# SSH2S
# (256653)
# Fuel Cell Coupled Solid State Hydrogen Storage Tank

***Marcello Baricco***

*SSH2S Coordinator*
*Università di Torino*
*marcello.baricco@unito.it*

# SSH2S in figure

***Beginning:***
***Feb. 1st, 2011***

***End:***
***Sept. 30th, 2014***

***Duration:***
***42 months***

***Budget:***
***3.5 M€ Total***
***1.6 M€ JU contribution***

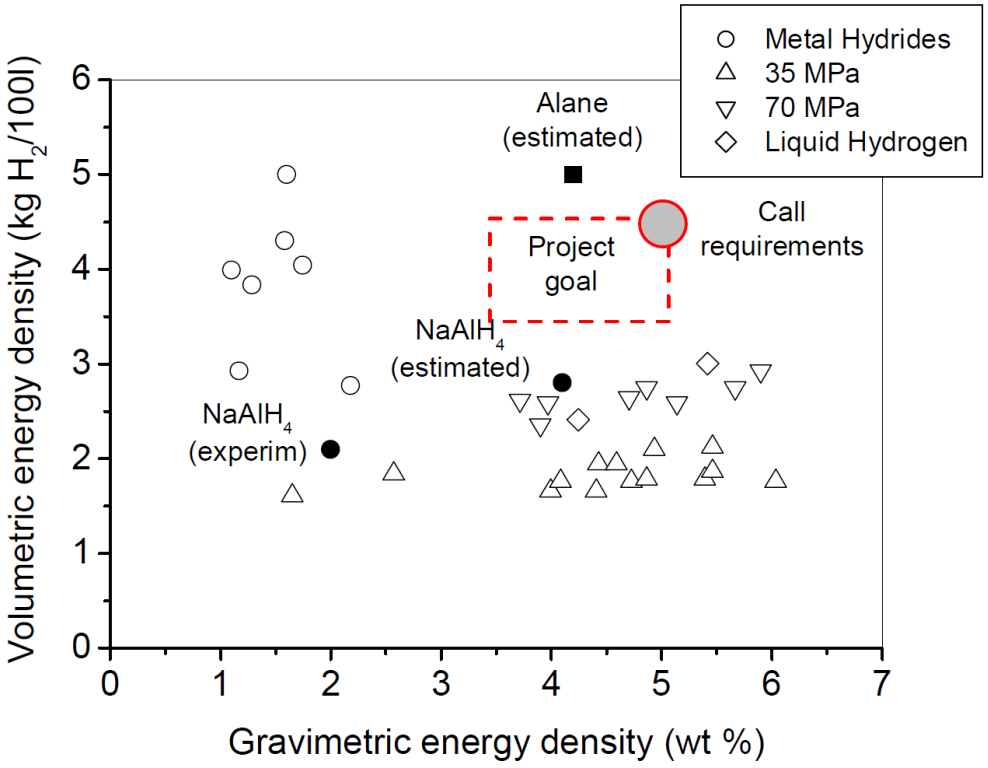
***Partners:***
***4 research + JRC***
***3 industries***

| Beneficiary Number * | Beneficiary name | Beneficiary short name | Country |
|---|---|---|---|
| 1. (Coordinator) | Università di Torino | UNITO | Italy |
| 2. | Institute for Energy Technology | IFE | Norway |
| 3. | Karlsruhe Institute of Technology | KIT | Germany |
| 4. | Deutsches Zentrum für Luft- und Raumfahrt e.V. | DLR | Germany |
| 5. | Tecnodelta s.r.l. | TD | Italy |
| 6. | Serenergy A/S | SER | Denmark |
| 7. | Centro Ricerche Fiat | CRF | Italy |
| 8. | Joint Research Centre of European Commission | JRC | Belgium |

# SSH2S in picture

# SSH2S goals

- ***Integration** between hydrogen storage system and HT-PEM fuel cell*
- ***Development of new materials** with high gravimetric and volumetric energy density*
- ***Technically relevant loading temperature and pressure***
- ***Loading time** and **stability** of performances after several cycles*
- ***New tank for supply of hydrogen flow.***
- ***Low cost***



