I-WEST

Intermountain West Energy Sustainability & Transitions

Water & Energy: How Do They Mix?

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SUBMITTED TO

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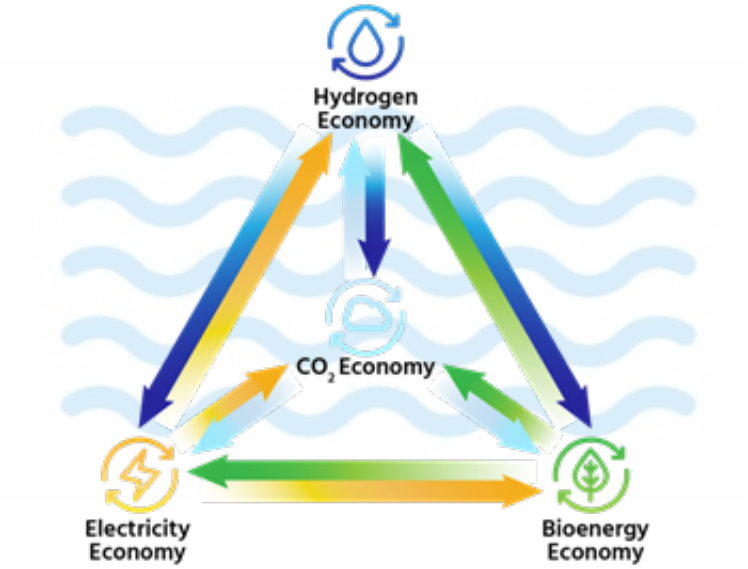
Overview

The Intermountain West Energy Sustainability & Transitions (I-WEST) project is focused on delivering a technology roadmap to transition six states in the U.S. Intermountain West to a carbon neutral energy system. I-WEST encompasses Arizona, Colorado, Montana, New Mexico, Utah, and Wyoming. The project is taking a place-based approach, which prioritizes the unique attributes of the region so that the resulting technology roadmap reflects pathways that are regionally relevant and can be put on an accelerated timeline to deployment.

As part of its Phase-1 assessment, the I-WEST team held a series of technology-focused workshops to better understand technology readiness, infrastructure, policy, and societal readiness related to each of the technology pathways under consideration. These include the capture and use of carbon dioxide, the production and use of carbon neutral hydrogen, and the production and use of bioenergy and bioproducts.

The workshops brought together leaders of current and emerging projects in the region and presented opportunities for participants to connect their capabilities with regional stakeholders and technology providers invested in building pathways to carbon neutrality in the region.

Results from the technology-focused workshops are being used to inform the final I-WEST report.



The interdependencies between hydrogen, carbon, and bioenergy economies demand a keen understanding of how they interact relative to workforce, common resource and infrastructure needs, and deployment timelines. Water is a cross-cutting factor that is of particular importance in the Intermountain West—a region currently experiencing prolonged drought and water shortages.

Workshop Summary

Water and its critical role in new energy economies was at the forefront of this public workshop. Stakeholders shared numerous regional initiatives focused on understanding how water is used in low-carbon energy technologies and how water-saving approaches can help ensure that water will not be a barrier to the energy transition.

As workshop panelist Tom Lowry of Sandia National Laboratories succinctly put it, "You need water to create and access energy." That goes for traditional fossil-based energy and hydropower, as well as for the carbon-neutral pathways of hydrogen (H_2); bioenergy; carbon capture, utilization, and storage (CCUS); and low-carbon electricity that I-WEST is assessing.

Workshop participants contributed a wide range of perspectives, concerns, and ideas that will help inform the I-WEST energy transition roadmap. With water being such a critical but limited resource in the Intermountain West states, there was a strong energy, environmental, and social justice component to the workshop.

Key takeaways from the workshop are summarized in section 2.0 of this report according to three themes: water and climate, water for low-carbon energy, and opportunities for non-traditional water.

1.0 Place-based Approach

1.1 Regional Relevance

Most Intermountain West states have been facing prolonged and severe droughts. Given the interdependences between water and energy systems, water management is an important component of a regional energy transition plan. Water is used in all phases of energy production—in electricity generation, water keeps power plants cool enough to function safely and efficiently, and in oil and gas production, water is used for hydraulic fracturing and enhanced oil recovery. Water is also essential for most renewable energy, including hydropower, concentrated solar power, geothermal energy, and bioenergy production. Many of the technology options to decarbonize these energy sectors also require water, which is why I-WEST is investigating water treatment technologies that can be deployed to either use existing wastewater streams or recycle water produced in decarbonization processes.

This workshop was held directly in response to concerns, questions, and ideas that regional stakeholders expressed to I-WEST in previous workshops and seminars.

