FUELING A LOW-CARBON FUTURE IN UTAH: THE ROLE OF HYDROGEN

C2ES CLIMATE *INNOVATION* 2050

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As an energy exporter with significant renewable resources and a strategic location in the west, Utah will be key to accelerating the United States' energy transition. Recently, the state has garnered international attention for its growing role in the bourgeoning hydrogen industry, with multiple industry-leading projects underway. Barriers remain to deploying hydrogen in a low-carbon future, but Utah has potential to play a leadership role in the hydrogen sector if it can address its own unique barriers. This brief provides insights from a C2ES roundtable held in November 2021 that explored the future of hydrogen in Utah. It highlights the benefits hydrogen can bring to the state, Utah's unique advantages in the growing hydrogen industry, and the challenges that must be addressed to unlock hydrogen's decarbonization potential, both in Utah and beyond.

INTRODUCTION

REGIONAL ROUNDTABLES

Achieving net-zero emissions will require large-scale changes across all sectors of the economy, and efforts to accelerate this transition are intensifying. To chart a pathway to sustainable, long-term prosperity, communities must be able to leverage their unique strengths and capitalize on emerging economic opportunities, while addressing barriers that are often poorly understood outside of their communities.

To that end, the Center for Climate and Energy Solutions (C2ES) is hosting a series of regional roundtables to bring together local, state, and federal policymakers; businesses of all sizes; community organizations and nonprofits; academics and issue experts; trade associations; investors; philanthropy; and others. These conversations are meant to elevate the perspectives of a diverse set of stakeholders who are deeply embedded in their communities and uniquely positioned to speak to the needs of their states and regions. They are also meant to create opportunities to integrate local perspectives into state and federal policy decisions and, importantly, identify concrete steps to better align the long-term vitality of these communities with the urgent task of facilitating economy-wide decarbonization.

Our second roundtable of 2021, held virtually "in" Utah, took place in November 2021 and brought together more than seven dozen stakeholders. The event explored the role Utah can play in the growing hydrogen industry; challenges related to hydrogen's production and use, both in Utah and elsewhere; and the infrastructure and policy investments that can maximize Utah's potential in a low-carbon future. This brief summarizes key takeaways from the discussion and—building on insights from the event and other conversations with local stakeholders—provides C2ES recommendations meant to align climate and economic objectives in Utah through the development of a robust, clean hydrogen industry.

FRAMING UTAH

Utah has a long history of energy production and is a net exporter of energy, making the state's energy sector critical to the western United States' low-carbon transition. Fossil fuels, including coal, natural gas, and oil, are currently heavily embedded in Utah's energy system and economy, but signs of a transition are showing, propelled by a larger transformation across the globe. Production of solar, wind, and geothermal electricity in Utah has grown over the past ten years, making clean energy increasingly important to Utah's economy.[1] In addition to these more established clean energy sources, Utah is at the forefront of a burgeoning hydrogen industry. Several Utah-based businesses have been leaders in hydrogen fueling, storage, and fuel cell technologies for years. Multinational corporations have also announced investments in Utah as they look to grow their hydrogen businesses.[2] As a result, Utah is earning international attention for these industry-leading projects. Investments in hydrogen—combined with advances in other low-carbon energies and technologies—have the potential to strengthen local economies, improve air quality, and reduce greenhouse gas emissions in Utah, while establishing the state as a hub for growing low-carbon industries. For Utah to capitalize on these opportunities, it must make proactive policy decisions and planning investments now.

KEY RECOMMENDATIONS

C2ES has identified a set of policy recommendations with input from stakeholders at the roundtable that would advance hydrogen's decarbonization potential and support its role in spurring economic development in Utah.

- Pursue research and development
  - Invest in research to quantify hydrogen's water needs compared to incumbent fossil fuels and advance technologies that minimize competition for critical water resources.
  - Undertake independent life cycle analyses at national labs and research universities to clarify emissions intensities of various hydrogen systems, including upstream emissions and the impact of hydrogen leakage, under a variety of real-world assumptions.
- Invest in infrastructure
  - Direct state and federal resources to establish alternative fueling stations along major freight corridors in Utah.
  - Co-locate hydrogen infrastructure with other types of energy and related infrastructure to facilitate the growth of hydrogen hubs in Utah.
- Grow awareness and demand
  - Expand public-private partnerships to enable government and companies across the value chain to collaborate on hydrogen technology applications and combine their purchasing power.
  - Develop a clearer national lexicon to describe hydrogen that allows the public to differentiate easily between hydrogen's life cycle carbon intensity.
  - Create state-level awareness programs that showcase Utah's existing hydrogen work, educate the public, and cultivate potential end users.
- Strengthen hydrogen planning and policy
  - Intentionally create synergies between hydrogen and the broader state energy system when implementing Utah's energy strategies.
  - Strengthen state and federal regulatory frameworks for hydrogen to effectively govern its production, transport, storage, and use, both in Utah and across the country.
  - Consider hydrogen energy production in the state's water plans.
  - Fund programs to identify and reduce leaked methane emissions at the state and federal levels.
  - Pass a suite of tax credits at the state and federal levels to support hydrogen projects, with incentives based on life cycle emissions intensity.

A PRIMER ON HYDROGEN

Hydrogen has long been used for myriad applications from refining petroleum, to producing fertilizer, to fueling NASA rockets.[3] While hydrogen has been touted as the "fuel of the future" multiple times over the past few decades, it has had several false starts.[4] But as momentum grows to decarbonize every sector of the economy, hydrogen is gaining renewed attention for the critical role it can play in the global energy transition. Hydrogen's potential applications are vast, but experts predict the fuel's most promising uses include:

