Solid-State-Based Hydrogen Loss Recovery During LH_2 Transfer

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DOE Hydrogen Program
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Project Goal

GOAL: Design, engineer, construct, and demonstrate a materials-based solution for the capture of H_2 from LH_2 boil-off loss events.

FINAL DELIVERABLE: Scalable prototype operating on-site to capture H_2 losses from a LH_2 transfer event and detailed technoeconomic analysis (TEA) evaluating financial feasibility, which includes evaluation of end uses for the captured H_2.

Overview

Timeline

Phase 1: 3/1/24 to 2/28/25

Phase 2: 3/1/25 to 2/28/26

Phase 3: 3/1/26 to 2/28/27

Project continuation determined annually by go/ no-go metrics

Budget

Total 3/1/24 -2/28/25: $2M

Total Project: $6M

Barriers to Overcome

General:

A. Cost, B. Weight and Volume, C. Efficiency, E. Refueling Time

Reversible Solid-State Material:

M. Hydrogen Capacity and Reversibility

O. Test Protocols and Evaluation Facilities

Critical Partners

- National Renewable Energy Laboratory
- Airbus
- Stoke Space
- Lawrence Berkeley National Laboratory
- Metropolitan State University of Denver

Project Potential Impact

LH_2 will be a key component of decarbonizing heavy-duty vehicle and aviation industries. Demonstrating boil-off loss mitigation is critical to accelerating industry adoption.

Project outcome	Impact
Report detailing TEA of materials-based system for recovering H_2 boil-off from LH_2 transfers.	Report will demonstrate economic feasibility and be a guide for developing TEAs specific to other LH_2 recovery applications.
Lab-scale prototype for testing materials of interest under conditions representative of various LH_2 loss event conditions.	The results will provide industry with a manageable list of materials to consider for H_2 recovery based on specific system requirements.
Prototype integrated with a LH_2 loss event to recover H_2 that would otherwise be released to atmosphere or flared.	Published report detailing prototype and results will provide a road map for integrating H_2 recovery systems into LH_2 infrastructures and demonstrate technical feasibility.

Approach: Project Overview

Task	Task deliverables
Identify target H_2 loss event for prototype integration	• Measure properties of hydrogen boil-off release during standard operation procedures (pressure, temperature, & rates) • Define material property parameter space based on target loss event release conditions
Down selection to material(s) for prototype demonstration	• Design and build lab-scale prototype for testing materials under varying uptake and release conditions. • Evaluate materials of interest at lab scale to determine performance under boil-off conditions (including gas temperature, pressure, and release rate) for material down select.
TEA of LH_2 boil-off recovery system including end use scenarios	• Report detailing TEA of materials-based LH_2 boil-off recovery system including evaluation of recovered H_2 end uses
Design, build, & demonstrate a kg scale materials-based H_2 boil-off recovery system	• Prototype integrated with a boil-off H_2 loss event, validating the technology performance for H_2 recovery and cost savings. • Publish details of on-site system design and integration with LH_2 infrastructure and the final system efficacy

Approach: material down select

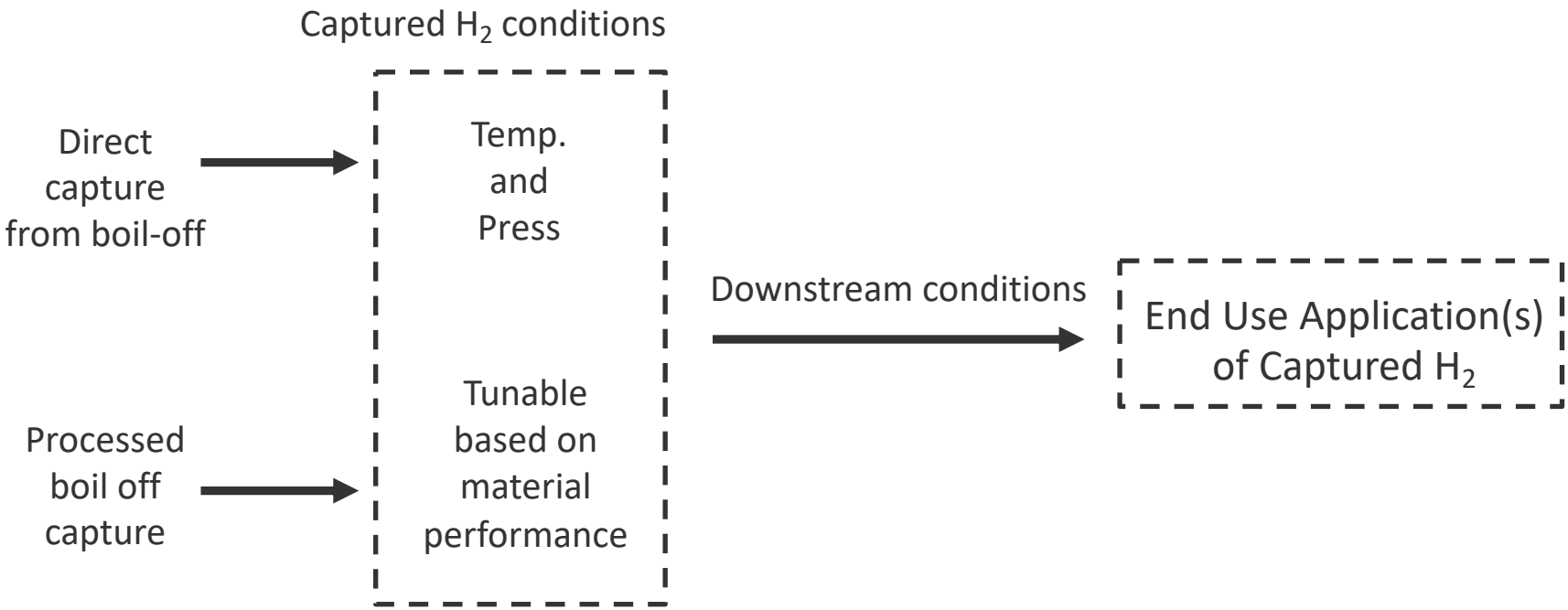
Identified target loss event defines material property parameter space: required H_2 uptake kinetics