1.2 Format and Approach

This virtual workshop was held as an open meeting to attract a broad range of energy stakeholders for a robust discussion that was regionally focused. I-WEST partnered with experts from Sandia National Laboratories to develop a lineup of speakers with diverse technical and regional perspectives. The workshop was advertised broadly through I-WEST communications channels, press releases, and social media. Targeted communications were also carried out by the I-WEST team to ensure that each of the states would be represented. A free online registration was required for the workshop, at which point registrants could enter questions or comments that they wanted to hear workshop panelists address during the roundtable discussions. In fact, I-WEST used that input to proactively structure the workshop agenda to address some of the common themes identified through the registration process. A full list of questions received is provided in Appendix A.

This workshop had a total of 196 participants from a wide range of sectors, including

- Concerned citizens
- City and state governments
- Utilities
- Energy project leaders
- Advocacy groups
- Consulting/engineering companies
- Investment companies
- Regional colleges and universities
- Non-profits
- Federal stakeholders
- National laboratories

A list of workshop participants is provided in Appendix B.

The approach for this workshop was a combination of technical presentations and roundtable discussions. This allowed workshop participants to participate in the dialogue and share information. An open mic session at the end of the workshop also allowed time for stakeholders to share comments and concluding thoughts. A copy of the agenda is provided in Appendix C.

Segment 1: Water Usage for Energy Today and Into the Future

This segment offered a high-level look at the interdependences between water and energy on a national scale, followed by a scaled-down presentation of the water landscape in the context of energy specifically for the Intermountain West. Rounding out the presentation was a forecast of regional climate in the near future and its potential impacts on water availability. This segment featured speakers and roundtable moderators from Sandia National Laboratories, the University of New Mexico, and Los Alamos National Laboratory.

Segment 2: Tour of Low-carbon Technology Water Usage
In a series of lightning talks by the I-WEST team, this segment provided a tour of regionally relevant technologies under assessment as part of the I-WEST roadmap for energy transition. Speakers explained how water is used for low-carbon electricity; low-carbon hydrogen; carbon capture, storage, and utilization; and bioenergy. Results from preliminary analyses were shown, as well as how water usage might be lowered with various technology solutions currently in development. Speakers and roundtable moderators were from Los Alamos National Laboratory and the National Energy Technology Laboratory.

Segment 3: Emerging Opportunities in Non-traditional Water
This segment defined "non-traditional" water, where it comes from, and how it can be used for low-carbon energy production. A regional case study in non-traditional water treatment was presented by a project leader from the Four Corners region, which also highlighted a partnership with Navajo Technical University, located on the Navajo Nation in New Mexico. Critical materials were discussed as a secondary benefit to produced-water treatment technologies. This segment featured speakers and roundtable moderators from the New Mexico Produced Water Research Consortium, PESCO, Inc., the US Geological Survey, and Sandia National Laboratories.

A video recording of the workshop, including the roundtable discussions, is available on the Events page of the I-WEST at https://iwest.org/events/.

2.0 Key Takeaways and Opportunities for Future Engagement

Segment 1: Water Usage for Energy Today and into the Future

Current Water Usage

- Between 4% and 8% of US energy consumption is related to water, including pumping for irrigation, treatment for drinking, and moving water where it is needed.
- In the Intermountain West, the lion's share of water usage is for agriculture, followed by municipal, industrial, thermoelectric generation (fossil-fuel power plants), and mining.
- One pathway to reducing the amount of water used for agriculture is to change crop types and irrigation methods.
- Aquifer recharge is a water-saving option since it does not evaporate; challenges include the lack of storage space, access to an aquifer, and the expense of treating the water before injecting it into the ground.
- There are three projects in NM that have used aquifer storage and recharge (ASR) since a law was passed over ten years ago allowing ASR; one of those is the San Juan-Chama Drinking Water Project in the metropolitan area of Albuquerque.

Climate Futures

- Water resources in the arid southwest are limited and over-allocated; the effects of climate change are expected to intensify these water shortages.
- Rising temperatures will reduce the amount of ground and surface water available; regional rivers and streams are expected to be heavily impacted.
- Climate change is expected to reduce mountain snowpack, cause earlier snowmelt runoff, and trigger increasing and more-frequent extreme events, such as flooding; these events are projected to increase and have more frequency starting in the 2030s and accelerating in frequency by the 2050s.
- Future precipitation forecasts in some areas show an average annual rainfall increase, but many forecasts overlook the intensity of the storm, which will reduce the amount of infiltration into aquifers—hard rains saturate the soil quickly and cause immediate runoff, whereas snowpack melts slowly and allows for infiltration.
- US agriculture production may change with the climate; currently, the Midwest states are known as America's Breadbasket, but with climate evolution Canada could become a bigger producer of agricultural products.
- Understanding the range of expected changes is critical to ensure the I-WEST region can mitigate and adapt to these changes.

