I-WEST

Intermountain West Energy Sustainability & Transitions

WORKSHOP SUMMARY

Regional Deployment of Hydrogen Utilization & Related Workshops

Virtual workshop held January 18, 2022

WORKSHOP FACILITATORS

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SUBMITTED TO

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Summary of Workshop on Hydrogen Utilization in the I-WEST Region

The I-WEST team organized two workshops on hydrogen (H2) as a potential pathway to carbon neutrality in the Intermountain West region. The first workshop, held January 11, 2022, centered on H_2 production. This second workshop focused on the role H_2 utilization in an energy transition strategy.

The International Energy Agency (IEA) projects global demand for hydrogen production to be over 200 Mt per year by 2030 in the net-zero scenario. This global demand represents an important opportunity for the Intermountain West as H_2 could be produced regionally using multiple pathways. H2 can also be utilized regionally to meet decarbonization goals including in fuel cells, electricity generators, and renewable fuels.

The workshop focused on near-term (0-5 years) low-carbon hydrogen utilization technologies deployment strategies in the I-WEST region. The overall objective of the workshop was to gather inputs to help answer the following questions:

- What are the potential markets (e.g., refining, mining, metals recycling, fuels, and exports)?
- What are the critical barriers to deployment (i.e., technical, infrastructure, financial, policy, regulations, societal)?
- What policies are needed for energy, equity and inclusion (i.e., sovereign nations)?
- What are the expected economic impacts (e.g., revenue, jobs)?

The workshop was held virtually due to COVID restrictions. Participants in workshop were primarily stakeholders of emerging H_2 production projects in the region that would be able to provide input to formulation of the I-WEST roadmap relative to the questions above. The workshop included 17 stakeholders from 15 organizations active within the region (section 1.1).

The workshop was held under Chatham House Rule, to facilitate a vibrant and candid discussion. The format of the workshop was a set of short presentations from key stakeholders followed by moderated roundtable discussion (section 1.2 & 1.3). The moderators for each session developed a set of questions to be used as prompts for the discussion (section 1.4), and these were circulated to the participants the week prior to the workshop.

Key takeaways from the workshop are summarized below and discussed in detail in Section 1.5.

- The consensus among workshop participants was that H_2 generation and utilization will play a role in the region but there will be trade-offs between different technologies during the transition to a net-zero carbon energy economy.
- The primary barriers to a carbon-neutral region are not technology based, but rather the adherence to a long-term commitment by the government, by establishing supporting policy and regulations, and developing supporting infrastructure.
- The participants identified four H_2 utilization technologies that could be deployed in the region over next 10-year period, including fuel cell vehicles, blending with natural gas (NG), power generation, and production of synthetic chemicals and fuels (e.g., ammonia, methanol, aviation fuels) by combining with CO_2.

1.0 Details of the Workshop

1.1 Workshop Attendees

STAKEHOLDERS

Name	Company Name	Job Title
Dory Peters	Big Navajo Energy Company	President/CEO
Brian DeBruine	Colorado Hydrogen Network	Director
Andrew Hegewald	Dominion Energy	Gas Business Development Manager
Jeffrey Eppink	Enegis, LLC	President
Ron Rebenitsch	Energy Engineering, inc	CEO
Mike Biddle	Evok Innovations	Partner
Ken McQueen	Kenergy Consulting LLC	Principal
Joe Merlino	Libertad Power Project	Managing Partner
Dan Klein	Libertad Power Project	Managing Partner
Will Thomson	Massif Capital	Managing Partner
Dan Lloyd, MT	Montana DEQ	Bureau Chief
Zane Rhodes	Newpoint Gas, LLC	President
Ian Andrews	RAW Energy	Consultant
R. Walje	RAW-Energy	Principal
Indra Bhattacharya	Tri-State Generation and Transmission Association, Inc.	R&D Program Manager
Elliot Metzger	Williams	Business Development
William McCabe	McCabe and Associates	Principal