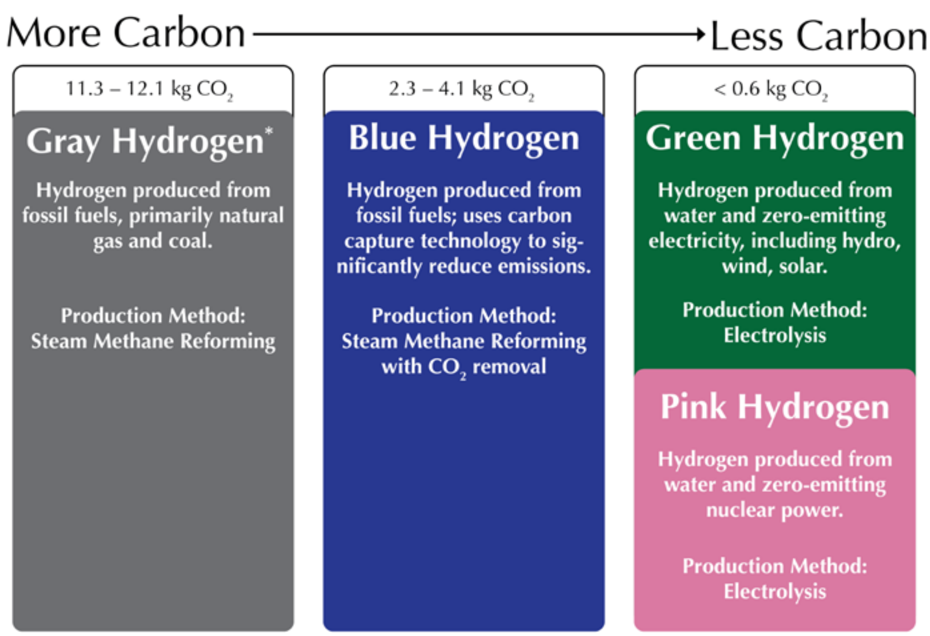
- as an energy source for sectors of the economy that are difficult to decarbonize by other means, including heavy-duty transportation (e.g., long-distance trucking, shipping, aviation) or industrial processes that require high heat (e.g., steel)
- as a source of long-duration (i.e., more than 12 hours) and seasonal energy storage, which has particular promise for balancing the grid and overcoming intermittency challenges with renewables
- as a feedstock for chemical and industrial products (e.g., fertilizer), through which hydrogen is already used today.[5]

Hydrogen can either be directly combusted or used in a fuel cell to create electricity. In either case, hydrogen creates no direct greenhouse gas emissions; however, depending on the process used to produce hydrogen, greenhouse gases may be released upstream.

Despite being the most abundant element in the universe, hydrogen primarily exists in compounds with other elements (e.g., in methane and water). As such, hydrogen must be produced, or separated, from these compounds. Roughly 95 percent of hydrogen produced today in the United States is made via natural gas steam methane reforming (SMR), which combines methane and high-temperature steam in a two-step reaction that results in hydrogen, along with carbon dioxide and heat.[6] Electrolysis is another production pathway, which splits water into hydrogen and oxygen using electricity, ideally from a zero-carbon power source, such as renewables or nuclear. Electrolysis is currently used on a much smaller scale and is more expensive per kilogram of hydrogen produced than SMR, but the pathway is key to reducing hydrogen's emissions intensity and minimizing dependence on fossil fuels.[7]

To differentiate between various production pathways, hydrogen types are often referred to by color (Figure 1), with each color referencing a different production process or fuel source.

Figure 1: An abridged rainbow of hydrogen



* In the United States, gray hydrogen is produced almost exclusively with natural gas; emissions values reflect the use of natural gas for production.

Source: For emissions estimates from gray, blue, and green hydrogen, see Maddy Ewing et al., Hydrogen on the path to net-zero emissions: Costs and climate benefits *(Calgary, AB: Pembina Institute, 2020),* https://www.pembina.org/reports/hydrogen-climate-primer-2020.pdf*; for emissions estimates from pink hydrogen, see Amgad Elgowainy, "GREET Model for Life Cycle Analysis of Greenhouse Gas Emissions" (Presentation at H2IQ webinar, October 28, 2021), https://www.energy.gov/sites/default/files/2021-11/h2iq-hour-10282021.pdf..*

While the federal government has been turning away from this color-coding system due to recently passed policies and broader industry trends, this brief uses these colors to refer to specific types of hydrogen(gray and blue hydrogen refer speccifically to hydrogen made from natural gas feedstock, not other fossil fuels). “Clean” or “low-carbon” hydrogen will be used to refer to hydrogen with a low emissions intensity, from any potential source. It also uses other terms, such as “natural-gas derived hydrogen” to refer to both blue and gray hydrogen.

Multinational corporations, the federal government, and international governments have all set ambitious goals for hydrogen and are investing billions of dollars in hydrogen technology and infrastructure.[8] With this momentum, hydrogen production alone is anticipated to have a total addressable market of more than US$1 trillion by 2050, up from roughly $125 billion today.[9] Given the state’s strategic assets, Utah is well positioned to benefit from this growth and play a key role in the expansion of the industry.

KEY TAKEAWAYS FROM THE DISCUSSION

The discussion at the regional roundtable explored the assets Utah possesses that can enable it to succeed in a low-carbon future, particularly on hydrogen; the challenges that must be addressed to unlock Utah’s potential; and the opportunities hydrogen can bring for the state.

ASSETS

Strategic location and logistics capacity

Utah’s central location has earned it the nickname the “crossroads of the west.” Situated roughly equidistant from seven major ports in California, Washington, and Oregon, Utah is a logistics artery for transferring goods to demand centers in the eastern United States.[10] As a result of this strategic location, 40 percent of the United States’ gross domestic product travels through Utah from western ports, especially from California.[11] While most of this traffic currently comes from trucks, Utah also has more than 1,300 miles of railroad track, with both Class I and short line railroads connecting the state with western ports, other western rail hubs, and across to the east.[12]

Utah strengthened its status as a logistics hub by establishing the Utah Inland Port Authority (UIPA) in 2018, a new government agency that oversees Utah’s logistics system. UIPA has made the sustainable movement of goods a priority and is investing heavily in alternative fuels infrastructure, including hydrogen fueling and electric vehicle charging. UIPA has engaged a number of private sector partners, attracting investment to establish alternative fueling stations in key freight locations across Utah, which will extend clean fuel corridors into the state and could make it a destination for zero-emissions fleets.[13]

Utah’s status as the “crossroads of the west” makes it uniquely positioned to lead on hydrogen production, transport, and use. First, Utah is well-connected to regional demand centers including Los Angeles, Las Vegas, and Denver via interstate pipelines, railroads, and highways, which makes the state a convenient base for the production and transport of hydrogen throughout the region. Second, because hydrogen holds particular promise for decarbonizing heavy-duty transportation, the growing logistics industry in Utah offers a natural user base for hydrogen applications, including in Class 8 trucks, rail locomotives, forklifts, cranes, and other heavy-duty vehicles essential to logistics operations. Integrating and scaling up clean hydrogen applications in the existing logistics system can also minimize the environmental and health impacts that system might otherwise create. As interest in new hydrogen technologies and use cases continues to grow—including from fleet operators, vehicle manufacturers, and fueling infrastructure companies—Utah could be well positioned to capitalize on its location and logistics capacity by becoming an investment destination for clean hydrogen in the west.