Needs identified in this segment

- More in-depth analysis is needed to better understand the water requirements for new low-carbon technologies and associated costs.
- Priorities and challenges related to water and energy need to be identified and analyzed by location, including at the state and county levels.
- An infrastructure inventory is needed to identify existing resources that can be utilized for emerging technologies, as well as to help identify infrastructure gaps.
- Environmental advocates need to be engaged to better understand concerns about how rivers, lakes, and dams will be impacted by new energy economies.
- More research needs to be done on the work that has been done to manage aquifer recharge, and what else needs to be done.
- Climate analysis of surface water availability is needed to understand current and future water utilization.
- Existing and emerging energy-related policies need to be researched and evaluated to better understand their impacts on water resources in the region.
- Communities are interested in learning about specific examples of opportunities (technologies, companies, etc.) that combine water conservation (including water recycling) with the energy transition.

Section 2: Tour of Low-carbon-technology Water Needs

Low-Carbon Electricity

Water is needed to cool power plants. Opportunities for lowering water needs include

- using reclaimed or discharged water
- using brackish or saline water for cooling
- utilizing dry cooling technology
- utilizing solar and wind
- reducing the amount of water required for cooling power plants by increasing their efficiency

Low-Carbon Hydrogen

Blue Hydrogen

- Blue hydrogen utilizes water for steam-methane reforming (SMR) and water-gas shift reactions. Barriers to blue hydrogen include infrastructure, storage, and public perception. Demonstrating that hydrogen can save water compared to current energy pathways will be critical to public acceptance and technology deployment.
- Opportunities for lowering water needs include using recycled processed water. R&D is needed to improve water purification technologies for reuse/recycling. Replacing coal-powered plants with NGCC reduces CO_2 emissions by 56% and water consumption by 33%.

Green Hydrogen

- Hydrogen can also be produced from water electrolysis, where the electricity used is generated by solar or wind. This process is known as green hydrogen.
- Opportunities for lowering water needs include using stranded brine water. R&D is needed to improve water purification technologies for reuse/recycling. Replacing hydrogen production via SMR with electrolysis reduces water consumption by >70%

CO_2 Point Source Capture

- Point source capture (PSC) requires water consumption for evaporative cooling but should not be a barrier to deploying this technology due to the low levels of water needed.
- Opportunities for lowering water needs include
    - Adoption of dry cooling systems reduces PSC water use and consumption by 90% or more, with a few percent impact on the final cost of capture
    - Potentially using reclaimed, discharged, or produced water

- Water uses for large-scale deployment
    - A generous estimate of point source emissions amenable for PSC is 200 Mt/yr (electricity generation is around 175Mt/yr), requiring approximately 200,000 acre-ft/yr for evaporative cooling. This is 2/3 of today's fossil electricity generation water use, or ~ 0.5% of total water use.

Carbon Storage and Utilization

- The water usage for Carbon storage and utilization is minimal compared to other technologies.
- Opportunities for lowering water needs include
    - Treating and reusing produced water, which can augment regional water supply and limit disposal needs
    - Additional research is needed to reduce the cost before the produced water can be treated at the scale required
- Currently, deep well disposal is the cheapest option for managing produced water.

Biofuels

- The water usage for bioenergy depends on the feedstock used. One liter of biofuel consumes 39-642L of water. The majority of biorefineries use groundwater, which could add stress in areas where the groundwater table is decreasing.
- Opportunities for lowering water needs include
    - Use of produced water instead of freshwater
    - Use of forest thinnings or crop residues instead of corn
- Water uses for large-scale deployment have been researched for the past decade but additional research is needed.

Needs identified in this segment

- Communities need a better understanding of the R&D being done to improve cleaning processes for non-traditional water.
- Companies need more information about how they can utilize alternative cooling methods for current technologies to conserve water.
- The role of hydropower in the energy transition is not well understood and requires explanation by experts to address concerns and/or misconceptions about how it would impact water resources.

Section 3: Emerging Opportunities in Non-traditional Water

Non-traditional Water Opportunities and Barriers

- The use of non-traditional water is a major opportunity for the I-WEST region. Many water cleanup options can help technologies reduce the amount of freshwater used for energy generation. Palo Verde, the nuclear power plant in Arizona, demonstrates this by using treated municipal wastewater for cooling.
- Water rights are complicated—even though produced water could be an enabling factor for many low-carbon energy pathways, each state has unique rules and regulations when it comes to water. For example, in New Mexico, produced and brackish waters have regulations associated with their treatment, withdrawal, and use. Understanding the regulatory and policy factors behind water is needed if the region wants to pursue non-traditional water for energy production.
- Additional barriers to using non-traditional waters include the cost and time needed to clean the water. Some technologies require higher purity. Electrolysis companies indicate potable water is required, making brackish water less feasible. Research and development to improve the processes for cleaning non-traditional waters continue to be a major opportunity for reducing cost and increasing efficiency.

Critical Materials: A Secondary Benefit

- Non-traditional waters can be used for mineral processing, such as recovering critical materials and other resources from brines. For example, current lithium extraction technologies require a lot of fresh water to elute the lithium once it has been trapped, and that is where non-traditional or cleaned-up water might serve some purpose. Then, of course, many of them require heating of the brine. The actual technology issues are scaling these industrial processes that would not dig deep into the freshwater resources of a region.
- Treatment and reuse provide an opportunity and a potential benefit to the region in terms of generating new water sources, but also certain treatment approaches can offer benefits related to resource recovery from waters themselves, including rare earth element.