I-WEST TEAM

Name	Company Name	Job Title
Andrea Maestas	Los Alamos National Laboratory	Program Manager
Babetta Marrone	Los Alamos National Laboratory	Scientist
Bob Schrecengost	U.S. DOE	Sr. Program Manager
Bob Stevens	NETL	General Engineer
Brooke Tucker	University of Utah	Programs Manager
Bulbul Ahmmed	Los Alamos National Laboratory	Postdoc
Charles Nye	University of Wyoming - CEGR	Research Scientist
Chelsea Neil	Los Alamos National Laboratory	Scientist
Crystal Gallegos	Los Alamos National Laboratory	PSA
Dale Keairns	Deloitte Consulting	Specialist Master
Dave Morgan	NETL	Physical Scientist
Derek Vikara	KeyLogic	NETL Support Contractor
Don Remson	NETL	Analyst

Eric Guiltinan	Los Alamos National Laboratory	Research Scientist
Eric Lewis	NETL	Research General Engineer
Erin Campbell RFF	Resources for the Future	Research Analyst
Felicia Taw	Los Alamos National Laboratory	R&D Manager 5
George Guthrie	Los Alamos National Laboratory	Dep Prog Dir
Gilles Bussod	Los Alamos National Laboratory	Research Scientists and Technical Project Manager
Istvan Robel	Los Alamos National Laboratory	Scientist
Jai-woh Kim	U.S. DOE	Senior Program Manager
Jeffrey Heikoop	Los Alamos National Laboratory	Scientist
Jeffrey Pietryga	Los Alamos National Laboratory	Group Leader, C-IIAC
Jim Gattiker	Los Alamos National Laboratory	Scientist
Jolante Van Wijk	Los Alamos National Laboratory	DGL
JS Shih	RFF	Fellow
Julie de Leon	Los Alamos National Laboratory	Group Leader, CEA-CAS
Jurgen Schmidt	Los Alamos National Laboratory	Scientist
Kevin John	Los Alamos National Laboratory	Chemistry Deputy Division Leader
Larry Daugherty	Los Alamos National Laboratory	Actinide Operations
Lee Spangler	Montana State University	Director, Energy Research Institute
Luciane Cunha	NETL	Supervisory Research / General Engineer
Masha Koleva	U.S. DOE	Chemical Engineer
Melissa Fox	Los Alamos National Laboratory	Program Director
Michael Gross	Los Alamos National Laboratory	Research Scientist
Mohamed Mehana	Los Alamos National Laboratory	Scientist
Nathan Welch	Los Alamos National Laboratory	Scientist
Rachel Atencio	Los Alamos National Laboratory	PM
Rajesh Pawar	Los Alamos National Laboratory	Scientist
Rajinder Singh	Los Alamos National Laboratory	Workshop Lead
Richard Fiorella	Los Alamos National Laboratory	Postdoc
Rob Braun	Colorado School of Mines	Scientist
Robert Braun	Colorado School of Mines	Scientist
Rod Borup	LANL	Scientist
Rodney Borup	Los Alamos National Laboratory	Scientist
Sam Thomas	U.S. DOE Office of Fossil Energy and Carbon Management	Director, Hydrogen with Carbon Management
Sandrasegaram Gnanakaran	Los Alamos National Laboratory	Scientist
Satish Karra	Los Alamos National Laboratory	Scientist
Scott Matthews	KeyLogic	NETL Support Contractor
Selena Gerace	University of Wyoming's School of Energy Resources	Research Scientist
Shaoping Chu	Los Alamos National Laboratory	Scientist

Sheila Van Cuyk	Los Alamos National Laboratory	Program Manager
Taraka Dale	Los Alamos National Laboratory	Scientist
Ting Chen	Los Alamos National Laboratory	Scientist
Troy Semelsberger	Los Alamos National Laboratory	Workshop Lead