Energy infrastructure and expertise

Key to the success of the hydrogen industry is robust infrastructure that allows for easy production, transport, and use of hydrogen fuel. Fortunately, Utah’s long history of energy production has equipped it with a range of relevant infrastructure that is key to hydrogen’s success, including natural gas and oil pipelines, railways, and transmission lines. Because Utah is a net exporter of energy, this infrastructure already connects to key demand centers across the West, including Colorado, Nevada, and California, allowing for convenient transport of hydro-

APPLYING UTAH'S "ALL OF THE ABOVE" ENERGY APPROACH TO HYDROGEN

During the planning process for the roundtable, as well as at the roundtable itself, a number of attendees emphasized Utah's commitment to technology neutrality, taking an "all of the above" approach to energy rather than picking "winners and losers." This approach is enshrined in Utah's state energy policy, which commits the state to promote the development of both renewable and nonrenewable energies, as well as "…hydrogen from all sources."[83] Indeed, Utah's assets—renewable energy resources, natural gas industry, and carbon capture potential—equip it to lead on producing hydrogen from multiple sources. Each pathway brings its own unique advantages and challenges. Natural gas-derived hydrogen, for instance, is currently cheaper than green hydrogen and generally consumes less water per unit of hydrogen produced. But natural gas-derived hydrogen has climate and health implications, as its production results in higher greenhouse gas emissions and releases criteria air pollutants, exacerbating already challenging air quality issues in Utah. As such, all states, including Utah, will need to determine which resource mix best suits their unique assets and needs, while ensuring that hydrogen's production and use result in the greatest climate and other benefits possible.

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gen produced in Utah. Even existing fossil fuel plants and their associated transmission and distribution infrastructure can serve as assets for future hydrogen needs. The Intermountain Power Plant Renewed (IPP Renewed) project, for instance, is replacing its coal-fired units with a combined-cycle natural gas and hydrogen plant while upgrading existing transmission infrastructure, demonstrating the value that legacy fossil sites can have in a decarbonizing economy. As the energy sector continues to turn away from fossil fuels toward low-carbon resources, finding creative uses for these assets can provide new opportunities for energy communities in transition.

Utah's energy history also means that communities and workers have strong energy sector knowledge that can be applied to the hydrogen industry. This is particularly true in rural towns, which have been heavily involved in the coal, oil, and natural gas industries for decades. As of 2021, Utah's electric power and fuels workers are concentrated in solar electric generation, oil and petroleum fuels, and natural gas generation, all segments that offer transferrable and complementary skills for hydrogen projects.[14] Despite the continued contribution of gas, petroleum, and coal to Utah's energy economy, there have recently been sharp drops in employment for these segments, compared to clean energy resources such as solar and wind.[15] These shifts in the workforce showcase the need to find new ways to utilize Utah's fossil-heavy energy expertise in emerging industries, like hydrogen.

Renewable energy potential

Utah has high renewable energy potential and has increasingly taken advantage of this potential in recent years, with the share of renewables in its energy mix increasing. In 2021, about 14 percent of Utah's total electricity generation came from renewables, with solar contributing over half that generation.[16] The rapid growth of Utah's solar industry propelled it to rank eleventh among states in its solar generating capacity by the end of 2021, with roughly 1.8 gigawatts of capacity.[17] Wind and geothermal are also significant resources in the state: In 2021, wind overtook hydropower as Utah's second-largest source of renewable electricity and Utah ranked third in the nation in geothermal electricity generation.[18] Utah's renewable energy resources are far from being fully developed. The state has up to 826 gigawatts of solar generating capacity; multiple sites in western and north-central Utah are suitable for additional commercial wind development; and only 20 percent of its potential geothermal sites have been developed to present.[19]

With greater penetration of renewables, these resources can help grow Utah's hydrogen industry, providing clean electricity for green hydrogen production. As renewable capacity increases, it is likely there will be more frequent periods of overgeneration when renewables production is high and electricity demand is low. If this overgeneration is consistent and sufficiently abundant, it is possible to use this excess electricity to create hydrogen instead of curtailing (wasting) production, thus boosting the economic value of those renewables by storing that energy for later use.[20] Hydrogen's long-term storage capacity (of days or weeks) makes it especially compatible with renewable resources by balancing the inherent intermittency of resources such as wind and solar, thus strengthening the grid. The growth of Utah's renewable energy and hydrogen sectors are therefore complementary and mutually reinforcing: Hydrogen can allow the state to maximize its renewable energy resources, while renewable energy can in turn accelerate the maturation of the hydrogen industry in Utah.

Geologic storage resources

Roundtable participants emphasized Utah's geology as a differentiating factor that can make it uniquely suited to lead on hydrogen and support the decarbonization of the broader western United States. Utah is home to the largest "Gulf-style" (i.e., narrow and deep) geological salt formation in the west, which can be a magnet for new hydrogen investments in the state. That's because salt caverns are currently the most effective method of storing hydrogen gas, given their self-sealing ability and potential to customize the shape and size of the caverns based on individual project needs.[21]

Mitsubishi and Magnum Development's Advanced Clean Energy Storage (ACES) project is already leveraging this geologic advantage, with aims to store the green hydrogen produced at the adjacent Intermountain Power Project in salt caverns to dispatch to the grid (thus delivering stored renewable energy to the west during periods of intermittency) or for use as a fuel in other sectors. Each of the roughly 100 storage caverns developed in the greater salt formation will be able to store 150 gigawatt hours (GWh) of energy (more than 40,000 shipping containers of lithium-ion batteries could store), for a total of 15,000 GWh stored by the project.[22] Already, new investors are showing interest in this project, including the Department of Energy's (DOE) Loan Programs Office, which in early June 2022 closed on a $504.4 million federal loan guarantee to build out a green hydrogen hub around the storage facility.[23] By fully taking advantage of this storage resource, Utah can facilitate job growth and economic development by attracting not only other hydrogen businesses to the state, but a range of industries interested in procuring Utahn hydrogen.