<u>Needs identified in this segment</u>

- In-depth analysis of the potential cost savings and incentives for companies utilizing non-traditional water is needed.
- Additional engagement with project leaders and technology developers is needed to better understand the R&D gaps related to water treatment.
- Engage companies using non-traditional water to share lessons learned with communities considering using non-traditional waters for energy production.

3.0 Workshop Resources

Resources shared by the facilitators, panelists, and audience members during this workshop are listed below.

- A low-to-no snow future and its impacts on water resources in the western United States: https://www.nature.com/articles/s43017-021-00219-y
- Annual Energy Outlook 2022: https://www.eia.gov/outlooks/aeo/
- Carbon Storage Atlas 5th Edition: https://www.netl.doe.gov/node/5841
- Characterizing Drought Behavior in the Colorado River Basin Using Unsupervised Machine Learning: https://agupubs.onlinelibrary.wiley.com/doi/full/10.1029/2021EA002086
- Food Grown with Produced Water Safe for Human Consumption: https://www.waterboards.ca.gov/press_room/press_releases/2021/pr02172021_food_safety.pdf
- NM Aquifer Storage and Recovery Act: https://www.srca.nm.gov/parts/title19/19.025.0008.html
- NOAA Climate Explorer: https://crt-climate-explorer.nemac.org/
- Water Analysis Tool for Energy Resources (WATER): https://water.es.anl.gov/

Appendix A

Questions/Comments from Participants

Segment 1: Water Usage for Energy Today and Into the Future

1. How much of a role do industrial water and emissions play in the total (for energy, water, emissions) coming from water/wastewater? Also, how does agriculture interplay with the energy-water nexus?
2. The sparseness of water in the West is a huge concern, especially as it relates to the 23-year drought and how to balance the environmental concerns over rivers, drainages, and dams with the need of the industry and populations in the Western states.
3. What are some examples of opportunities (technologies, companies, etc.) that combine water conservation (including water recycling) with the energy transition?
4. Including someone from the Walton Foundation might be interesting since they are doing a lot around the 'theory of change' for the upper and lower Colorado.
5. What opportunities exist for replacing hydropower from Colorado River dams with other renewable resources, and how long would it take to convert? Would greater flexibility in operating Glen Canyon and Hoover Dams without producing electricity improve the water supply situation? And what would be the relative costs?
6. How much work has been done to manage aquifer recharge for New Mexico?
7. There is strong interest in how different energy pathways might impact water availability in the future climate.
8. There is an understanding that some I-WEST states, in particular Colorado, may prohibit/limit rainwater harvesting, probably because of concerns related to aquifer and surface management. What are pathways for helping to address challenges related to aquifer recharge?
9. There are noted changes in aridity that will impact water use for agriculture. We also know the shift from snow to rain in the winter. How are these likely to affect water availability for energy, and will these effects be seen soon in the next decade or so, or how long might they take to be felt?
10. Is the Brackish Groundwater National Desalination Research Facility (BGNDRF) in New Mexico part of I-WEST?
11. Please explain why a heavy snowpack replenishes the aquifer better than abundant rain.

Segment 2: Tour of Low-Carbon Technology Water

1. If we are going to transition to H_2 production and CCUS in the future, how much water does each of those technologies use, compared to today's conventional power generating plants (fossil and nuclear)?
2. What types of water produced water, brackish water, freshwater, can be used to produce hydrogen?

3. Is the capacity of the local subsurface to store carbon a concern? How many years of CO_2 production might be stored locally by typical full-scale power plant?
4. Is induced seismicity a concern for subsurface carbon storage?
5. What is the takeaway you want to share with communities uncertain of water usage for energy? What are the things to think about, the pros and the cons? What opportunities are there for communities in the I-WEST region?
6. How much total water is consumed in the production of electrolytic hydrogen? What water will be used to produce the hydrogen?
7. The use of water for cooling methods for the Escalante Power Plant was estimated at over one million gallons per day. It is understood they own water rights and take from the aquifer. As a result, Bluewater Lake is now nearly empty. Are there other cooling methods the plant could use that would conserve water use?
8. What opportunities exist for replacing hydropower from Colorado River dams with other renewable resources, and how long would it take to convert? Would greater flexibility in operating Glen Canyon and Hoover Dams without producing electricity improve the water supply situation? And what would be the relative costs?
9. Comparing battery electric water usage with electrolysis, including water usage for battery element mining, would be helpful.
10. What are the water requirements for modular nuclear power plants?
11. How might we compare water use (or lack thereof) to cool the infrastructure in the transition to lower-carbon energy resources?
12. Pumped hydro is currently the most cost-effective energy storage. One could imagine putting more turbines and pumps at locations that already have both high and low water reservoirs ... varying the level of the reservoirs more rapidly than is currently done. Electric transmission is key to this concept. Can we do an economic study of the role of increased pumped storage if we improve transmission efficiency (think HVDC)?
13. Improved transmission is key to averaging out the intermittency of wind and solar.
14. Please compare and quantify the water costs required for CCUS and other GHG mitigation strategies.
15. When considering the water usage for these different technologies, the types of water available, and the cleanliness required for each of these, is it possible, especially in the case of cooling, to use poor-quality water? Is that going to be cost-prohibitive? Is there a hierarchy of best matches for lower-quality water-to-energy use for these different technologies? And if you think about these technologies in a hierarchy, where can we best match lower-quality water to energy use?