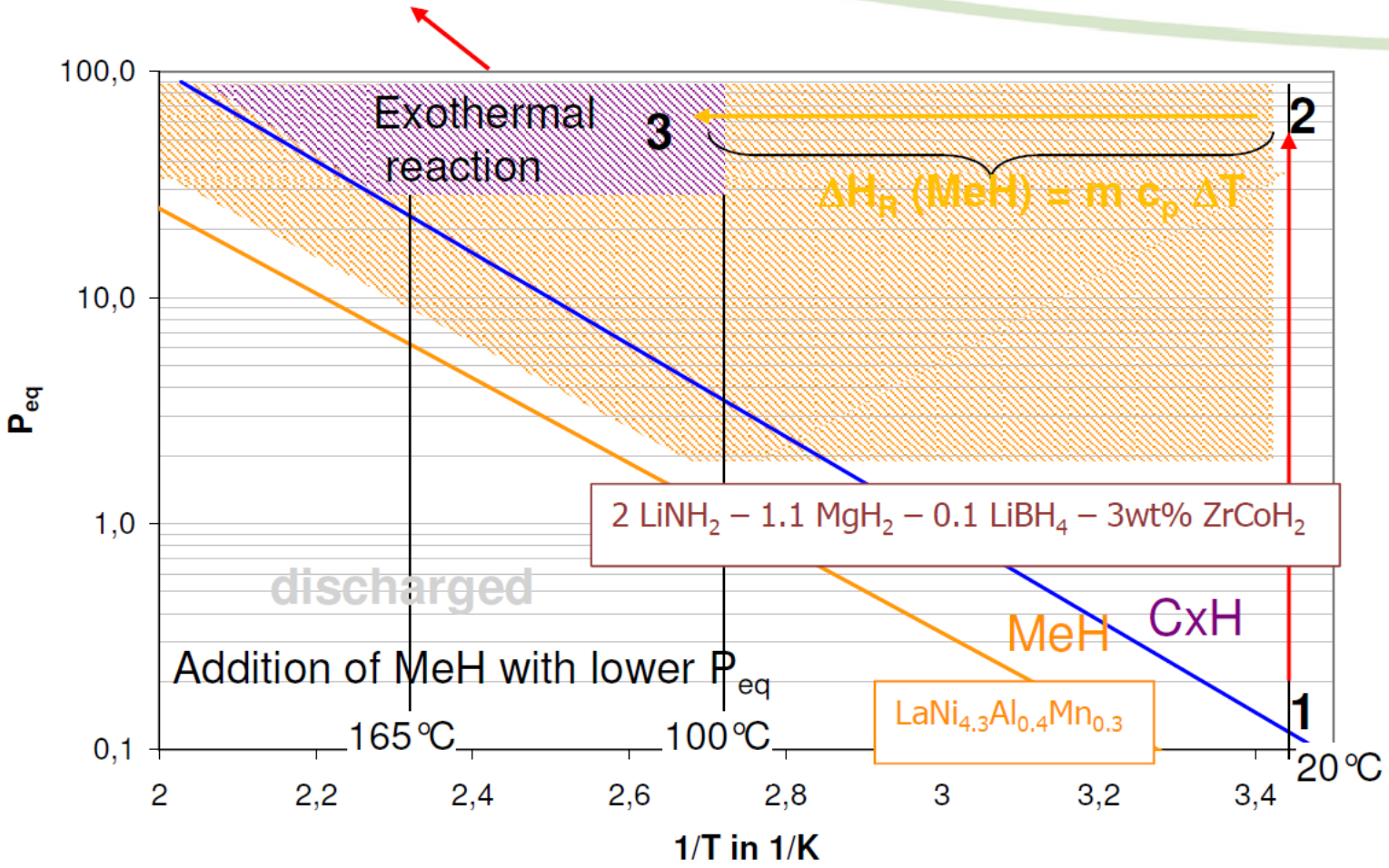

***Volumetric and gravimetric energy density of hydrogen storage systems***

# SSH2S challenges

- *Design, synthesis and physico-chemical characterization, of existing and novel materials for solid state hydrogen storage.*
- *New two-materials concept for the tank, combining hydrogen sorption properties of complex hydrides and metal hydrides.*
- *Development of a prototype tank.*
- *Integration of materials/tank systems with HT-PEM Fuel Cell (1 kWel).*
- *Application of the integrated system as APU for a LTV.*

*Lab-scale tank*

# SSH2S Combo concept



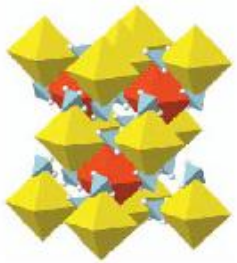

***Concept of reactor based on «double material»***

# SSH2S expected results

- *An up-scaled production of a material with capacities of up to 4.5 $H_2$ wt%, fully reversible at 180° C.*
- *High stability on cycling.*
- *New concepts on the coupling of solid state hydrogen tank with HT-PEM fuel cells.*
- *Development of a prototype 1 kW integrated system*
- *Possible application to a 5 kW APU.*
- *Business opportunities for MSE.*