Utah's geologic assets can serve to store not only hydrogen, but also carbon dioxide that would otherwise be emitted in the production of blue hydrogen (hydrogen produced via steam methane reforming with carbon capture). Saline reservoirs again offer an attractive option for carbon storage, as do the state's depleted oil and gas fields. Research entities in Utah, including the Utah Geological Survey and the Energy and Geoscience Institute at the University of Utah, have undertaken or are currently pursuing work to classify Utah's carbon storage potential and demonstrate the performance of sequestration pilots.[24] Enhancing the state's ability to capture and reliably store carbon will be an imperative for reducing emissions if Utah is to pursue hydrogen production from fossil fuels.

Competitive business environment and growing innovation economy

Utah's competitive business environment offers a way to harness its assets to spur economic development. Utah consistently ranks as one of the top states for business in the United States due to high economic growth, strong business incentives, low energy costs, and other factors.[25] In addition, Utah is a hub for innovation and offers a growing startup and tech ecosystem, bolstered by organizations such as Silicon Slopes, Grow Utah, and multiple accelerator programs, as well as government-run services including those offered at the Utah Innovation Center.[26] Utah's innovation advantage extends into technologies with specific climate implications: In a 2021 index, Salt Lake City ranked as the 27th top cleantech innovation hub in the United States, underscoring the region's leadership and potential for growth.[27] The state's commitment to entrepreneurship, technological innovation, and business growth can establish Utah as a magnet for the hydrogen industry, helping bring jobs and revenue to the state. A strong hydrogen industry can, in turn, attract additional companies to the state who are looking to establish and expand their low-carbon businesses.

CHALLENGES

Managing water use responsibly

Concerns about water availability for hydrogen production permeated conversations with stakeholders prior to the roundtable, driven by Utah's persistent drought. As of late May 2022, 100 percent of the state was in drought, with 99.9 percent of the state's area classified as in severe or extreme drought.[28] Given these conditions, multiple roundtable participants raised questions about Utah's suitability for green hydrogen production specifically,

Table 1: Water consumption for hydrogen production pathways (gal/kg)

SMR			ELECTROLYSIS	
CENTRALIZED	CENTRALIZED W/ CCS	DISTRIBUTED	CENTRALIZED	DISTRIBUTED
2.4	2.9	2.5	4.1	2.9

Source: Han & Elgowainy (2017): https://www.hydrogen.energy.gov/pdfs/17005_water_consumption_ldv_fuels.pdf

which requires water as a feedstock to split into hydrogen and oxygen, suggesting that other hydrogen production pathways may be more optimal for the state.

Water required for hydrogen production includes both water that is withdrawn, but later discharged, and water that is consumed, by either evaporation or being incorporated into the product. Both SMR and electrolysis require water consumption and withdrawals, and the precise amount of water required varies depending on site-specific parameters. SMR generally consumes less water than electrolysis does, depending on whether carbon capture is involved (carbon capture requires additional water) and whether the hydrogen is produced in central locations or smaller, distributed facilities. Accounting for water used in the production process and cooling, hydrogen production generally requires varied amounts of water (Table 1).

In addition to these direct water needs, both SMR and electrolysis require high-quality water with low impurities, necessitating pretreatment that, depending on the technology used, can require additional water, although this water is usually able to be treated and reused. Water needs for electrolysis further vary based on the electricity source. For instance, electrolysis using wind typically consumes less water per kilogram of hydrogen than natural gas SMR when accounting for both upstream and direct water use.[29]

While hydrogen's water intensity should be considered carefully in evaluating projects in Utah, a few roundtable participants emphasized the need to compare hydrogen's water use not to a baseline of zero, but to the water use of the fuels that hydrogen might replace, especially more water-intensive fossil fuels. The IPP Renewed project, for instance, reports it will significantly reduce its water use by switching from coal to renewable-powered electrolysis; the amount of water the project will use to produce enough green hydrogen for a 30 percent fuel blend for one year is roughly equal to the amount the existing coal units would consume at full load on three hot summer days.[30] Hydrogen's total water needs will also depend on how widely the fuel is used. If it is deployed predominantly in instances with few low-carbon alternatives (e.g., heavy industry, long-distance trucking), its water impact will be smaller than if it is widely used throughout society in applications where less water-intensive low-carbon alternatives exist (e.g., renewable electrification).

A few roundtable participants also highlighted the potential of hydrogen production pathways that would minimize consumption of fresh water, such as using wastewater or stormwater for hydrogen production. Indeed, Utah and its neighbors recently signed a memorandum of understanding (MOU) to jointly apply for federal hydrogen hub funding, committing in that MOU to address hydrogen production's potential impacts on western water use, including by pursuing "opportunities to use water that is currently used for or generated by other industrial or power generation purposes."[31] Regardless of its source, water for hydrogen production should be purified.

Federal research efforts are underway to develop innovations that can minimize purification needs for electrolysis. The Infrastructure Investment and Jobs Act (hereafter bipartisan infrastructure law), passed in 2021, for instance, includes funding for a clean hydrogen electrolysis program that will research electrolyzer designs that can handle impurities, including saltwater.[32] Accelerating research into water-saving technologies at the federal level, coupled with planning intentionally for hydrogen's water requirements at the state level, can help Utah responsibly manage water amid growing hydrogen demand.

Minimizing greenhouse gas emissions

Hydrogen is only valuable as a decarbonization tool if its full life cycle emissions are significantly lower than fossil alternatives. While hydrogen does not release greenhouse gases when combusted or used in a fuel cell, the hydrogen production process can be a significant source of emissions, especially since most hydrogen produced today is derived from natural gas.

Indeed, several roundtable participants raised questions about hydrogen's emissions benefits when that hydrogen is produced with natural gas. Hydrogen derived from natural gas, with or without carbon capture, produces life cycle emissions multiple times greater than those of hydrogen produced via electrolysis powered by renewables or nuclear, although even natural gas-derived hydrogen may offer emissions benefits to traditional fuels such as diesel.[33] The exact emissions produced per kilogram of gray or blue hydrogen, though, depend on a variety of factors, including upstream methane leakage rates, carbon capture rates, and more. As such, it is important to capture the full life cycle of hydrogen when assessing its emissions impact under a variety of real-world scenarios. This life cycle approach is particularly imperative for Utah, which, according to one recent study, has methane leakage rates up to three times higher than the national average in the natural-gas producing Uinta basin, in part due to older and low-producing wells.[34] Without strong measures to identify and address this leakage, Utah's natural-gas based hydrogen could have markedly higher life cycle emissions than hydrogen produced in surrounding states, hampering the state's ability to compete in low-carbon markets.

