# I-WEST

## Intermountain West Energy Sustainability & Transitions

**WORKSHOP SUMMARY**

I-WEST Hydrogen Production

*Virtual workshop held January 11, 2022*


**WORKSHOP FACILITATORS**

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**ROUNDTABLE MODERATORS**

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**SUBMITTED TO**

U. S. Department of Energy

Office of Fossil Energy and Carbon Management

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## Summary of Workshop on Hydrogen Production in the I-WEST Region

The I-WEST team organized two workshops on hydrogen ($H_2$) as a potential pathway to carbon neutrality in the Intermountain West region. This first workshop focused on the role of $H_2$ production 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 low-to-zero carbon pathways and either be used regionally or exported to other areas.

The workshop focused on $H_2$ production opportunities in the Intermountain west region over the next 0-5 years, and aimed to assess regional technology and societal readiness. The overall objective of the workshop was to gather inputs to help answer the following questions:

- What potential projects and/or opportunities are emerging in the region for production of low-to-zero carbon hydrogen?
- What are the critical barriers to deployment (i.e., technical, infrastructure, financial, policy, regulations, societal readiness)?
- 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 24 stakeholders from 21 organizations active within the region (section 1.1).

The workshop was held under the 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). The moderators for each session developed a set of questions to be used as prompts for the discussion (section 1.3), 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 1.4.

- Several $H_2$ production projects are under development in the I-WEST region utilizing the currently available commercial production pathways, including, green, blue and grey.
- Combined, all the planned projects in the I-WEST region are expected to produce ~ 500 Kilo tons of $H_2$ per year in the next 5-10 years.
- Carbon capture and sequestration (CCS) will be critical to reduce the carbon intensity of natural gas derived $H_2$. Water scarcity in the I-WEST region is a concern for large scale $H_2$ production.
- $H_2$ deployment at large scale will require significant capital investment, including for developing transportation and storage infrastructure.
- Extending the applicability of 45Q tax credits to include blue $H_2$ production as well as making other funding mechanisms available for economic and workforce development will be needed to facilitate large scale $H_2$ deployment.

# 1.0 Details on the Workshop

## 1.1 Workshop Attendees

**STAKEHOLDERS**

| Name | Company | Title |
|---|---|---|
| Allen Toweill (Chevron) | Chevron | Technology Strategy |
| Alyssa Wahlin | Dominion Energy | Engineer II |
| Andrew Hegewald | Dominion Energy (Richmond, VA) | Gas Business Development Manager |
| Anja Bendel - WY Energy Authority | Wyoming Energy Authority | Program Director |
| Brian DeBruine | Colorado H2 Council | Co-Directors |
| Crystal Heter | Tallgrass | Chief Operating Officer |
| Dan Klein | Libertad Power Project | Managing Partner |
| Dory Peters | Big Navajo Energy | President |
| Elliot Metzger | Williams | Business Development |
| Ian Andrews | SCS | Consultant |
| Indra B. | Tri-State Generation and Transmission Association, Inc. | R&D Program Manager |
| Jeff | Tallgrass MLP Operations. LLC | Senior Director Origination |
| Jeff Waite | Oberon Fuels | Director, Commercial Development |
| Jeffrey Eppink | Enegis, LLC | President |
| John Byrom | PESCO | Business Development Manager |
| Laura Nelson | FJ Management | Director Community Affairs and Sustainability |
| Matt Weaver | NEL Hydrogen | Business Development Manager |
| Patricia Kelley | New Day Hydrogen | CCO and General Counsel |
| Ron Rebenitsch | Energy Engineering, inc | CEO |
| Shaun Davison | Pilot LNG, LLC | Chief Development Officer |
| Tiffany James | Magnum and ACES Delta | Executive Consultant |
| Unsiat Zahra | Dominion Energy | R&D Engineer 1 |
| William De Los Santos | Williams | Business Development Lead - Renewables |
| Wish Krishnamoorthy | BayoTech | Chief Technology Officer |