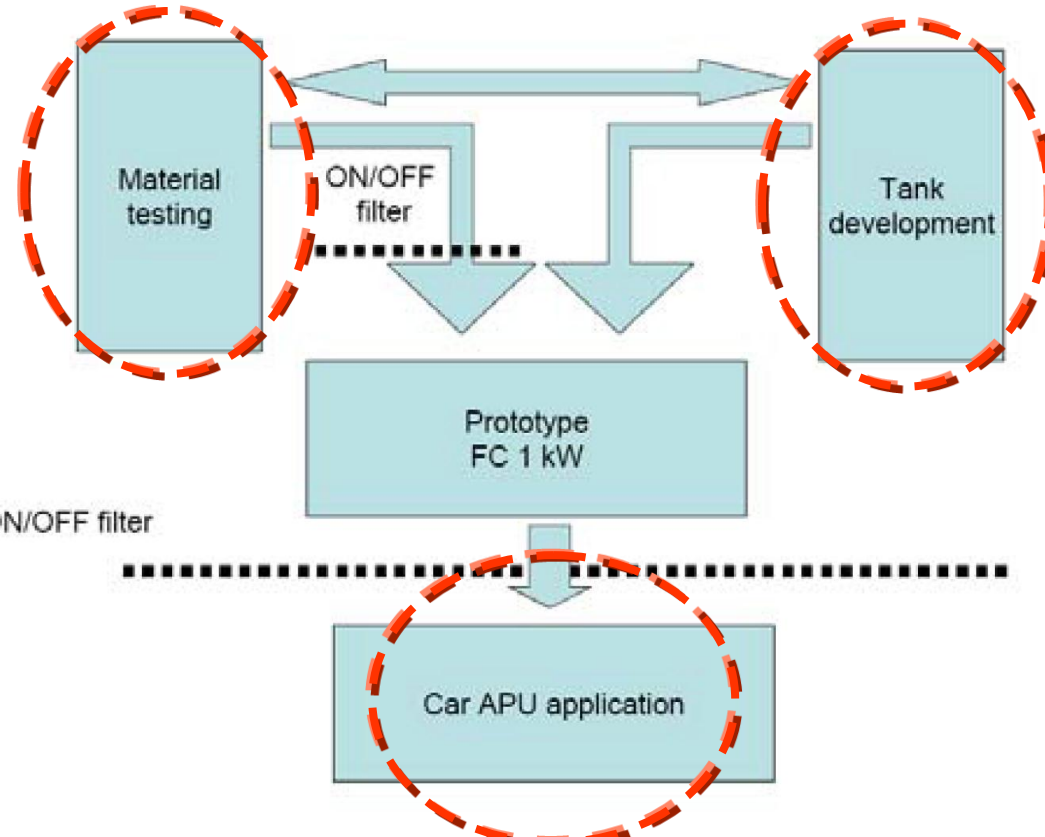

*Selected Full Electric Vehicle for APU*

# SSH2S scheme

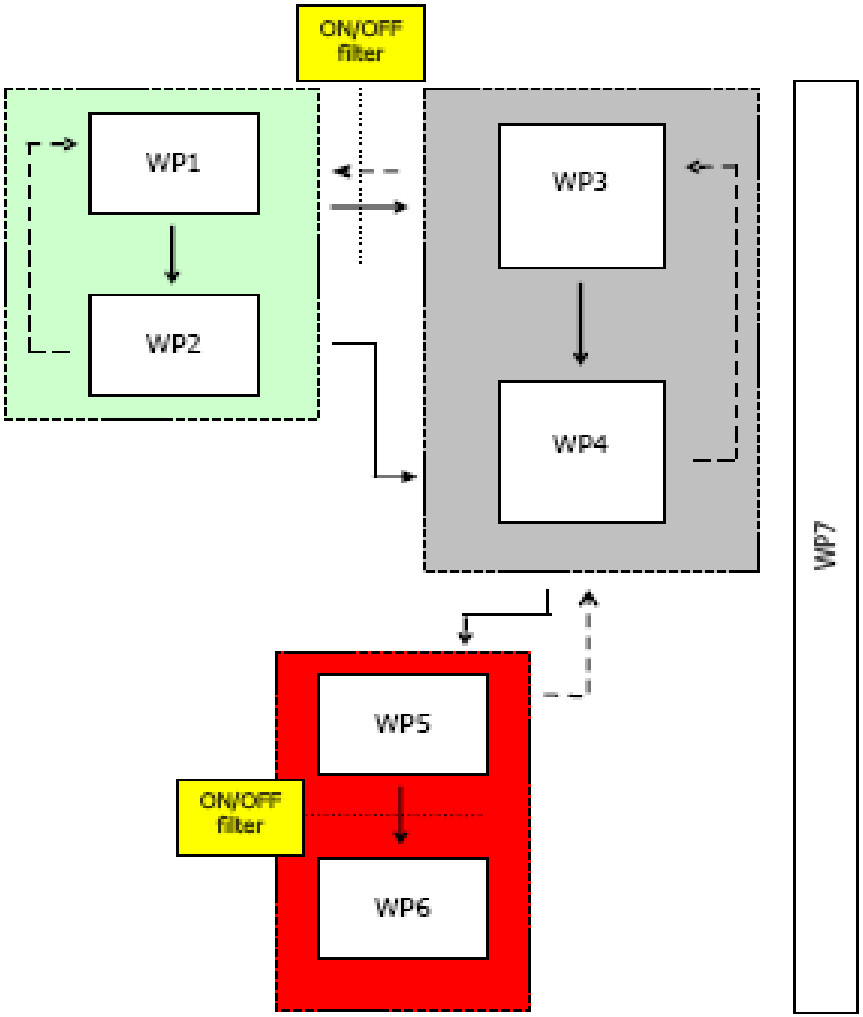


***From new materials to integrated APU system.***

## INNOVATION



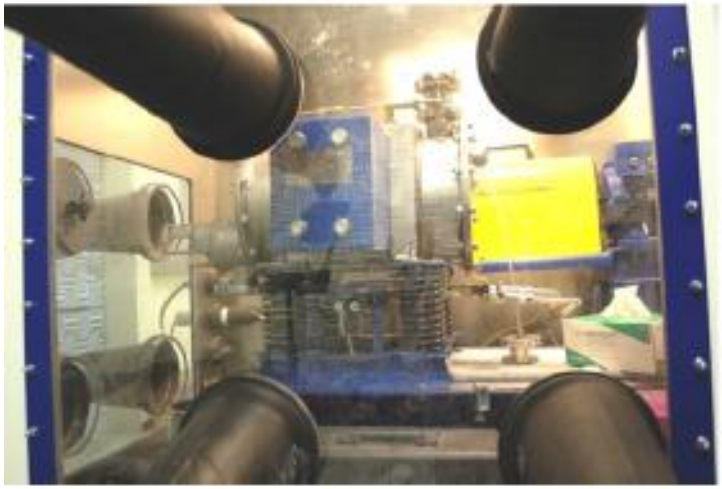
# SSH2S workplan




| WP | Title | Type | Leader |
|---|---|---|---|
| 1 | Material Design and Synthesis | RTD | KIT |
| 2 | Materials Characterisation | RTD | IFE |
| 3 | Lab-scale Tank Development | RTD | DLR |
| 4 | Fabrication and Testing of Prototype Tank | RTD | TD |
| 5 | Tank-FC integration (1 $kW_{el}$) | RTD | SER |