Segment 3: Emerging Opportunities in Non-traditional Water

1. In terms of lithium extraction, is there an advantage to looking for thermal areas where you are dealing with more geothermal heated fluids and are there technology barriers that we need to overcome that would make it more economic?
2. What are the opportunities for non-traditional water in New Mexico, and explain what could be considered low-hanging fruit?
3. Are there opportunities for using solar and in terms of your thermal source for treating produced water?
4. There is an understanding that some I-WEST states, in particular Colorado, may prohibit/limit rainwater harvesting, probably because of concerns related to aquifer and surface management. What are pathways for helping to address challenges related to aquifer recharge?
5. What technologies are in the works for making beneficial use of produced water?
6. How do water demands for various H_2 production methods compare, among themselves and to conventional fuels?"
7. Please evaluate the beneficial reuse of oil and gas industry wastewater to support energy transition.
8. Are there any drivers to encourage wider adoption of oil and gas-produced water for recycling, including recreation usage?
9. What opportunities does N.M. have to utilize brackish or produced water for hydrogen production, and is this an economically viable use of the alternative water resources?
10. Is there a simple function or conversion factor which takes salinity as an input to estimate the energy cost of reducing salinity by a given factor? Such a function would help with cost estimating.
11. What are some examples of opportunities (technologies, companies, etc.) that combine water conservation (including water recycling) with the energy transition?
12. What barriers to greywater or blackwater reuse remain, and how can they be eliminated?

General Questions

1. It would be helpful to discuss the utilization of produced water to support energy needs.
2. How can Wyoming be a part of the solution?
3. Thorium Nuclear reactors are a possible energy source for desalinization plants and pump stations for drinking water pipelines in the desert regions of the U.S. and Mexico for urban consumption and hydroponic farms. Getting the Department of Energy and Nuclear Regulatory Commission to change such regulations and policies in support of progressive new technologies increases the potential for sustainable water, food supply, and critical resources, i.e., domestic rubber plants and energy.
4. Please address the topic of commercial grounds watering and runoff/waste. Is there a way of determining where there are aquifers in the ground? The location of aquifers will be necessary for determining where population growth can occur.

Appendix B

Participant List

Name	Company Name	Job Title
James Lyon	AECOM	Unlisted
Jeff Tripp	AGNC	Economic Development Coordinator
Phil Carter	Albuquerque Wildlife Federation	Vice President
Whitney Dobson	Aris Water	Unlisted
Will Clendenning	Aris Water Solutions	Beneficial Reuse Intern
Julia Szinai	Berkeley Lab	Postdoc Researcher
Kate French	BlueGreen Alliance	Field Organizer
Charles Nye	Center for Economic Geology Research	Research Scientist
Jada Garofalo	Center for Energy Regulation & Policy Analysis, School of Energy Resources, University of Wyoming	Unlisted
Fred Verner	Chevron	Regulatory
Hyun Kim	City of Gillette	City Administrator
Bryce Beck	City of Sedona	Sustainability Coordinator
Susan Sherman	COGCC	Field Inspector
Maria Eisemann	Colorado Energy Office	Senior Transportation Policy Analyst
Kevin Hinshaw	ConocoPhillips	Unlisted
Louis Salazar	ConocoPhillips Company	Director, External Affairs

Name	Company Name	Job Title
Manika Prasad	CSM	Professor
Dale Keairns	Deloitte Consulting LLP	Specialist Master
Deborah Dixon	DKD Engineering Inc.	President
Ian Andrews	ECS	Consultant
Beverly Michael	Enchanted Peace & Wellness Center, LLC	Grants City Councilor
Elena Melchert	Energia Consulting LLC	President
Curtis Burdette	Energy Capital Economic Development - Gillette, WY	Vice President
Edward Saltzberg	ERS Advisors	President
Mike Biddle	Evok Innovations	Partner
Darrious Betts	Exxonmobil	Engineer
Wade Holdeman	Fort Sumner Irrigation District	Manager
Arvin Trujillo	Four Corners Economic Development	CEO
Keri Hutchins	Hilcorp Energy	Landman
Johnathan Clemmer	J.G. Management Systems	Mechanical Engineer
Nicole Gardner	JG Management Systems	Project Manager
Christopher Smith	JGMS-Government Services, LLC	Construction Engineer
James Gover	Kettering University	Professor Emeritus
Vicki Barbur	KLS	Sr Advisor
Pamelya Herndon	KWH Law Center for Social Justice and Change	CEO
Daniel Klein	Libertad Power Project LLC	Managing Partner