1.2 Workshop Presenters

Name	Company Name	Job Title
Zane Rhodes	Escalante H2 Power	President
Indra Bhattacharya	Tri-State Generation and Transmission Association, Inc.	R&D Manager
Will Thomson	Massif Capital	Managing Partner
Mike Biddle	Evok Innovations	Partner
Dan Klein	Libertad Energy	Managing Partner & I-West Partner
Rod Borup	LANL	Scientist
Robert Braun	Colorado School of Mines	Scientist
Dory Peters	Big Navajo Energy Company	President and CEO
William McCabe	Navajo Nation Oil and Gas	Vice President
Andrew Hegewald	Dominion Energy	Gas Business Development Manager

1.3 Workshop Agenda (18 Jan 2022)

Time	Topic	Presenter
10:00-10:10	Introduction and I-WEST Overview	**George Guthrie** Los Alamos National Laboratory
10:10-10:20	Summary of I-WEST Hydrogen Production Workshop	**Troy Semelsberger** Los Alamos National Laboratory

Time	Topic	Presenter
Ten-minute presentations will introduce regional projects and/or company perspectives on the potential role of hydrogen utilization in a strategy to decarbonize the Intermountain West. Please use the chat to document your questions throughout the presentations so they can be addressed during the roundtable discussion.		
10:20-10:30	Hydrogen Utilization (Escalante Project)	**Zane Rhodes** Escalante H2Power
10:30-10:40	Power Generation	**Indra Bhattacharya** Tri-State Generation
10:40-10:50	Financial Perspectives on Hydrogen Utilization	**Will Thomson** Massif Capital
10:50-11:00	Financial Perspectives on Hydrogen Utilization	**Mike Biddle** Evok Innovations
11:00-11:15	Hydrogen Utilization and Demand	**Dan Klein** Libertad Energy
11:15-11:25	Heavy Duty Fuel Cells	**Rod Borup** Los Alamos National Laboratory
11:25-11:35	Hydrogen Utilization	**Robert Braun** Colorado School of Mines
11:35-11:45	Big Navajo Energy Company	**Dory Peters** President/CEO Navajo Nation Oil and Gas **William McCabe** VP Navajo Nation Oil and Gas
11:45-11:55	Utah H2 Project	**Andrew Hegewald** Dominion Energy
11:55-12:00	Break	-
12:00-2:00	Roundtable Discussion	**All**
	Moderators: **Brian Debruine,** CTO at New Day Hydrogen and Founder of the Colorado Hydrogen Network **Charles Nye,** Research Scientist, School of Energy Resources, University of Wyoming	
2:00	Wrap up	**Troy Semelsberger and Raj Singh** Los Alamos National Laboratory

1.4 Workshop Prompts/Questions

The following questions were provided to the workshop presenters to address during their presentations. They were asked to focus on the relevance to the I-WEST region (MT, UT, MT, NM, AZ, CO). Workshop participants were encouraged to formulate follow-up questions prior to the workshop and/or raise them during the roundtable discussion.