**I-WEST TEAM**

| Name | Company | Title |
|---|---|---|
| Alan Krupnick | Resources for the Future | Senior Fellow |
| Andrea Maestas | Los Alamos National Laboratory | Program Manager |
| Babetta Marrone | Los Alamos National Laboratory | Scientist |
| Bailian Chen | Los Alamos National Laboratory | Scientist |
| Bob Schrecengost | U.S. DOE | Sr. Program Manager |
| Bob Stevens | US Dept. of Energy - NETL | General Engineer |
| Brooke Tucker | Academic | Programs Manager |
| Bulbul Ahmmed | Los Alamos National Laboratory | Postdoc |
| Charles Nye (UWyo CEGR) | 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 |
| Daniel Eldridge | Los Alamos National Laboratory | Postdoc |
| Dave Morgan | National Energy Technology Laboratory | Physical Scientist |
| Derek Vikara | National Energy Technology Laboratory | NETL Support Contractor |
| Don Remson | NETL | Analyst |
| Donald Hickmott | Los Alamos National Laboratory | Guest Scientist |
| Erin Campbell | Resources for the Future | Research analyst |
| Eric Guiltinan | Los Alamos National Laboratory | Research Scientist |
| Eric Lewis | National Energy Technology Laboratory | Research General Engineer |
| Garrett Gay | University of Wyoming | Research Scientist |
| George Guthrie | Los Alamos National Laboratory | Deputy Program Director |
| Gilles Bussod | Los Alamos National Laboratory | Research Scientist and Technical Project Manager |
| Hari Viswanathan | Los Alamos National Laboratory | Scientist |
| Hayden Miller | Los Alamos National Laboratory | Postdoc |
| Jeffrey Heikoop | Los Alamos National Laboratory | Scientist |
| Jim Gattiker | Los Alamos National Laboratory | Scientist |
| Jolante Van Wijk | Los Alamos National Laboratory | DGL |
| JongGeun Seong | Los Alamos National Laboratory | Postdoc |
| JS Shih | RFF | Fellow |
| Julie de Leon | Los Alamos National Laboratory | Deputy Group Leader |

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|---|---|---|
| Lee Spangler | Montana State University | Director, Energy Research Institute |
| Luciane Cunha | DOE-NETL | Supervisory Research/General Engineer |
| Kody Powell | University of Utah | Assistant Professor |
| Masha Koleva | 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 Weiland | National Energy Technology Laboratory | Senior Fellow |
| Nathan Welch | Los Alamos National Laboratory | Scientist |
| Neal Sullivan | Colorado School of Mines | Associate Professor |
| Prasant Sharan | Los Alamos National Laboratory | Scientist |
| Qinjun Kang | Los Alamos National Laboratory | Scientist |
| Rachel Atencio | Los Alamos National Laboratory | Project Manager |
| Rajesh Pawar | Los Alamos National Laboratory | Scientist |
| Rajinder Singh | Los Alamos National Laboratory | Staff Scientist & Manager |
| Rangachary Mukundan | Los Alamos National Laboratory | Scientist |
| Richard Fiorella | Los Alamos National Laboratory | Postdoc |
| Rob Braun | Colorado School of Mines | Professor |
| Rob Simmons | University of Utah | Carbon Science Initiative Director |
| Ryan Richards | Colorado School of Mines | Professor |
| Sanna Sevanto | Los Alamos National Laboratory | Research scientist |
| Scott Matthews | KeyLogic | Scientist |
| Selena Gerace | University of Wyoming's School of Energy Resources | Research Scientist |
| Shaoping Chu | Los Alamos National Laboratory | Scientist |
| Timothy Grant | DOE-NETL | Scientist |
| Troy Semelsberger | Los Alamos National Laboratory | Scientist |