Name	Company Name	Job Title
Mary Crosby	Lincoln County	Grant Writer
Bob Wessely	Middle Rio Grande Water Advocates	Past President
Maggie Althaus	Montana Trout Unlimited	Unlisted
Alex Puglisi	National Wildlife Federation	Western Water Project
Patricia Kelley	New Day Hydrogen	CCO
Brian Schath	New Mexico Environment Department	Environmental Analyst
Hongmei Luo	New Mexico State University	Professor
Patricia Sullivan	New Mexico State University	Director, Office Of Strategic Initiatives
Kurt Anderson	NM Geothermal LLC	Unlisted
Hannah Grover	NM Political Report	Reporter
Mike Hightower	NM Produced Water Research Consortium	Director
Michelle Martinez-Woodson	NNSA/LAFO	Spp Program Manager
Matt Mcmonagle	NovoHydrogen	CEO
Cristin Reno	Oberon Fuels	Manger, Regulatory Affairs
David Mann	Oberon Fuels	VP
Nathan Brady	Office of Legislative Research and General Counsel	Policy Analyst
Betty Pun	OGCI Climate Investments	Technology Principal
Kirstie Mcpherson	OJT	Community And

Name	Company Name	Job Title
		Economic Development Manager
Lauren Dennis	Penn State	Ph.D. Student
John Byrom	PESCO (Process Equipment and Service Company)	Business Development Manager
Hassan Niazi	PNNL	Policy Analyst
Rob Heineman	Pojoaque Valley Irrigation District	Board Member
Frantz Beznik	Procter & Gamble	R&D Head - Sustainable Living
Anna Lamberson	Retired	Unlisted
Norman Norvelle	Environmental Health Scientist	Retire But Active In Environmental Organizations
Tessa Murdock	Salt River Project	Research Engineer
Peter Kobos	Sandia National Laboratories	Manager, Water Power Technologies
Thomas Lowry	Sandia National Laboratories	Principle Geohydrologist
Thushara Gunda	Sandia National Laboratories	Unlisted
Nicole Jackson	Sandia National Laboratory	Unlisted
Stephanie Kuzio	Sandia National Laboratory	Unlisted
Jinxuan Hu	Select Energy Services	Vice President - Engineered Water Solutions
Rick Mccurdy	Select Energy Services	VP - Innovation & Sustainability
Nancy Partridge	SMSI	Consultant

Name	Company Name	Job Title
Roxy Evans	SolMem	Business Director
Patricia Ewanski	Salt River Project	Unlisted
Russell Barrus	State of Utah Division of Water Resources	Engineer
Philip Gleckman	Sunvapor, Inc.	CEO
Michael Stahl	Tallgrass Water	Director Of Operations
Ashwin Dhanasekar	The Water Research Foundation	Unlisted
Oral Saulters	Tribal TAB	Senior Partner
Matt Miller	U.S. Rep. Teresa Leger Fernandez	Field Representative
Alice Barthel	Unlisted	Unlisted
Arnel Garcesa	Unlisted	Unlisted
Brooke Gienapp	Unlisted	Unlisted
Cary Meister	Unlisted	Unlisted
Chase Gruber	Unlisted	Unlisted
Connor Nelson	Unlisted	Unlisted
Dan Hooks	Unlisted	Unlisted
Diane Cook	Unlisted	Retired
George Roe	Unlisted	Unlisted
James Griffith	Unlisted	Unlisted
Jason Anderson	Unlisted	Unlisted
Jesse Freedman	Unlisted	Unlisted
Jessica Robinson	Unlisted	Unlisted

Name	Company Name	Job Title
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Katherine Shera	Unlisted	Unlisted
Kayley Shoup	Unlisted	Unlisted
Kody Powell	Unlisted	Unlisted
Luciane Cunha	Unlisted	Unlisted
Mark Bibeault	Unlisted	Principal Research And Design Engineer
Rajesh Pawar	Unlisted	Unlisted
Robert Page	Unlisted	Unlisted
Rudolph Rothenhauser	Unlisted	Student
Sheila Van Cuyk	Unlisted	Unlisted
Tracy Sweetman	Unlisted	Unlisted
Wendy Lukas	Unlisted	Unlisted
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Grant Doty	Utah Division of Water Resources	Engineer
Laura Haskell	Utah Division of Water Resources	Engineer
Rick Webster	Utah Division of Water Resources	Project Specialist
Blake Bingham	Utah Division of Water Rights	Deputy State Engineer
Miken Larson	Utah Iron, LLC	CFO
Sam Brucker	Utah Legislature	Managing Policy Analyst
Rikki Hrenko-Browning	Utah Petroleum Association	President
Scott Hynek	Utah Water Science Center	Geologist, Geochemist,