One potential solution to Utah's methane leakage challenge is to produce hydrogen using sources of methane that would otherwise be emitted. Potential sources of this methane include at natural gas facilities (using gas that would otherwise be flared), landfills, wastewater treatment plants, or agricultural sites. Depending on the feedstock and technology used, these production pathways can create a fraction of the emissions that would be released in fossil-based hydrogen production.[35] Several entities in Utah are already looking into these alternative sources, including Dominion Energy with landfill gas, Big Navajo Energy at flare gas sites, and the Utah Clean Cities coalition at wastewater treatment facilities.[36]

Hydrogen's emissions implications come not only from the process of producing hydrogen, but also from the leakage of hydrogen into the atmosphere. Hydrogen is an indirect greenhouse gas, meaning it does not itself create warming, but reacts with molecules in the atmosphere to increase the concentrations of other greenhouse gases, as well as lengthen the lifetime of methane in the atmosphere.[37] One study currently in peer review found that this interaction could diminish hydrogen's emissions reduction potential if leakage is not controlled, especially in the short term when hydrogen's impact is most intense.[38] When hydrogen leakage is high (10 percent leaked per unit deployed), the study found hydrogen could yield nearly twice as much warming compared to fossil fuel counterparts in the first five years following deployment, with eventual large decreases over the long run. Fortunately, minimal leakage (1 percent leaked) would enable hydrogen to yield an 80 percent decrease in warming during that same period, showing the imperative to minimize or eliminate hydrogen leakages across the fuel's life cycle to maximize its climate benefit.

Abating criteria air pollutants

Hydrogen can offer significant air quality benefits for Utah by enabling renewable energy to scale up and significantly reducing pollution from point sources such as cars and trucks. Still, multiple roundtable participants stressed these benefits will be dependent on how that hydrogen is produced and ultimately used. The process of creating hydrogen from fossil fuels, for instance, will result in the same pollutants that occur in conventional fossil fuel combustion processes. For natural gas, this includes volatile organic compounds, carbon monoxide, nitrous oxides (NOx), and particulate matter that are released during SMR.[39] If hydrogen is created with non-polluting sources, such as nuclear and renewable energy, its air pollutant challenges are minimized.

Regardless of how hydrogen is created, its ultimate use can also result in air pollutants depending on the application. If used in a fuel cell, hydrogen produces only electricity, heat, and water, with no co-pollutants. When hydrogen is combusted, though, it produces NOx, which creates respiratory issues along with environmental impacts. These NOx emissions can be abated by burning the hydrogen at lower temperatures, designing combustors to minimize exposure with nitrogen in the air, or treating exhaust gases to reduce NOx following combustion.[40] These interventions come with tradeoffs, though, such as reduced power output and performance or higher costs, and it remains unclear how much of the NOx emissions can be eliminated with these measures.[41]

These air quality impacts should be considered when determining how hydrogen will be produced and used in Utah, given the state's existing air quality challenges. Opting for hydrogen production pathways and uses that greatly minimize or eliminate pollutants (such as using green hydrogen in fuel cells or implementing robust NOx-abating measures in combustion), can ensure the state realizes the maximum air quality benefits hydrogen can bring.

Strengthening hydrogen's cost competitiveness

Multiple roundtable participants raised questions about how hydrogen's cost could impact the fuel's future applications. These cost questions arose both when comparing hydrogen to fossil fuel technologies (such as diesel-powered trucks), to other low-carbon solutions (such as solar plus storage or battery electric vehicles), and when comparing types of hydrogen to each other (green vs. blue vs. gray).

Several attendees expressed that achieving cost parity between conventional fossil fuels and hydrogen is pivotal to unlocking the fuel's potential. The need to rapidly reduce hydrogen costs is especially true for green hydrogen, which is currently two to three times more expensive than its blue counterpart, globally.[42] Several roundtable participants expressed confidence that green hydrogen would become competitive in the near future, based at least in part on the fact that the federal government is investing significantly in driving down green hydrogen's cost. In 2021, DOE launched its Hydrogen Shot with a goal of reaching $1 per kilogram of clean hydrogen in a decade.[43] The bipartisan infrastructure law later added a steppingstone to that goal by funding a clean hydrogen electrolysis program at DOE to reduce the cost of electrolytic hydrogen to less than $2/kilogram by 2026. Due both to efforts such as these, as well as market factors that increasingly favor low-carbon products, BloombergNEF predicts that green hydrogen produced from renewables could be cheaper than blue hydrogen by 2028 in many locations in the United States and worldwide by 2030; these cost advantages are particularly true for areas with zero or negatively priced excess renewable electricity.[44] Given that the largest component of green hydrogen's cost is the price of renewable electricity, achieving high renewable penetration at low cost will be key to achieving this price decline. In addition, expanding hydrogen production and applications in Utah and elsewhere can help achieve the economies of scale that some roundtable participants said was necessary to reduce prices.

Even when hydrogen reaches cost parity with fossil fuels, several roundtable participants pointed out that it will still need to compete with other low-carbon solutions for market share, raising questions about hydrogen's competitiveness compared to these alternatives. Indeed, hydrogen may not be the most attractive low-carbon solution in every case, due to cost and other factors. For instance, NREL predicts that even though hydrogen fuel cell electric vehicles (FCEVs) will reach total-cost-of-driving parity with diesel vehicles by 2035 for light, medium, and heavy-duty truck applications without incentives, battery electric vehicles will still outcompete FCEVs for shorter distances. [45]

Market-based incentives can be highly effective tools to lower the cost of hydrogen production and ramp up adoption of clean hydrogen technologies, such as heavy-duty FCEVs. This approach is in line with Utah's energy code, which emphasizes the use of market forces to drive energy resource use, but also allows for incentives to "ensure the state's optimal development and use of energy resources."[46] Utah has several hydrogen incentives already in place. In 2019, the Utah State Legislature passed a law to allow the state's Community Impact Fund and High-Cost Infrastructure Development Tax Credit to go toward hydrogen facilities and plants that produce, store, or distribute hydrogen for use in zero-emission vehicles, for electricity generation, or for industrial use.[47] In March 2021, the state adopted two distinct hydrogen tax credits. One offers a tax credit through 2030 to qualified heavy-duty alternative fuel vehicles, including hydrogen-powered vehicles (provided that at least half of the vehicle's miles are driven in the state to maximize local benefits); another provides a 12 cent per kilogram tax credit for hydrogen production (using renewable and nonrenewable resources) up to 5,600 metric tons of hydrogen per taxable year, and up to two years after commercial service begins.[48] In March 2022, the state passed a law allowing its Department of Natural Resources to make loans and grants available for hydrogen vehicle and refueling equipment through its clean fuels program.[49]