## 1.2 Workshop Agenda

| Time | Topic | Presenter |
|---|---|---|
| 10:00-10:10 | Introduction and I-WEST Overview | **George Guthrie**<br>Los Alamos National Laboratory |
| 10:10-10:25 | In a joint venture with Magnum Development and Mitsubishi Power, Chevron is working to produce, store, and transport hydrogen at utility scale for power generation, transportation, and industrial uses in the western US. This presentation will offer perspectives on steam methane reforming (SMR) technologies from the joint venture project, located in Delta, UT adjacent to Intermountain Power Plant. Chevron is also exploring hydrogen production from natural gas, including that which is produced in the I-WEST region. | **Al Toweill**<br>Chevron, Technology Strategy Developer |
| 10:25-10:40 | Oberon Fuels has regional collaborations with LANL (NM) and is working to develop other partnerships in the Intermountain West with companies capable of converting DME into fuel-cell grade hydrogen. This presentation will focus on bio-derived hydrogen carriers (e.g., dimethyl ether) for the long-term storage and transport of hydrogen. Oberon and Suburban Propane are working together to provide blended DME-propane fuel to decarbonize the propane sector with initial market penetration in Southern California. Suburban Propane has distribution networks in AZ, UT, CO & NM. | **Jeff Waite**<br>Oberon Fuels, Market Development |
| 10:40-10:55 | Nel is partnering with NREL (CO) and LANL (NM) on several hydrogen-related consortia and demonstration projects. This presentation will offer perspectives on Intermountain West opportunities to deploy low-temperature utility, residential, industrial, and community scale electrolysis to produce green hydrogen. | **Matt Weaver**<br>Nel, Business Development Manager |
| 10:55-11:10 | The Colorado School of Mines, an I-WEST partner, is addressing regional needs in electricity generation and energy storage. This presentation will focus on opportunities in the Intermountain West region for hydrogen production using high temperature electrolysis. | **Neal Sullivan**<br>Colorado School of Mines |
| 11:10-11:25 | Currently, the bioeconomy represents a growing opportunity space for the Intermountain West. This presentation will discuss technologies for producing | **Shaun Davison**<br>Pilot NG, Chief Development Officer |

| Time | Topic | Presenter |
|---|---|---|
| | renewable natural gas generated from landfills and biomass in the I-WEST region to produce hydrogen. Topics will include end-use applications in the region (e.g., LNG fueled mining equipment, SMR), distribution infrastructure, and export opportunities. | |
| 11:25-11:35 | Break | |
| 11:35-11:50 | Williams (WY) handles 30% of the natural gas in the US and works closely with customers to provide the necessary infrastructure to serve growing markets and safely deliver natural gas products to reliably fuel the clean energy economy. This presentation will discuss green hydrogen production using renewable energy and hydrogen transport using the existing natural gas infrastructure in Wyoming. | **Elliot Metzger**<br>Williams, Strategist and Business Developer |
| 11:50-12:05 | New Day Hydrogen (CO) builds and operates hydrogen fueling stations for the "other" electric vehicle: fuel cell electric vehicles. With onsite electrolysis, NDH provides a zero-emission solution for fleets and others who have been left behind by battery electric options. NDH is focused on developing both the supply and demand for hydrogen transportation by providing hydrogen fueling as a service. NDH educates potential customers about vehicles, incentives and advantages of fuel cell technology, and then finances and operates modular stations to meet their needs. | **Patricia Kelley**<br>New Day Hydrogen, Chief Commercial Officer |
| 12:05-12:20 | Pesco is partnering with Bayotech (NM) to develop and deploy modular hydrogen generating units. This presentation will explore opportunities for distributed, on-site hydrogen production from natural gas, as well as associated water treatment needs for the I-WEST region. | **John Byrom**<br>Pesco, Business Development Manager |
| 12:20-12:35 | The Colorado Hydrogen Network is relied on as a platform and voice for hydrogen stakeholders in the Intermountain West region and throughout the world. This presentation will provide perspective on the essential role of hydrogen in energy transition, show overlooked sources of zero-carbon hydrogen, and discuss the need to develop the demand and supply ecosystem in synchrony. | **Brian Debruine**<br>New Day Hydrogen, Chief Technology Officer; Colorado Hydrogen Network, Co-founder |
| 12:35-1:50 | Roundtable Discussion<br>Moderators: | **All** |