| 6 | Final User Test | DEM | CRF |
| 7 | Management | MGT | UNITO |

# SSH2S WP1-2 results

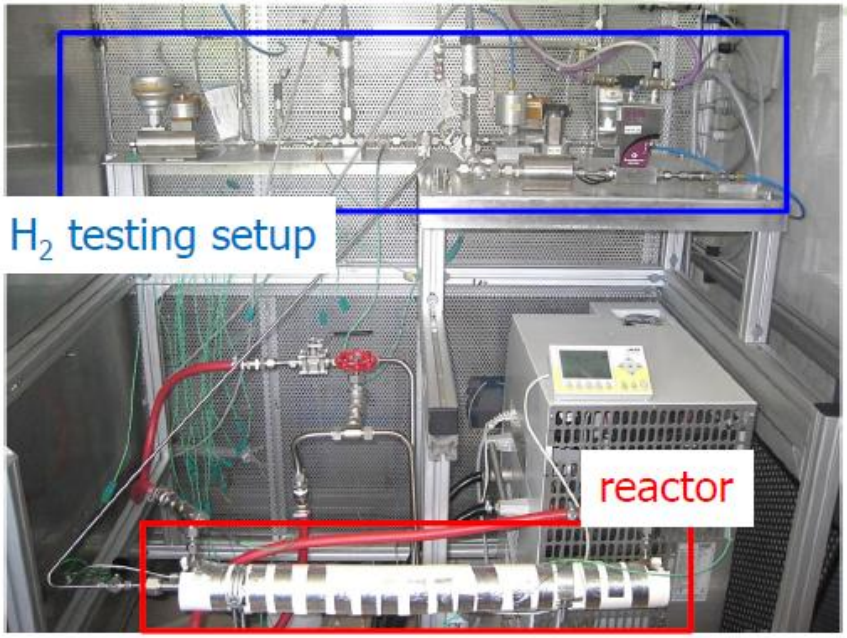
- *The role of additives on the Li-Mg amide systems have been explored.*
- *$2\ LiNH_2 + 1.1\ MgH_2 + 0.1\ LiBH_4 + 3wt\%\ ZrCoH_3$ has been selected and prepared in up-scaling conditions.*
- *A batch of 3 kg of complex hydride has been made available.*
- *A maximum 4.5 wt% gravimetric density has been obtained, with good cyclability.*
- *Li-Mg amide systems have been shown to be suitable for the development of the hydrogen tank.*