These programs can help, but more can be done to scale up clean hydrogen production and use in the state. Federal grants, low-cost or interest-free loans, and research and development funding can help technologies mature and reach the economies of scale necessary to lower hydrogen's cost. In addition, Congress should pass investment and production tax credits (ITCs and PTCs) for hydrogen, which were included in the now-stalled Build Back Better Act, to level the playing field between hydrogen and other technologies. [50] The Utah State legislature should also consider added incentives for hydrogen production under a certain emissions intensity to enhance the ability of the state's growing hydrogen industry to compete in global, low-carbon hydrogen markets.

Growing in-state hydrogen demand

Utah has historically exported more energy than it consumes, and this trend could hold true in the growing hydrogen sector. Utah's current largest hydrogen production project, for instance, will send most of its hydrogen-derived power to Los Angeles.[51] Even when hydrogen demand comes from out-of-state, it can nonetheless provide a vehicle for economic growth in Utah by spurring investment and creating jobs. This is particularly true in the near-term, since Utah does not currently have sufficient in-state demand to warrant large scale hydrogen projects. Still, some roundtable participants expressed that for Utah to capture the full benefits hydrogen can bring, including air quality improvements and jobs across the hydrogen supply chain, more needs to be done to grow demand for hydrogen applications in the state. Utah's transportation, logistics, and industrial sectors present ready opportunities to expand hydrogen applications and grow the state's user base.

Government investment and coordination can be one way to grow the hydrogen market in Utah. The UIPA, for instance, has formed a partnership with companies called Project Beehive to cultivate a hydrogen user base in its logistics operations.[52] At the federal level, DOE has released the H2 Matchmaker tool, which visualizes ongoing hydrogen activities and enables viewers to connect with potential suppliers of, or users for, hydrogen across the country.[53] Outreach and awareness efforts such as these can help grow hydrogen's applications in Utah.

Creating a regulatory framework for hydrogen

Hydrogen's growing applications in the energy industry and other major sectors of the economy warrant a modernization of regulations to effectively govern its production, storage, transport, distribution, and use, in the way that similar frameworks regulate the oil, gas, and mining sectors at the federal and state levels. Without this comprehensive framework, one roundtable participant expressed concerns about not only a lack of market fairness but also the certainty businesses need to enable investment.

A range of federal regulations do currently apply to hydrogen, but in many cases, hydrogen is regulated incidentally as one of many covered products, and often, rules that do exist were written to regulate certain characteristics of hydrogen (i.e., its safety) rather than the hydrogen industry as a whole.[54] Much of the regulation currently applicable to hydrogen pertains to its chemical and industrial uses, safe packaging and labelling, and transport by rail, waterways, and road.[55] As hydrogen is integrated into energy systems and other major sectors of the economy, targeted regulations will be needed to ensure responsible use of resources (e.g., water), to safeguard public health and safety, and to provide regulatory certainty to potential investors. There are no existing regulations that apply to key segments of the hydrogen value stream, including its blending in natural gas pipelines; potential import/export terminals for hydrogen; and the fuel's residential and commercial heating applications.[56] In addition, one roundtable participant pointed to the need for financial assurance mechanisms to address any long-term liabilities or decommissioning of hydrogen projects, in the way such mechanisms exist for other energy projects such as coal.

The current moment offers an opportunity for states and the federal government to create hydrogen regulations that can streamline the growth of the industry while it occurs. This proactive regulatory approach can facilitate, rather than hinder, the development of the industry by giving companies the confidence needed to invest in hydrogen projects and infrastructure. With an incomplete regulatory framework at the state and federal levels, companies may channel significant sums into hydrogen projects only to later be required to satisfy newly issued regulations. Ongoing federal efforts supported by the passage of the bipartisan infrastructure law may be a first step to providing this clarity. Under the law, DOE is tasked with creating a national clean hydrogen strategy and roadmap, which would identify appropriate points of interaction among various federal agencies engaged in hydrogen, clarify their responsibilities, pinpoint potential regulatory obstacles, and recommend modifications to solve those challenges.[57] As the federal government pursues this work, Utah may wish to undertake similar efforts to clarify hydrogen's regulation at the state level and provide guidance for hydrogen applications that must be governed locally, such as integrating hydrogen safety considerations into local building codes.

Expanding enabling infrastructure

While existing energy infrastructure is an asset for Utah that can serve the hydrogen sector, there remain additional infrastructure needs that must be met to enable hydrogen's potential and bring down costs, from production through end use.

Hydrogen transport infrastructure is one of these needs. Roundtable participants showed interest in using existing natural gas infrastructure, namely pipelines, to transport hydrogen. But hydrogen can only be injected up to a certain percentage blend with natural gas (generally five to 15 percent) before the hydrogen may compromise the integrity of certain pipelines by causing embrittlement.[58] Creating dedicated hydrogen pipeline systems or retrofitting existing pipelines (e.g., adding a lining) to reduce embrittlement and potential leakage could be a solution to this challenge. While retrofitting is an attractive option to take advantage of existing infrastructure, one roundtable participant emphasized that it may prove costly, and these costs should be weighed when determining where retrofitting offers benefits over alternatives. Other options for hydrogen transport explored at the roundtable include via rail or trucks, which can offer advantages over pipelines in locations where pipeline infrastructure is lacking or would be costly to retrofit, or for areas where hydrogen demand is not high enough to warrant pipeline construction. If deployed on a set route and schedule, railways and trucks could create a "virtual pipeline" to send hydrogen to demand centers across the region.

In addition to hydrogen transport infrastructure, hydrogen fueling infrastructure was a significant need explored throughout the roundtable. California currently leads the country in the number of hydrogen fueling stations, and although neighboring states, including Arizona and Colorado, have multiple pending hydrogen fuel corridors (where some stations exist at far distances), Utah's fueling infrastructure is still in its infancy.[59] This lack of infrastructure was pointed to as a significant challenge for the state to attract zero-emission fleets. Some roundtable participants emphasized that, without ready infrastructure, clean fleets may reroute away from Utah, leaving conventional fleets to continue to travel through the state and exacerbating Utah's air quality challenges.