1. What current fossil-based industries are best suited for your technology?
    a. (e.g., cement vs. coal plant vs. natural gas plant, etc.)
2. What is the current state-of-the-art of your technology and is it deployed commercially?
    a. Scalability, reliability, cost…
    b. Timeframe to deploy technology (from design to operational)
3. Is additional R&D needed to improve or develop the next generation of your technology?
    a. Are there R&D needs specific to the I-WEST region/states?
4. What are the primary barriers to market penetration in the I-WEST region/states?
    a. Technology vs. policy vs. social vs. economic
5. What is the potential/anticipated job-creation capacity for this technology?
    a. Number of jobs
    b. Construction vs. operators
6. For your technology, is it better to have decentralized vs. centralized facilities?
7. Geographically, where is your technology best deployed?
    a. Are there lessons learned from prior deployments?
8. What enabling technologies/industries or raw materials are required for your technology to be sustainable?
        i. Metals, recycling facilities, etc.
9. What are the economies of scale for intended application?
    a. Modularity
10. What infrastructure (e.g. pipeline, grid, roadway, rail, etc.) is needed for large-scale adaptation of hydrogen generation in the I-WEST region?
11. What are the known or anticipated impacts on water resources and alternative (e.g. brackish, produced) water resources in the context of hydrogen production in I-WEST region?
12. How can we address fugitive methane emissions and their impacts on the transition to hydrogen as a pathway to decarbonizing the I-WEST region?
13. What are the advantages and barriers, specific to the I-WEST region, to capturing and sequestering CO_2 emissions from hydrocarbon derived hydrogen production processes?
14. What (if any) contractual agreements are in place that might prevent communities from implementing renewable resources?
15. What incentives are required and/or provided to landowners who dedicate land for renewable energy?
16. At the deployment scale, are there concerns about impacts on the I-WEST ecosystem (e.g., deforestation, water tables, etc.)?
17. Water is a central concern throughout the Intermountain West, and water usage to produce hydrogen *solely* for regional would be low, it would increase significantly if hydrogen is used to export natural gas. How do concerns about water impact decisions about technology options for generating hydrogen? Are there new technologies emerging that could generate hydrogen from non-potable water? What advancements would be needed in conventional desalination technology to make produced waters and brines a viable resource for hydrogen production?

18. Many communities within Intermountain West are limited with respect to enabling infrastructure (pipelines, grid, broadband, rail, etc.). How does infrastructure factor into technology options for the region? What are the key infrastructure investments that could be game changers for deployment within the region?
19. Several commercial technologies are available for hydrogen generation through electrolysis or steam-methane reforming. To what extent do these need adaptations for the Intermountain West region? What new technology developments for hydrogen generation could be game-changers for deployment within the region?
20. Fugitive methane emissions are a concern for some parts of the Intermountain West. How does this impact hydrogen deployment in the region? How does this factor into concerns about life-cycle emissions associated with hydrogen as a pathway? Do these fugitive methane sources provide an opportunity for small scale hydrogen generation? Are there technology developments relative to fugitive methane that could be game changers for hydrogen as a viable pathway?
21. Hydrogen generation requires hydrogen demand. How might hydrogen demand evolve within the region (scale and timing)? Is hydrogen a viable option for decarbonizing natural gas exports that are important to regional economies?
22. CO_2 storage is an important technology enabler for some routes to hydrogen generation. What considerations on regional CO_2 storage are important to you in deciding to move forward with a hydrogen generation project?

1.5 Summary of Key Takeaways

The presenters and attendees of the Hydrogen (H_2) Utilization Workshop represented the I-WEST region (UT, NM, WY, CO, AZ, MT) with a broad range of expertise ranging from R&D, policy and regulation, early- to mid-stage finance, utility power and transmission, and infrastructure—the necessary components to build a regional coalition to decarbonize the I-WEST. The affiliations of the workshop participants ranged across academic institutions, national laboratories, state and federal government, sovereign nations, small and large companies and financial institutions. Overall, the workshop led to some key outcomes and lessons -

1. It provided an opportunity to foster new collaborations among the participating regional stakeholders
2. The regional stakeholders recognize that a regional, grassroots carbon-neutral strategy is the best approach for the long-term economic viability of the region,
3. The primary barriers to a carbon-neutral region are not technology based, but rather the adherence to a long-term commitment by the government, by establishing supporting policy and regulations, and developing supporting infrastructure.
4. There will be trade-offs between different technologies during the transition to a net-zero carbon energy economy.

Four “near-term” H_2 utilization technologies that could potentially result in significant CO_2 emission reductions in the region were highlighted during the workshop. “Near-term” in this context is defined as the deployment of currently commercial hydrogen utilization technology across the I-WEST region over next 10-year period. The four H_2 utilization approaches included fuel cell vehicles, blending with natural gas (NG), power generation, and production of synthetic chemicals and fuels (e.g., ammonia, methanol, aviation fuels) by combining with CO_2. A brief summary identifying the advantages, disadvantages, and

market penetration scenarios for the regional deployment and adoption of hydrogen in the I-WEST region follows.