*Vibrational ball mill for large scale preparation*

# SSH2S WP3 results

- *Experiments and calculations on double materials concept have demonstrated a significant synergic effect.*
- *Extended equations for thermo-fuid-dynamic modelling have been set up.*
- *Two different lab scale tanks have been designed and put in operation to test different combination of mixed materials.*

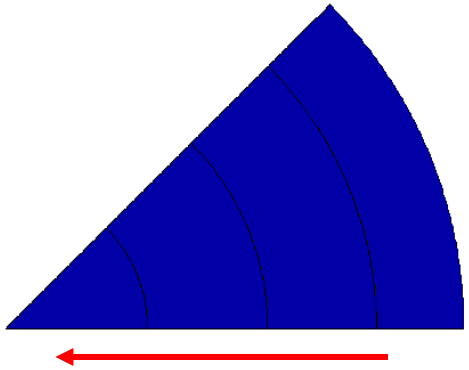



*Testing setup with integrated tank (600 g)*

# SSH2S Combo simulation

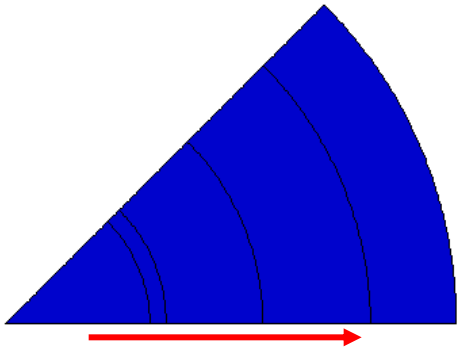
***temperature***

$T_i$ (t=0) = 20 °C; $T_{oil}$ (t=0) = 130 °C; t = 0…1800 s



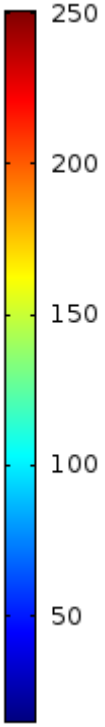
Pure Amide

powder bed is heated from outside



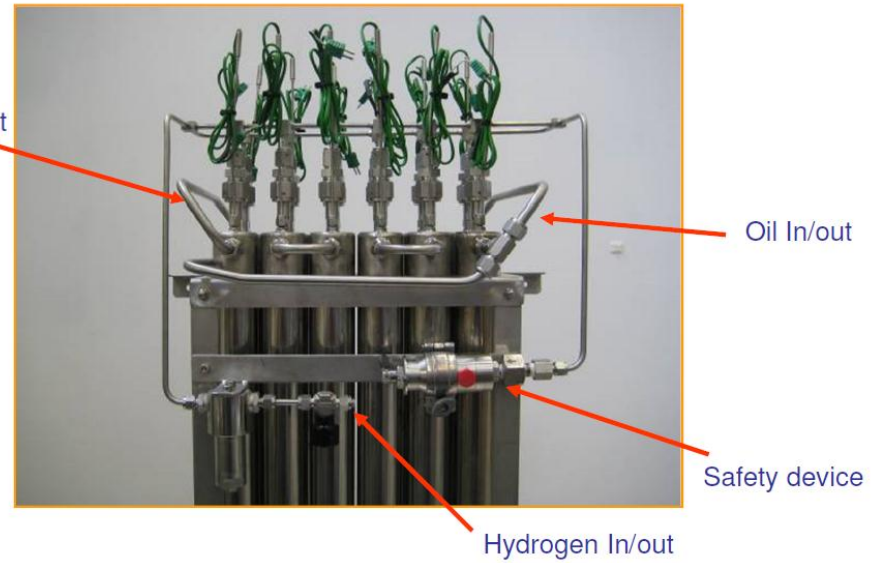
Combi-Tank

reaction is initiated at the center



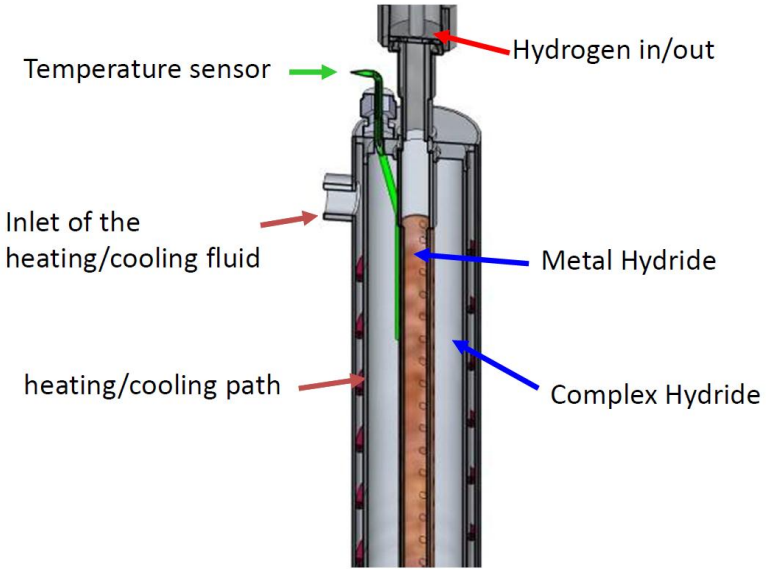
# SSH2S WP4 results

- *A prototype tank have been developed.*
- *On basis of thermo-fuid-dynamic simulations, a detailed drawing of the hydrogen tank has been prepared.*
- *A glove-box has been set-up and it is ready for the fabrication of the tank. Preliminary welding tests have been performed.*
- *A complete report on safety for the hydrogen tank has been produced.*

