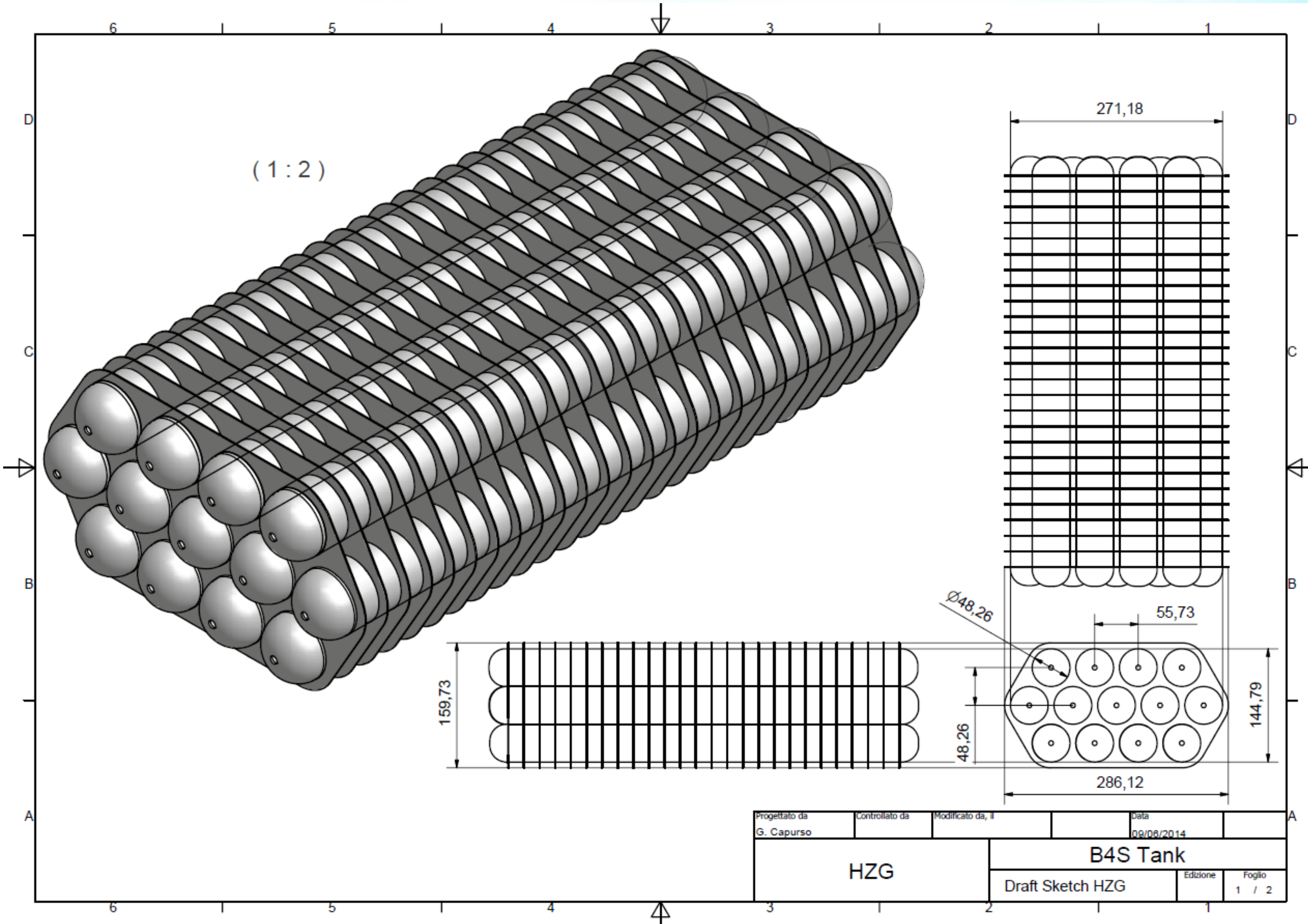
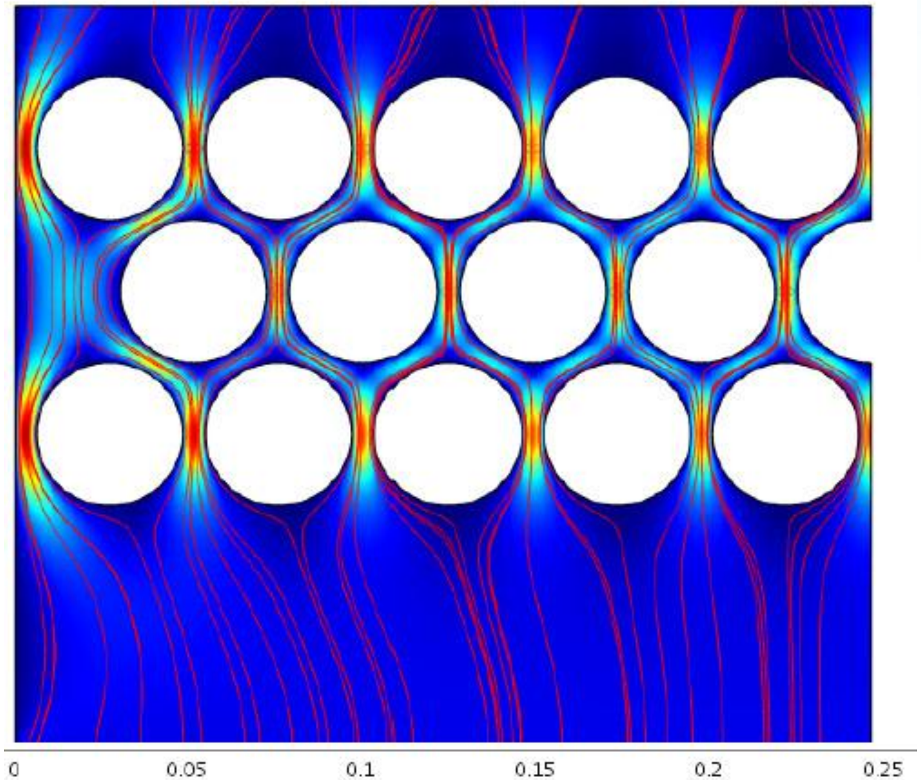