| Time | Topic | Presenter |
|---|---|---|
| | **Brian Debruine,** Chief Technology Officer at New Day Hydrogen and Founder of the Colorado Hydrogen Network<br>**Charles Nye,** Research Scientist, School of Energy Resources, University of Wyoming | |
| 1:50-2:00 | Wrap up | **Troy Semelsberger and Raj Singh**<br>Los Alamos National Laboratory |

## 1.3 Workshop Prompts/Questions

**Discussion topics/questions for the roundtable discussion:**

The following questions were used to spur discussion during the roundtable. Participants were encouraged to provide input based on their knowledge and experience, and also formulate follow-on questions.

1. What infrastructure (e.g. pipeline, grid, roadway, rail, etc.) is needed for large-scale adaptation of hydrogen generation in the I-WEST region?
2. 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?
3. How can we address fugitive methane emissions and their impacts on the transition to hydrogen as a pathway to decarbonizing the I-WEST region?
4. 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?
5. What (if any) contractual agreements are in place that might prevent communities from implementing renewable resources?
6. What incentives are required and/or provided to landowners who dedicate land for renewable energy?
7. At the deployment scale, are there concerns about impacts on the I-WEST ecosystem (e.g., deforestation, water tables, etc.)?
8. 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?

9. 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?

10. 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?

11. 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?

12. 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?

13. $CO_2$ storage has been flagged as 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?

### 1.4 Summary of Key Takeaways

Currently, in US 10 million tons of $H_2$ is produced annually for use in predominantly industrial process and fertilizer production. With water as the only product of its combustion, $H_2$ is a clean energy carrier and is expected to play a significant role in achieving carbon-neutral energy economy. Given the presence of large natural gas (NG) reserves the I-WEST region can emerge as the leader in $H_2$ production for local use as well as for export to other regions. While $H_2$ is a clean fuel, both the $CO_2$ released from $H_2$ production via steam methane reforming (SMR) and fugitive methane emissions (resulting during the production of natural gas) are significant greenhouse gas sources. Integrated carbon capture and sequestration (CCS) is a potential path-forward for mitigating the $CO_2$ emissions from the SMR process. Water electrolysis is rapidly emerging as a $H_2$ production technology for $CO_2$-free $H_2$ production via integration with renewable solar and wind power sources. It is anticipated that the pathways for $H_2$ production to meet the existing industrial and emerging transportation sector needs in the near future (next 5 years) will constitute a mix of $H_2$ production from fossil fuels and water electrolysis.

The key summaries of workshop discussions are described below.

- Several $H_2$ production projects are currently under development in the I-WEST region covering grey, blue and green $H_2$ production pathways. New Mexico is leading the way with NG-derived $H_2$ production at both large and modular scale. Two large projects (Libertad Power Project and