One impediment to establishing hydrogen infrastructure mentioned in the roundtable, though, is the "chicken and egg" problem in which companies want to see refueling infrastructure in place before adopting hydrogen technologies, but infrastructure investors also need assurances about future user demand to build facilities. Recognizing this challenge, Utah government and companies are taking the first step to invest in hydrogen fueling stations to attract user demand. The UIPA has convened private sector partners through Project Beehive and has begun discussions with neighboring states to identify and build out alternative fueling stations in key corridors and cultivate a user base for those stations. With these proactive infrastructure investments, hydrogen users can gain confidence to locate in Utah, bringing economic, health, and environmental benefits to the state.

Bolstering public awareness

Familiarity with hydrogen as a fuel is still low, which creates challenges for the industry's growth. Hydrogen proponents participating in the roundtable reported that, given hydrogen's relative nascence, the public may not understand hydrogen's applications or its unique benefits and challenges. One public awareness challenge that multiple industry representatives reported facing is around hydrogen safety. Hydrogen behaves differently than other materials consumers are accustomed to interacting with, such as gasoline or natural gas. It is much lighter, meaning it dissipates quickly if leaked, and it burns nearly clear. For hydrogen to be successfully deployed, especially in public-facing applications, the public needs to be made aware of these differences to confidently interact with hydrogen technologies. In turn, rigorous leak detection and safety mechanisms must be put in place, and explained to consumers, to ensure the integrity of hydrogen systems. Awareness raising around hydrogen's benefits and challenges, including safety considerations, is key not only for the public, but also for potential hydrogen users to be able to effectively evaluate the value of hydrogen compared to alternatives.

The terminology conventionally used to describe hydrogen may contribute to the lack of public understanding around the fuel. Participants raised the hydrogen "rainbow"—referring to hydrogen types by color (see Figure 1)—as a nondescriptive and potentially confusing naming convention. A more explanatory method that refers to hydrogen's attributes or emissions intensity would help clarify the various types of hydrogen and make the industry more publicly accessible, while also making it clearer which hydrogen is produced via low-emission approaches. Hydrogen might, for example, be referred to as "natural gas-derived" or "renewable" rather than gray, blue, or green. Already, efforts are underway to move away from hydrogen colors and toward a common definition of "clean hydrogen." As instructed by the bipartisan infrastructure law in 2021, DOE and the Environmental Protection Agency (EPA) have begun developing an initial standard for clean hydrogen, which can be derived from any source and should not, as an initial definition, exceed two kilograms of carbon dioxide equivalent produced per kilogram of hydrogen at the site of production.[60] The creation of this standard would allow hydrogen produced from any source (fossil fuel or otherwise) to be labelled as "clean" as long as it meets those carbon intensity requirements. Even with these efforts, though, the federal government, state governments, and industry will need to improve public understanding of what this new standard means and offer ways for potential hydrogen users to easily compare various hydrogen types to suit their needs, even if they meet the definition of "clean" (e.g., a climate-conscious industrial user may still prefer using hydrogen derived from renewables over hydrogen derived from natural gas with carbon capture, even if both are labelled "clean" with the emissions intensity standard).

OPPORTUNITIES

Supporting Utah's economic transition

An energy transition is already underway both globally and in the United States. Investment in clean energy assets in the United States has grown 70 percent in the past five years alone, reaching a record-breaking $105 billion in private sector investment in 2021.[61] As a result of these investments, energy workforces are shifting. Jobs in the U.S. coal industry, which has long been important to Utah, have seen declines since 2015, while jobs in solar, wind, and geothermal grew across the country.[62] This transition points not only to risks for Utah's workforce in the decades to come, but also significant opportunities—with proper support from policymakers—for growth in a low-carbon economy, including in the bourgeoning hydrogen sector.

A prominent example of this opportunity is the IPP Renewed project, which will provide employment opportunities to many of the workers affected by the closure of the original coal-fired IPP. According to the Utah Foundation, the project will directly create 500 temporary construction jobs and 120 ongoing jobs in hydrogen generation, while indirectly supporting several hundred additional supply chain jobs in the process. [63] These jobs cannot accommodate all employees of IPP, given that coal power generation is more labor intensive than hydrogen, but the jobs and tax revenue generated by the IPP Renewed project can serve as a lifeline to workers and the local economy. A mature hydrogen supply chain can provide further economic opportunities through jobs in hydrogen infrastructure development, transport, storage, vehicle manufacturing and maintenance, and more. A robust hydrogen supply chain can also have a ripple effect, serving to attract new employers to the state interested in accessing Utah's hydrogen.

The employment potential for the hydrogen industry is predicted to ramp up rapidly. The Fuel Cell and Hydrogen Energy Association estimates there could be 700,000 jobs across the hydrogen value chain by 2030 in the United States, increasing to 3.4 million jobs by 2050.[64] Major corporations, including Siemens, Toyota, Chevron, bp, Shell, and others, have already announced billions of dollars in hydrogen investments. Utah's strategic location, natural resources, and bourgeoning hydrogen sector make the state an attractive destination for these companies to expand their businesses, and its skilled energy workforce offers them a ready talent pool. For Utah's workers to thrive in the hydrogen industry, though, they will need to be equipped with training and job placement programs that can expand their skills and offer reliable pathways to new employment opportunities. This workforce investment is an imperative for Utah to capitalize on the employment potential hydrogen brings in the state's energy transition.

Establishing Utah as a hydrogen innovation leader

Several roundtable participants emphasized Utah's potential to be on the leading edge of the booming hydrogen industry. Utah's assets, including its strong business environment, natural resources, energy expertise, and growing innovation ecosystem, can help the state benefit from accelerating innovative clean energy industries, including hydrogen. Already, Utah is home to international investors and local businesses with industry-leading hydrogen efforts. OxEon Energy, Renewable Innovations, and Lancer Energy are innovators on hydrogen production and fueling technologies.[65] Stadler Rail, which has its North American headquarters in Salt Lake City, is currently designing the first hydrogen-powered passenger train to operate in the United States.[66] The IPP Renewed project will use the world's first gas turbine designed to operate on 100 percent green hydrogen, and the adjacent ACES hydrogen storage project is the largest project of its kind in the world.[67]

Public and private interest in hydrogen has escalated quickly, and significant funding is being channeled to research, development, demonstration, and deployment of hydrogen technologies. These investments in innovation signal potential to bolster funding for Utah's research universities, attract a range of low-carbon businesses to the state, equip workers with sought-after skills, and drive job growth and economic development. Technical, policy, and financial support can maximize the value of these investments by facilitating the long-term deployment of new technologies and lasting job creation.