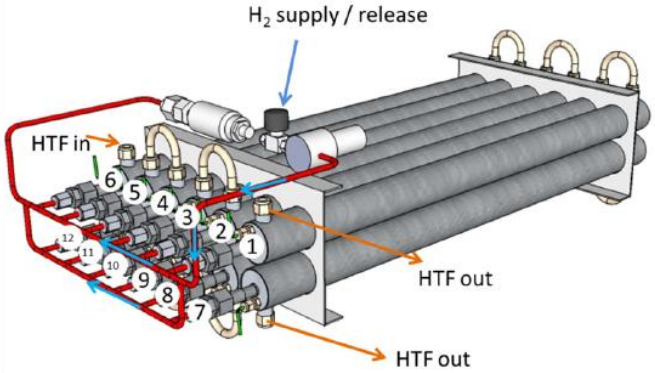



*Prototype tank (3 Kg)*

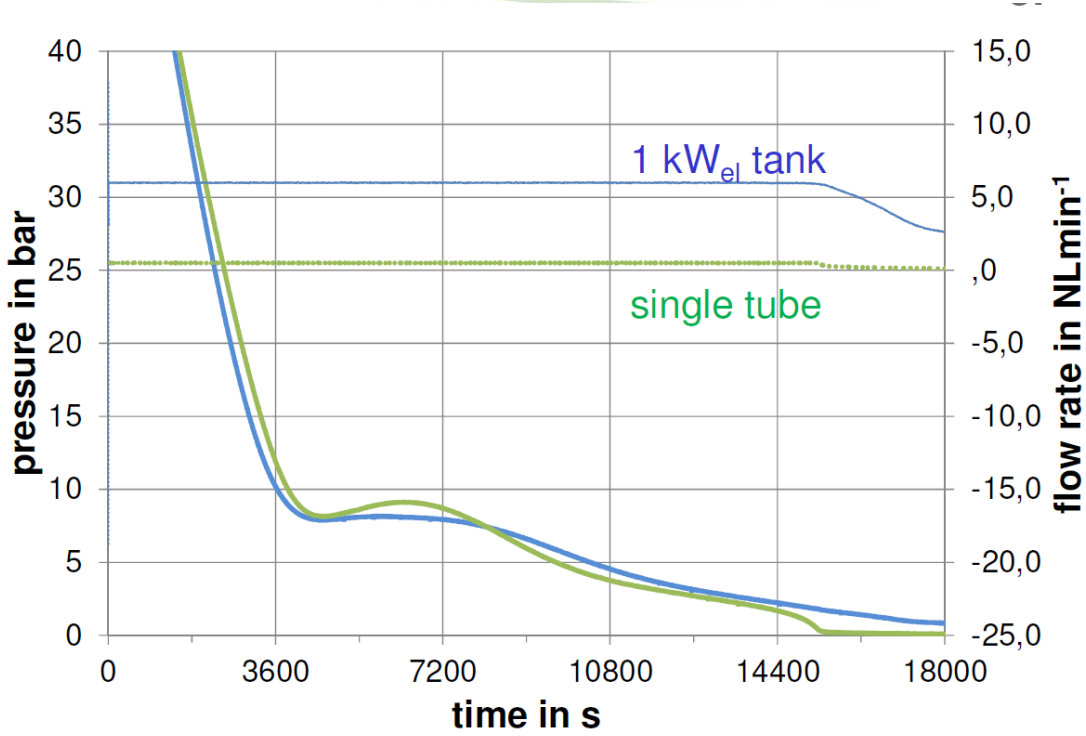
# SSH2S Combo results




***Single tube***



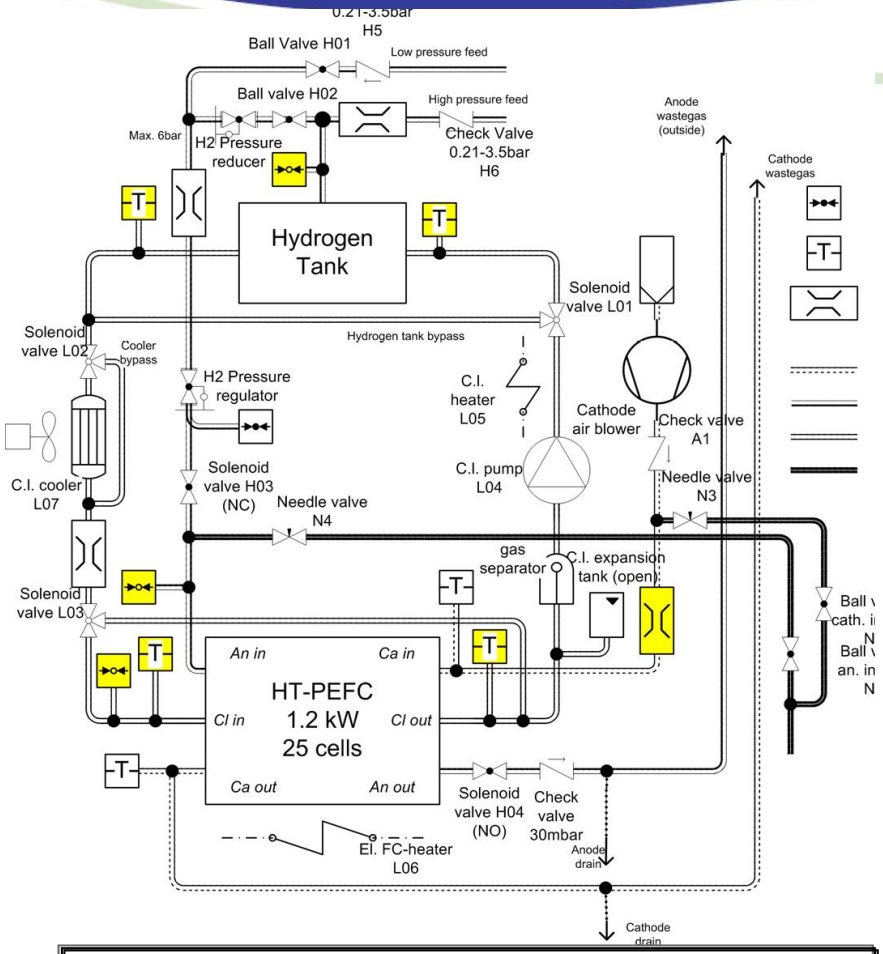

***1 $kW_{el}$ tank***




***4 h with 1 $kW_{el}$ possible***

# SSH2S WP5 results

- ***Integrated system** has been considered.*
- ***Requirements** have been defined, as a starting point for further developments.*
- ***BoP** for the integrated 1 kW system has been defined.*
- *Preliminary **tests on fuel cell** stack and components have been performed.*




***Circuit diagram***

# SSH2S WP6 plans

- *The APU will be installed inside the vehicle*
- *Safety issues are under investigation (e.g. hydrogen sensor).*
- *LCA analysis is planned.*
- *Techno-economical evaluation is planned.*