Name	Company Name	Job Title
		And Hydrologist
Charles Cassagnol	Western Ecology, LLC	Owner/CEO
John Leeper	Wood E and I Inc	Civil Engineer
Tyler Harris	Wyoming Department of Environmental Quality	Natural Resources Program Principal
Jason Feltner	Wyoming State Engineer's Office	Program Supervisor, Surface Water
Ryan Klenner	Arizona State University	Sustainability & Business Development
Sarah Porter	Arizona State University	Director of the KYL Center for Water Policy
Stephanie Arcusa	Arizona State University	Postdoc
William Brandt	Arizona State University	Dir of Strategic Integration
Catherine Clark	Department of Energy	AAAS Fellow in FECM
Sonrisa Lucero	DOE - Economic Impact and Diversity	Special Advisor for Stakeholder Engagment
Chris Gunn	DOE - Office of Energy Justice	Special Advisor on Grid Innovation and Justice
Michael Rinker	DOE EERE	Senior Technical Advisor
Zac Taie	DOE-HFTO	Technology Manager
Scott Matthews	KeyLogic	Unlisted
Taylor Vactor	KeyLogic	NETL support contractor
Charles Poling	Los Alamos National Laboratory	PIO
Chelsea Neil	Los Alamos National Laboratory	Scientist

Name	Company Name	Job Title
Donald Hickmott	Los Alamos National Laboratory	Guest Scientist
Duncan Campbell	Los Alamos National Laboratory	R&D Engineer
Duncan Mcbranch	Los Alamos National Laboratory	Program Director
Fangxuan Chen	Los Alamos National Laboratory	Student
Genna Waldvogel	Los Alamos National Laboratory	Sustainability Manager
Jeff Simpson	Los Alamos National Laboratory	Tech Writer / Professor
Jeffrey Heikoop	Los Alamos National Laboratory	Group Leader
Jim Benedict	Los Alamos National Laboratory	Climate Scientist
John Sarrao	Los Alamos National Laboratory	Deputy Director for Science, Technology, and Engineering
Julie De Leon	Los Alamos National Laboratory	DGL Communication Arts and Services
Kirsten Fox	Los Alamos National Laboratory	Communications Specialist
Kurt Solander	Los Alamos National Laboratory	Research Scientist
Larry Daugherty	Los Alamos National Laboratory	Weapons Production
Lisa Kisner	Los Alamos National Laboratory	Communications Specialist
Madison Montoya	Los Alamos National Laboratory	Student
Marie Kroeger	Los Alamos National Laboratory	Scientist
Martin Ma	Los Alamos National Laboratory	Postdoc
Matthew Brazil	Los Alamos National Laboratory	Technical Project Manager

Name	Company Name	Job Title
Maxine Mcreynolds	Los Alamos National Laboratory	Associate General Counsel for Environment, Safety, and Health
Melissa Fox	Los Alamos National Laboratory	Program Director
Michael Rosenow	Los Alamos National Laboratory	IH
Mohamed Mehana	Los Alamos National Laboratory	Unlisted
Molly Cernicek	Los Alamos National Laboratory	Unlisted
Monica Maes	Los Alamos National Laboratory	PSA2
Pat Fitch	Los Alamos National Laboratory	LANL Associate Laboratory Director
Rich Fiorella	Los Alamos National Laboratory	Unlisted
Steve Tobin	Los Alamos National Laboratory	R&D Engineer/Scientist
Tala	Los Alamos National Laboratory	Intern
Thanh Ho	Los Alamos National Laboratory	Program Manager
Thomas Jistel	Los Alamos National Laboratory	Water Management Intern
Walter Short	Los Alamos National Laboratory	HP
Wanyi Nie	Los Alamos National Laboratory	scientist
Yudi Wong	Los Alamos National Laboratory	Emergency Preparedness Coordinator
Bailian Chen	Los Alamos National Laboratory	Scientist
Cris Mulcahy	Los Alamos National Laboratory	ESH Counsel
Larry Lucero	Los Alamos National Laboratory	Executive Advisor
Michael Moss	Los Alamos National Laboratory	P2 Program

Name	Company Name	Job Title
Prashant Sharan	Los Alamos National Laboratory	Unlisted
Tim Goering	Los Alamos National Laboratory	Environmental Professional
Lee Spangler	Montana State University	Director, Energy Research Institute
Tom Feeley	National Energy Technology Laboratory	Manager
Haoying Wang	New Mexico Tech	Unlisted
Jianjia Yu	New Mexico Tech	Research Engineer
Mai Tran	Retired	Fellow
Jhih-Shyang Shih	RFF	Fellow
Tim Cronin	U.S. Department of Energy	Advisor for Energy Community Policy
Kate Gordon	U.S. Dept of Energy	Senior Advisor to the Secretary
Tim Grant	U.S.DOE/NETL	Physical Scientist
Andrew Schuler	University of New Mexico	Professor
Brennan Davis	University of New Mexico	Research Assistant
Caroline Scruggs	University of New Mexico	Assoc Prof
Janie Chermak	University of New Mexico	Professor and Chair - Economics
Renia Ehrenfeucht	University of New Mexico	Professor
Selena Gerace	University of Wyoming's School of Energy Resources	Research Scientist
Barry Basile	US Department of Energy	Senior Consultant

