H_2 Carriers for long duration energy storage

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DOE Workshop on Long Duration Energy Storage March 10, 2021

Pacific Northwest NATIONAL LABORATORY

Lawrence Livermore National Laboratory

NREL NATIONAL RENEWABLE ENERGY LABORATORY

COLORADO SCHOOL OF MINES

Sandia National Laboratories

BERKELEY LAB

Acknowledgements - contributors

- PNNL (Mark Bowden, Kriston Brooks, Ba Tran, Kat Grubel, Jothi Kothandaraman, Abhi Karkamkar, Sam Johnson, Oliver Gutierrez, Ahmed Tbaileh, Chirag Mevawala, Shuyun Li, Vish Viswanathan, Mallik Vallem)
- LBL (Hanna Breunig, Peng Peng, Kelvin Yoro, Ji Su, Jinghua Guo, Jeff Long, Hiroyasu Furukawa)
- NREL (Tom Gennett, Noemi Leick)
- LLNL (Sneha Akhade, Brandon Wood)
- SNL (Mark Allendorf, Vitalie Stavila, Jon Snider, Matt Witman)
- ANL (Rajesh Ahluwalia, Dennis Papadias)
- University of Hawaii (Craig Jensen, McKinley Prager, Sunil Shrestha)
- University Southern California (Travis Williams, Nick Alfonso)
- Washington State University (Hongfei Lin, Zhun Dong, Shaoqu Xie)
- DOE (Zeric Hulvey, Ned Stetson, Scott Jorgenson, Kevin Ott)

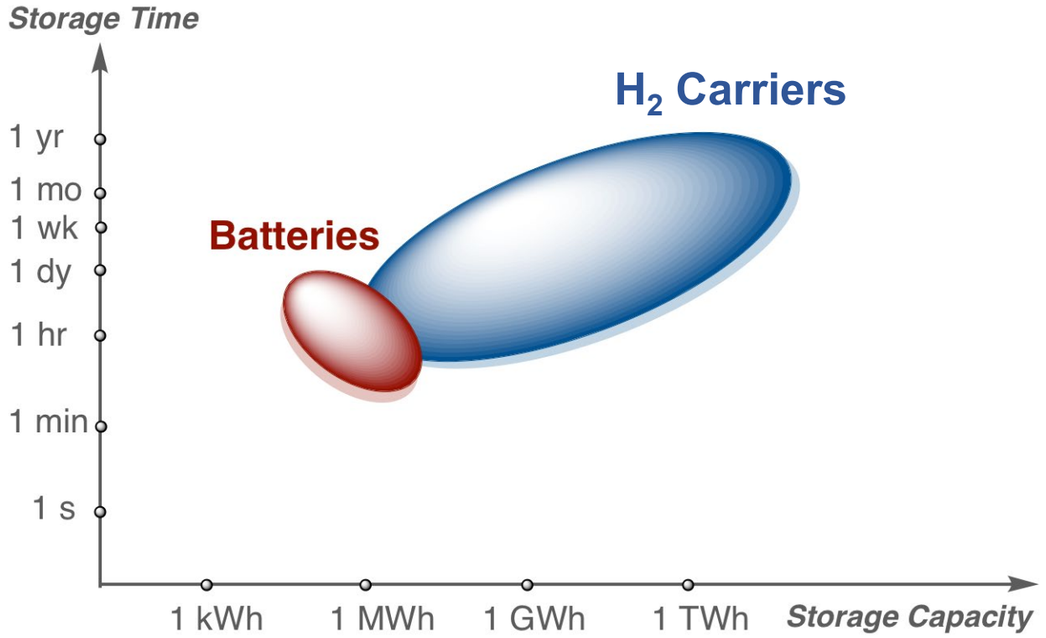
Carriers – H_2 rich materials used to Store or Transport energy