- Given the large renewable solar and wind resources and land that can be used to generate green H_2, the I-WEST region is in a unique position to become a leader in green H_2 production. However, the ability to use and transport H_2 within and outside the I-WEST region is a limiting factor for increasing green H_2 production creating a supply vs. demand conundrum. A near-term opportunity to break the supply vs. demand paradox is to blend H_2 with natural gas using the current natural gas transportation infrastructure. This approach will establish a foundation for hydrogen production and can lead to accelerating the market adoption of fuel cell vehicles and production of renewable fuels and chemicals.
- In addition to fuel cell vehicles the fuel cell transportation sector requires a reliable H_2 supply infrastructure including filling stations. Integrating on-site electrolyzers and H_2 filling stations supplying on-demand H_2 offers early market adoption of fuel-cell vehicles by developing the supply and demand of H_2 in parallel. The workshop attendees recognized that this strategy is unlikely to be adopted by the general population; and the necessary catalyst for early market adoption could potentially be conversion of existing government as well as commercial vehicle fleets from internal combustion engines to fuel cell vehicles. Organizations and commercial entities with large vehicle fleets such as airports, USPS, FedEx, Amazon, and local as well as state governments were identified as pivotal players to the broader adoption of H_2-based fuel cell vehicles.
- Green H_2 for power production is unlikely given that the green H_2 production cost is currently not competitive with natural gas. There may be some niche applications with economic viability to use green H_2 as a power generating fuel; for example, when the produced hydrogen cannot be stored or transported. Although turbines operating on 100% hydrogen have been demonstrated, they are not in widespread commercial use. Hydrogen blending with natural gas offers a potential pathway to establish the regional production and market supply of green H_2 supporting the ensuing growth in market demand.
- The global financial outlook for H_2 one-offs is very challenging. In the US, the emerging markets for H_2 are industrial heating, cement production, fuel cells and steel production. Aside from fuel cells, currently there is limited availability of investment funds for H_2 related technologies. The interesting investment opportunities for H_2 utilization in the I-WEST region were identified as production of renewable fuels and chemicals.
- A potential avenue to maximize efficiency, storage, and utilization of H_2 is to develop industry clusters that co-locate several different types of industries similar to the ones being developed in the UK. Strategically locating such industry clusters in the I-WEST region could be the best-case scenario from a techno-economic standpoint.
- A key factor in commercially realizing a carbon-neutral strategy is the ability to get cheap financing and grants. Early-stage financing is extremely difficult to get, with approximately 1% of startups being funded. Mid-stage financing is equally challenging because to get mid-stage public financing the companies are required to hit around 50% of the expected revenue.
- The workshop participants agreed that wind and solar will not eliminate the use of fossil fuel in the near future. Consequently, efforts to minimize carbon emissions through CO_2 capture and addressing fugitive methane emissions will be necessary.
- Renewable di-methyl ether (DME), produced from biomethane or green H_2, can be blended with propane to “decarbonize” the I-WEST propane market. In addition, biomethane is a readily available, near-term option to partially offset the emissions from fossil-based natural gas.

- A potentially slow growth in the regional demand does not preclude the I-WEST region from becoming one of the largest exporters of renewable H_2 by taking advantage of the fastest growing demand for H_2 outside the region (e.g., TX and CA). One of the major challenges to exporting H_2 outside the region is the lack of infrastructure to transport large volumes of hydrogen. The long-term storage and transport of H_2 are known issues; however, strategies to use salt domes as storage could be viable for some geographic locations. In the absence of suitable underground storage, chemicals such as methanol, ammonia, or dimethyl ether can be used as hydrogen carriers to overcome the storage and transport issues of gaseous or liquid hydrogen.
- The biggest challenge facing the region and the nation is the lack of a long-term vision and commitment to develop policies, legislations, regulations, and incentives to maintain a sustained effort to truly address the climate change.