Name	Company Name	Job Title
Jai-Woh Kim	US Department of Energy	Program Manager
Amanda Lounsbury	Unlisted	AAAS STP Fellow
Eva Rodezno	Unlisted	Unlisted
Yonatan Abebe	Unlisted	Contractor
Babetta Marrone	Los Alamos National Laboratory	Senior Scientist
Jim Gattiker	Los Alamos National Laboratory	Scientist
Jolante Van Wijk	Los Alamos National Laboratory	Unlisted
Katrina Bennett	Los Alamos National Laboratory	Unlisted
Mary Ewers	Los Alamos National Laboratory	Scientist
Troy Semelsberger	Los Alamos National Laboratory	Unlisted
Derek Vikara	National Energy Technology Laboratory	NETL Support Contractor
Stacy Timmons	New Mexico Institute of Mining & Technology	Unlisted
Bruce Thomson	University of New Mexico	Research Professor

Appendix C

Workshop Agenda

Time	Topic	Presenter
9:00 AM	**Welcome and Opening Remarks** Bringing water to the forefront of the dialogue on energy transition.	**John Sarrao** Los Alamos National Laboratory
9:05 AM	**Introduction to Water and Energy Transition in I-WEST** Overview of I-WEST and the objectives of the workshop.	**Jolante Van Wijk** Los Alamos National Laboratory
Segment 1: Water Usage for Energy Today and Into the Future		
9:10 AM	**Energy-Water Nexus** Big-picture look at the interdependencies between water and energy on a national scale.	**Stephanie Kuzio** Sandia National Laboratories
9:20 AM	**Current Water Usage in the Intermountain West** Regional water landscape today in the context of energy.	**Bruce Thomson** University of New Mexico
9:30 AM	**Water and Climate Futures in the Intermountain West** Forecasts of climate in the near future and its impacts on water availability.	**Katrina Bennett** Los Alamos National Laboratory
9:40 AM	**Roundtable Discussion with Q&A** **Panelists:** Stephanie Kuzio, Bruce Thomson, Katrina Bennett **Moderators:** Nicole Jackson and Tom Lowry (Sandia)	**All participants join in the discussion**
Segment 2: Tour of Low-Carbon Technology Water		
9:55 AM	**Potential Energy Transition Pathways for the I-WEST** Overview of regionally relevant technologies under evaluation by I-WEST.	**Jolante Van Wijk** Los Alamos National Laboratory
	Lightning Talks on Water Needs for Transition Pathways How is water used in low-carbon technologies and what is the potential for reduced water usage in the future? • Low-Carbon Electricity • Low-Carbon Hydrogen • Carbon Capture • Carbon Storage and Utilization	**Mary Ewers** Los Alamos National Laboratory **Troy Semelsberger** Los Alamos National Laboratory **Jim Gattiker** Los Alamos National Laboratory **Derek Vikara** National Energy Technology Laboratory

	• Bioenergy	**Babetta Marrone** Los Alamos National Laboratory
10:30 AM	**Roundtable Discussion** **Panelists:** Mary Ewers, Troy Semelsberger, Jim Gattiker, Derek Vikara, Babetta Marrone **Moderators:** Jolante Van Wijk and George Guthrie (Los Alamos)	**All participants join the discussion**
10:45 AM	**Break**	

Segment 3: Emerging Opportunities in Non-traditional Water

10:50 AM	**Opportunities for Non-traditional Water in the Intermountain West** A look at the nature of and opportunities with produced water.	**Mike Hightower** New Mexico Produced Water Research Consortium
11:00 AM	**Regional Case Study in Non-traditional Water Treatment** PESCO, Inc. will discuss their water treatment pilot and startup testing in Farmington, NM in partnership with New Mexico Tech and Navajo Technical University.	**John Byrom** PESCO, Inc.
11:10 AM	**Critical Materials: A Secondary Benefit** Extracting critical materials for energy transition from produced water.	**Scott Hynek** United States Geological Survey
11:20 AM	**Roundtable Discussion** Panelists: TBD, John Byrom, Scott Hynek **Moderators:** Tom Lowry and Stephanie Kuzio (Sandia)	**All participants join the discussion**
11:35 AM	**Open Mic** Final comments from workshop participants on the discussion topics, or suggestions for I-WEST events on the topic of water and energy. **Moderator:** Jolante Van Wijk	**Open to all** (Begin with participants who submitted comments at registration)
11:50 AM	**Closing Remarks**	**Melissa Fox/George Guthrie** Los Alamos National Laboratory
12:00 PM	**Adjourn**	