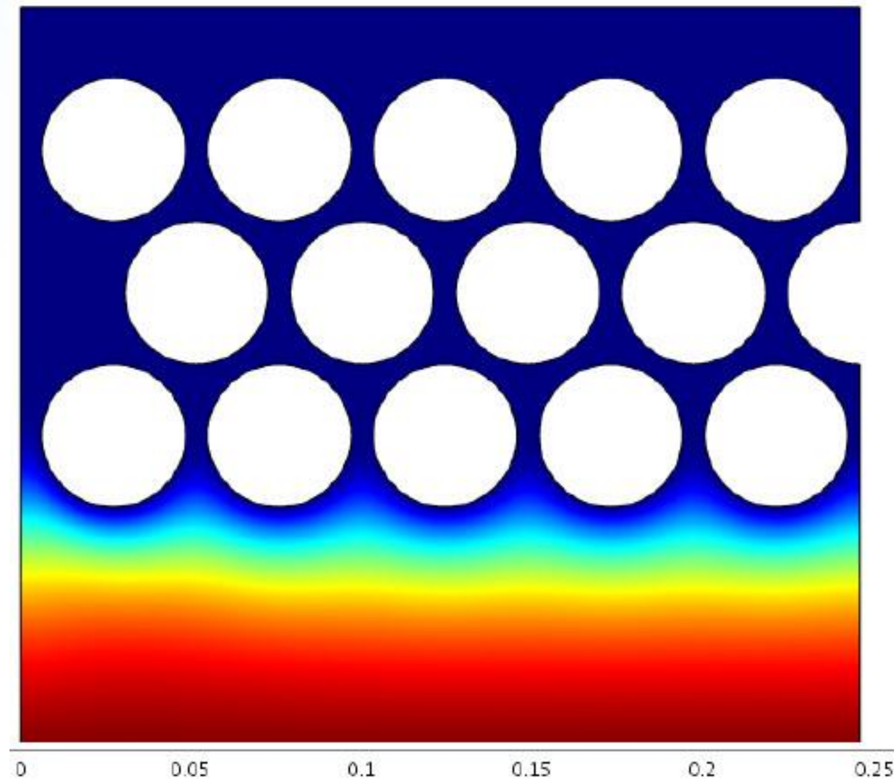
# Tank Design, first Version