Escalante $H_2$ Power) currently in planning phase are anticipated to start $H_2$ production for clean power in 2024. Both projects will leverage existing infrastructure (e.g. NG transport pipeline, grid access, road/rail network) to keep the costs low and potential geologic $CO_2$ storage opportunities in close proximity to the project sites. Libertad Power Project (NM) will be an entirely new facility while Escalante $H_2$Power (NM) will transform an existing coal-fired power plant. On modular scale Bayotech Inc. (NM) is expected to commission three 1 ton/day $H_2$ production units by 2023 in the I-WEST region [and expects to deploy total 34 units worldwide by 2024]. On the green $H_2$ production pathway, Intermountain Power Project (IPP) in Utah will use 1000 MW electrolyzers to produce green $H_2$ using renewable energy. IPP anticipates co-firing "green" $H_2$ with NG in gas turbines to start in 2030 and a complete transition to 100% $H_2$ gas turbine is expected by 2050. Williams Company in Wyoming is performing a FEED study for blending $H_2$ produced by renewable energy into existing NG pipeline infrastructure. Capturing fugitive NG for $H_2$ production was discussed as an existing opportunity to not only capture the more potent greenhouse gas but also to use it as a feedstock for $H_2$. Big Navajo Energy has plans to capture 65% of 100 million cubic feet per day of fugitive/flared natural gas for $H_2$ production by 2030 (and ramping it up to 80% by 2040). Deployed $H_2$ production from renewable power sources is under consideration for fueling $H_2$ vehicles. A $H_2$ fueling station with on-site "green" $H_2$ production (~16-120 kg/day) is expected to be operational in Colorado by 2023/2024 with potential growth to 5-10 stations by 2027. Nuclear power use is also being explored for $H_2$ production for power production. Palo Verde nuclear power plant will use six million tons of stored $H_2$ for 200 MWH electricity production during peak hours. Combined, all the planned projects in the I-WEST region are expected to produce ~half a million ton of $H_2$ per year in 5-10 years.

- Both alkaline and PEM electrolyzer technologies are developed with largest single cell design capacity of 1.25 MW. Several facilities with electrolyzer capacity ranging from 20 to 100s of MW are operational throughout the world with potential generation capacity reaching 2 GW (Norway) in next 4 years. The cost of electricity is critical factor affecting the cost of green $H_2$ production which is forecasted at $1.50/kg "achievable" with $20/MW of renewable electricity. Optimum facility engineering design and supply chain management plays a significant role in achieving low green hydrogen production costs. In addition, DOE investments for the development of electrolyzers will be greatly beneficial.
- It is anticipated that a significant portion of the $H_2$ produced in the I-WEST region in the near future will be blue $H_2$ which will rely on carbon-dioxide capture and storage (CCS). The region has significant geologic $CO_2$ storage capacity, however challenges associated with obtaining a Class VI well permit in timely manner was mentioned as a critical barrier to accelerating Blue $H_2$ deployment in the region.
- $H_2$ deployment at large scale requires significant capital. Currently 45Q tax credit is not available for CCS from $H_2$ production operations. Extending 45Q to $H_2$ production as well as making other funds available for economic and workforce (e.g. Perkins Grant) development will be needed to facilitate large scale deployment. OEM incentives for fuel cell vehicles including incentives for fuel cost difference between $H_2$ and diesel will help to ramp up $H_2$ production.
- Water is used in both $H_2$ production from natural gas and electrolysis. Water scarcity in the I-WEST region is a concern for large scale $H_2$ production. Electrolyzers need ~2.7 gal of deionized water or 4 gallons of portable water to produce 1 kg of $H_2$. Similarly, SMR process of $H_2$ production from the natural gas uses ~3.5 gallons of water per kg of produced $H_2$. While water resources are scare

in the I-WEST region, water availability was not raised as a concern by the workshop participants citing that water usage for $H_2$ production will be significantly lower than the current water needs for agriculture. In addition, produced and brackish water available in the I-WEST region can be an alternate resources of water for the $H_2$ production process but will result in additional costs for treating and purifying the water to make it suitable for use in $H_2$ production technologies.

- Intermittent and unreliable availability of solar and wind resources is a challenge for large scale green $H_2$ production based on renewable energy.
- $H_2$ storage will play a critical role in large scale H2 production. Use of salt caverns for underground $H_2$ storage is one of the options. IPP is planning to use salt caverns in Utah with an estimated 5500 million ton of $H_2$ storage capacity.
- Infrastructure for $H_2$ transportation was identified as one of the critical needs. Utilities in the I-WEST region are exploring the use of existing natural gas pipeline infrastructure to transport $H_2$. Current projects in I-WEST region are evaluating 5% $H_2$ blending in NG pipelines with anticipated timeline for execution by 2030. Carriers such as dimethyl ether (DME) is another possible pathway to transport $H_2$ in liquid phase.