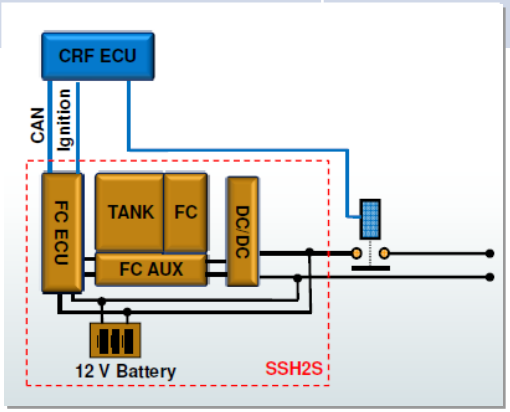

*Load area of LTV*

# SSH2S vs MAIP/AIP

## AA 2: Hydrogen Production, Storage & Distribution

| *MAIP/AIP targets* | *Project goal* | *Project status* | *Gaps bottlenecks in RTD* |
|---|---|---|---|
| *Long-term and break-through oriented research on improved solid state hydrogen storage options for increased efficiency and storage capability, i.e. 2nd generation hydrogen storage technology.* | *Integrated system to be demonstrated in a prototype APU system (1 kW) and possibily in (5 kW)* | *Architecture under development. Good material properties* | *Intrinsic properties of materials not yet optimized* |

*Architecture for Daily Electric*

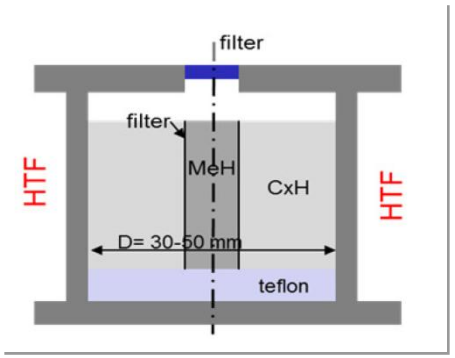


# SSH2S vs MAIP/AIP

## AA 2: Hydrogen Production, Storage & Distribution

| MAIP/AIP targets | Project goal | Project status | Gaps bottlenecks in RTD |
|---|---|---|---|
| Storage materials with capacities ≥ 6 wt.%, ≥ 60 kg $H_2/m^3$ reversibly releasing hydrogen at operating temperatures compatible e.g. with PEM FC, HT PEM FC or SOFC / MCFC | Approx. 5 wt% $H_2$ (amides)<br>7-11 wt% wt% $H_2$ (mixed borohydrides)<br>Double materials concept | Storage materials with capacities up to 4.5 wt% $H_2$<br>Reversibility at 180 ° C<br>Single reaction step<br>Stability on cycling<br>Stop for mixed borohydrides | Lack of reversibility in new developed materials |

**Double Materials concept**



# SSH2S vs MAIP/AIP

## AA 2: Hydrogen Production, Storage & Distribution

| MAIP/AIP targets | Project goal | Project status | Gaps bottlenecks in RTD |
|---|---|---|---|
| *Improved system density for $H_2$ storage (2015: 9 %wt of $H_2$)* | *4 wt% of $H_2$<br>40 kg $H_2/m^3$<br>Close to room temperature and pressure* | *Not yet available<br>Gravimetric density likely lower than goal<br>Volumetric density likely OK* | *High gravimetric density material with suitable properties not yet available* |
| *Cost effective production routes of the materials* | *< 1250 €/kg H2* | *Not yet available, but higher than goal* | *Low production for limited market* |


***HT-PEM for integrated system***

# SSH2S dissemination

- ***Workshop of FCH-JU projects on hydrogen storage* - *BOR4STORE, EDEN, HYPER, SSH2S - Oct. 2nd, 2013 in Tenerife (Spain).***
- ***Main topics discussed are the following:***
  - ***Materials for solid-state hydrogen storage***
  - ***Hydrogen tanks based on solid-state materials***
  - ***Integration of solid-state hydrogen tanks with fuel cells***
  - ***Final use and applications***
- ***Workshop of FCH projects related to APU in Torino (Italy) as a final event of the project (i.e. June 2014). DESTA and FCGEN agreed to join the meeting.***
- ***Publications and conferences.***

# SSH2S cross cutting issues

- *Training: 3 PhD student and 5 PostDocs involved in the projec*
- *Website www.ssh2s.eu*
- *Post-project activities to be defined*
- *Connections with national and international hydrogen projects and organizations*






# acknowledgments


New Energy World IG
fuel cells & hydrogen for sustainability

*Thank you for your attention*

N.ERGHY

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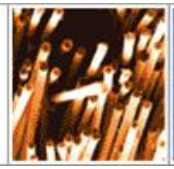
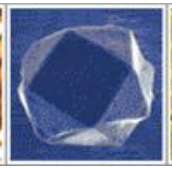


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