# Thermal Coupling / Heat Exchange Medium




Flow Field @ u=0.03m/s




Temperature Field

- ✓ Rather homogeneous temperature distribution around tank modules
- ✓ Sufficient heat transfer from heat exchange medium to hydrogen storage material for hydrogen release

# PROJECT TARGETS AND ACHIEVEMENTS

- Scale-up of materials synthesis to kg scale
- Design of Li-RHC based hydrogen storage tank
- Design of heat exchange with SOFC

- Next steps
  - Construction of integrated SOFC – hydrogen storage system including heat exchange
  - System testing (>500 cycles)
  - Techno-economical evaluation

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# RISKS AND MITIGATION

- Heat transfer between SOFC and storage tank
  0.5 kW@350 – 600° C!
  - simulation of heat transfer shows feasibility
  - simulation to be validated in real system
- Final capacity of hydrogen storage tank
  - exact system capacity unknown (under construction)
    - light weight, low volume ⇔ 100 bar $H_2$ (wall thickness, weight), 600° C (steel strength),
    - compact heat exchange (volume)
  - mitigation
    - Optimise construction with respect to internal pressure and temperature
    - Identification of potentials in tank construction for capacity increase
    - But obey reasonable safety measures

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# Risks and mitigation

- Cycling stability of storage material
  - so far less than 50 cycles in 250 g of powder material $\Rightarrow$ stable capacity
  - cycling stability should be enhanced by planned pelletizing of storage material (previously shown)
  - possible means of mitigation (after project)
    - further tune reaction paths by additives, pressure and temperatures
    - prevent phase segregation by confinement
- Cost of storage tank and SOFC
  - cost higher than expected in budget estimation
  - mitigation: contribute to project by own ressources of beneficiaries

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# SYNERGIES WITH OTHER PROJECTS AND INITIATIVES

- BOR4STORE builds on EU projects
  - STORHY, COSY, NESSHY, FLYHY; exchange with SSH2S
- Joint activities
  - Joint Workshop with SSH2S, EDEN & HYPER projects 10/13
  - Joint Final Event of BOR4STORE, EDEN & HYPER under discussion
  - COST Action MP1103 “Nanostructured materials for solid state hydrogen storage”
  - H2FC infrastructure project
- Interactions with international-level activities
  - BOR4STORE beneficiaries partners of
    - Concert-Japan iTHEUS (Europe – Japan)
    - MC ITN ECOSTORE (Europe - Japan)
    - HGF-CAS Joint Research Group RevHy (Germany - China)
  - 5 groups send experts to IEA HIA Task 32 “Hydrogen based energy storage”

# HORIZONTAL ACTIVITIES

- Training and Education:
  - 6 PostDoc or PhD positions
- Safety, Regulations, Codes and Standards
  - Agreement on harmonized materials testing procedures
  - Complete System Design according to international rules for pressurized containers and systems
  - BOR4STORE results could be used for new standard for stationary hydrogen stores based on solid state materials

# DISSEMINATION ACTIVITIES

- Dissemination & public awareness
  - Press release upon project start
  - Presentation at N.ERGHY GA, May 2012, Prague
  - Presentations at Int. Conferences (MH2012, Japan, GRC2013, Italy, MH2014, UK)
  - Presentation at FC Expo 2013, Japan
  - Joint SSH2S, BOR4STORE, EDEN & HYPER projects workshop 2.10.2013
  - Joint Public Final Dissemination Workshop, 2015, under discussion
- Publications & patents
  - more than 30 peer reviewed publications so far
  - 1 patent applied for

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# EXPLOITATION PLAN

- Changes to FCH technology development and/or commercialisation
  - Demonstration of high capacity low pressure hydrogen storage under application relevant conditions (≥ TRL3)
  - Intensive work on lowering cost in hydrogen storage
  - Economical evaluation CAPEX ⇔ OPEX (no compression, cooling, or liquefaction)
- Planned exploitation
  - Industry partner ZOZ
    - Mechano-chemical processing for cost effective materials synthesis
    - Hydrogen storage tank systems
  - KATCHEM
    - Synthesis of novel boron hydride compounds
  - Abengoa
    - System integration of hydrogen storage with high temperature applications

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# EXPECTED IMPACT

- demonstration of high capacity, low pressure hydrogen storage & integration with application
  - feasibility of technology
- cost reduction
  - Low cost raw materials and cost effective materials processing, simple tank construction
  - Low pressure storage
    $\Rightarrow$ no compression, cooling, or liquefaction
    $\Rightarrow$ no maintenance, no downtimes
  - significant reduction of OPEX in stationary storage (high number of reloading cycles)
- Transfer to industry
  - Guaranteed by 3 industry partners
  - Licensing of technologies dependent on identification of future applications

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