Materials of interest identified based on HyMARC expertise

Initial down-select: equilibrium gas capacities at relevant pressure and temperatures.

Evaluation of down-selected material sorption properties under relevant operating conditions representative of target loss event.

Approach: TechnoEconomic Analyses (TEA)

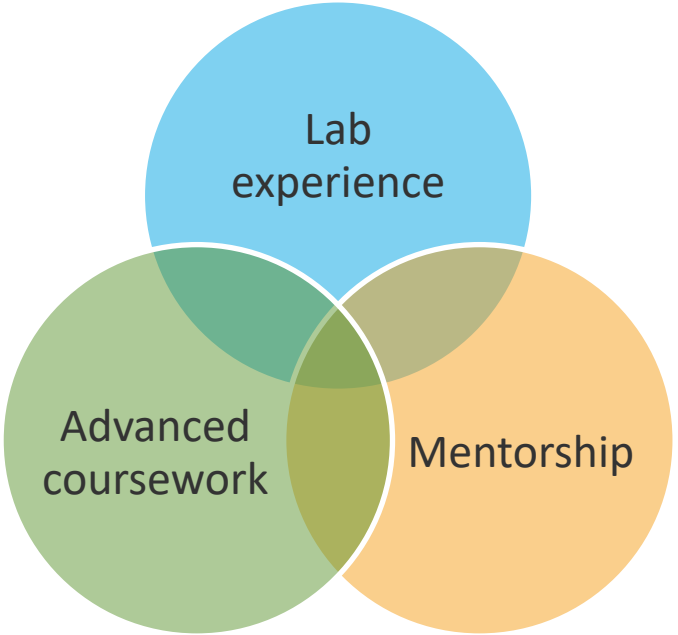


TEA will guide system design for net energy and monetary loss minimization.

Approach: DEIA

Bridge-to-career program with first-in-the-nation models for students from underrepresented (URM) groups to provide **skills** and **laboratory experience** critical to a successful industry or national laboratory career.

- Collaboration with Metropolitan State University of Denver, a Hispanic serving institution (HSI)
- Tailored Coursework plus Research Experience with researcher at Colorado School of Mines, National Renewable Energy Laboratory, Stoke Space, or Lawrence Berkeley National Laboratory
- Tiered Mentorship with Trained Mentor
- Networking and community engagement opportunities



Approach: safety planning and culture

Safety is the priority within this project at all sites:

- World-class expertise from research scientists, engineers and safety personnel is available on-site at each site
- All OSHA and DoE Hydrogen Safety Best Practices will be followed
- All project team members will attend relevant training courses including those on: cryogenics, electrical, chemical waste, pressurized gas energetics, etc.
- Extensive safety training and mentoring will be required of all new interns, graduate students, postdocs etc.
- Scope of work will be defined, evaluated for safety, and approved by safety personnel prior to initiating any research activity
- Systems will be designed with safety prioritized and reviewed by safety engineers at the respective laboratories at the design and readiness verification stages
- Detailed documentation of hazards, procedures, and maintenance will be written for all new instrumentation and capabilities developed

Accomplishments and Progress

- Successful face-to-face kick-off meeting
  - Initial project tasks established for each partner
  - Project communication planned including monthly meetings and method of data sharing.
- Initial materials of interest defined.
- Initiated lab-scale prototype design.
  - Prototype to be used to evaluate materials under *in operando* conditions.

Remaining Challenges and Barriers

Challenge: Ensuring material properties and system design at lab-scale will successfully translate to large scale system.

Mitigation: Model system at scale

- Gas flow as function of tank design
- Gas interaction with material as function of material form factor
- Heat generation and profile
- Efficacy of heat management system design

Model lab-scale system ⇄ Experiments to validate lab scale system model → Model boil-off capture system at scale ⇄ Iterative design process utilizing system modeling for system optimization

Summary

This project is focused on the engineering of a critically needed, materials-based solution for the capture of H_2 from boil-off loss events.

- Mitigating hydrogen (H_2) losses throughout all stages of transfer operations is critical to enabling liquid hydrogen (LH_2) as a high use and high-capacity energy storage reservoir, both in terms of cost and in limiting the environmental impact of H2 as an indirect greenhouse gas.
- Project deliverables:
  - Scalable prototype operating to capture H_2 losses from a LH_2 transfer event
  - Detailed technoeconomic analysis (TEA) evaluating financial feasibility, which includes evaluation of reliquification and/or power generation as end uses for the captured H_2.

This project is the pathway to design, develop, engineer, and demonstrate a materials-based LH2 boil-off recovery system.

Acknowledgements

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Thank You!

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