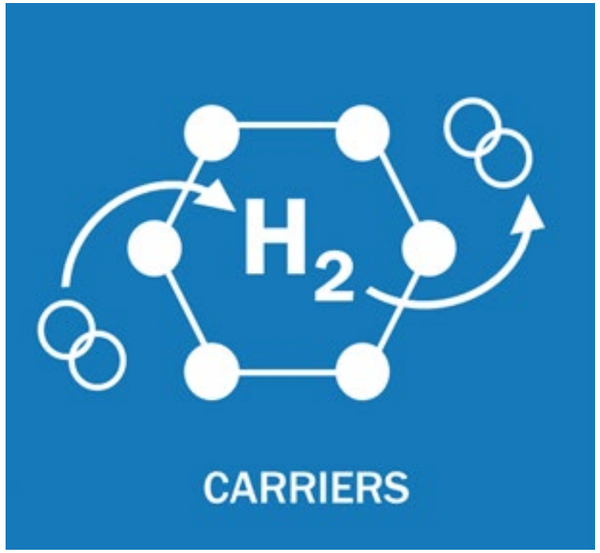
- Suited to larger energy, longer storage time applications
  - Scalable – like a flow battery
  - Geographically agnostic
- Different scenarios envisaged
  - Stationary (backup power, industrial …)
  - Mobile (bus, truck, ferry …)
  - Used and regenerated onsite (seasonal storage)
  - Transported to and from a central regeneration facility (regional fuel depot)
- More complex - require additional equipment
  - Reactors, separators, pumps
- Can be solid or liquid
  - Sorbents or chemical compounds
  - Not simply compressed or liquid H_2

compress H2	**kg H_2/m³**
250 bar	18
500 bar	30
liq H2	70
cryo comp H2	87
MCH	**47**
NEC	**54**
DBT	**56**
NH3	**128**
EtOH/EtOAc	**35**
DME(aq)	**60**
MeOH(aq)	**150**
H_2CO_2(aq)	**53**
$KHCO_2$(aq)	**30**
LaNi5	**118**
AlH3	**37**

Context of energy storage demand – days and MWhs

- Advantages
  - Liquids to take advantage of infrastructure
  - By the numbers - generic H2 carrier
  - 50 kg H_2/meter^3 (20 kWh/kg H_2)
  - 1 meter^3 ~ 1 MWh
  - ambient temperature and pressure
  - stability years
- Challenges
  - Round trip efficiency (< 0.7 x 0.6)
  - Setting general targets for multiply applications





- Industrial entities
  - Chiyoda - Japan
  - Hydrogenious - Germany
  - Hynertech – China
  - HydroSil - France
- Government entities
  - US Department of Energy Hydrogen Fuel Cell Technology Office – HyMARC – Hydrogen Materials Advanced Research Consortium – an Energy Materials Network

Major R&D Challenges – TBD by experiment, computation and modeling

- Known knowns – *things we know we need to know*
  - Gravimetric and volumetric density of material
  - Thermodynamic properties of material “T1bar” (do we want T 95% conversion?)
  - Physiochemical properties (mp, bp, vp, viscosity, solubility)
  - *Energy and power requirements for use case*
  - *Storage duration and duty cycle for use case*
  - Optimum thermodynamic properties - ΔH / ΔS plot
  - Catalysis: reactivity and selectivity; stability – Weisz criteria
- Known unknowns – *things we know we need to know but don’t know yet*
  - *Round trip efficiency – how far are we from (0.7 x 0.6)?*
  - *How big is the reactor*
  - *What are the components required for the reactor, purification*
  - *What is the OPEX and CAPEX?*
  - *What is the most expensive component?*
  - *Can we make a H_2 carrier without H_2 (electrochemical reduction)*
  - *If a catalyst is ‘fast’ enough – can we make it cheaper, more stable?*
  - *Buffering – start up shut down, transients – average rates and peak rates*
- Unknown knowns – *things we know we should know but are currently unaware of knowing*
  - What are the catalysts used today?
  - Are the catalysts sufficient? TOF, selectivity, lifetime, $
- Unknown unknowns - *things we don’t know that we need to know*