Modernizing and expanding energy infrastructure

Infrastructure development for the hydrogen sector is at once a challenge and an opportunity for Utah. Roundtable participants raised the potential for Utah to benefit from the expansion of hydrogen and associated infrastructure, especially with federal funding that will support the buildout of hydrogen "hubs." Through the bipartisan infrastructure law, DOE will provide $8 billion to create at least four regional hubs, where infrastructure will be co-located to allow for streamlined hydrogen production, storage, delivery, and end use. According to research by the Great Plains Institute, Utah is among the locations most suited for a hydrogen hub in the United States given its existing infrastructure, including railroads, highways, natural gas and oil pipelines, industrial facilities, and geologic storage opportunities.[68] Siting a hydrogen hub in Utah could grow a hydrogen ecosystem in the state that helps achieve even greater economic and other benefits than a single project would, for instance by supporting new renewable energy projects, transmission and distribution lines, and other enabling energy infrastructure, which in turn could facilitate grid modernization, construction jobs, tax revenue, and further growth of Utah's energy sector. Access to hydrogen infrastructure can also attract new industries to the state to take advantage of the hydrogen fuel, including low-carbon industrial, manufacturing, or transportation companies. With funding applications anticipated to open in mid-2022, states are vying heavily to have their regions selected as a hydrogen hub, recognizing the economic potential that this infrastructure could bring. Utah, New Mexico, Colorado, and Wyoming have already agreed to partner in applying for one of these hubs, as have Louisiana, Oklahoma, and Arkansas and New York, New Jersey, Massachusetts, and Connecticut.[69]

In addition to highlighting the potential of hydrogen hub infrastructure in Utah, roundtable participants also pointed out opportunities for the state to strategically develop hydrogen projects in proximity to existing energy infrastructure to streamline production and address other energy-related challenges. For instance, locating an electrolysis facility near a large solar field could reduce the need to curtail excess solar generation and take full advantage of the state's solar generating capacity. Similarly, siting an SMR facility near gas flare sites, landfills, or compressed natural gas stations can minimize challenges of transporting feedstock to distant hydrogen production facilities, reduce methane leakage in pipelines, and minimize waste of and emissions from feedstock sources that would otherwise be unused. As Utah state agencies work to implement the state's recently released Energy and Innovation Plan, they should consider how hydrogen can be deployed synergistically with existing energy infrastructure to both maximize economic benefits and minimize energy system challenges.

Improving air quality

Utah faces significant air quality challenges year-round. In general, winter inversions trap particulate matter close to the ground, while in the summer, sunlight reacts with pollutants—including NOx and volatile organic compounds—to create ground-level ozone.[70] These air quality challenges are particularly acute on the Wasatch Front, where mountains trap pollution: Salt Lake City, for instance, has on multiple occasions ranked among the top five worst cities in the world for air quality.[71] While the causes of Utah's air pollution vary depending on the season, significant sources include mobile sources (e.g., cars, trucks, trains, aircrafts), industrial facilities, refineries, and power plants. Fortunately, hydrogen presents an opportunity to reduce or eliminate emissions from many of these sources, especially heavy-duty applications where few viable alternatives exist.

One of the most promising applications to maximize hydrogen's air quality benefits in Utah is as an alternative fuel for heavy-duty transport, such as Class 8 trucks or trains. Utah has the highest percentage of truck traffic on its highways in the nation: Truck traffic accounts for 23 percent of total highway traffic in Utah, nearly twice the national average of 12 percent.[72] Switching this large truck fleet from traditional internal combustion engines running on diesel to hydrogen FCEVs would offer a significant reduction in particulate matter, NOx, carbon monoxide, and other pollutants that diesel fuel releases. Utah can promote this switch is by establishing alternative fueling stations through key truck corridors, which could help make the state a magnet for the clean fleets that already operate in California and elsewhere; without this infrastructure, Utah's truck traffic may continue to be dominated by polluting fleets. The UIPA is also working to boost the state's freight rail industry, underscoring another promising application for hydrogen technologies.[73] The state legislature has already taken steps to promote clean fuels in rail operations with the goal of improving air quality: a concurrent resolution passed in March 2022 encouraged the use of 100 percent zero-emission engines in short-line locomotives, industrial plant locomotives, and switch engines by 2050.

Hydrogen also offers promise in other emitting sectors, such as industry, where electrification may not be feasible due to high heat needs. Switching out fossil fuels used at Utah's cement, steel, and chemical facilities to clean hydrogen, where suitable, can eliminate the release of NOx, particulates, and other harmful pollutants.

Still, as described previously, certain hydrogen production pathways and uses can create air quality concerns that may offset these benefits. The state government and industry will therefore need to follow strict pollutant standards to minimize harmful criteria emissions or prioritize hydrogen applications with no such direct emissions in order to maximize hydrogen's air quality improvement potential.

POLICY RECOMMENDATIONS

PURSUE RESEARCH AND DEVELOPMENT

Invest in research to quantify hydrogen's water needs compared to incumbent fossil fuels and advance technologies that minimize competition for critical water resources. While research on hydrogen's water needs has been conducted, this research does not often consider how the broad adoption of hydrogen technologies would impact water supplies when accounting for displacement of incumbent fuels, such as diesel, coal, or gas. This understanding is critical to allow for informed systems-level water management and energy decisions, especially in drought-constrained states like Utah. DOE, its national laboratories, and research universities should address this topic by modelling water needs for future hydrogen use scenarios in the United States, taking into consideration water shortages caused by climate change. Further, these entities should ramp up research and demonstration projects that pilot electrolyzer innovations to minimize water constraints, such as building on the research—supported by the bipartisan infrastructure law—into electrolyzers that can handle impurities. Advancing such technology research could open up uses for other water supplies, such as saltwater, wastewater, etc., that would lessen competition over high-quality water sources.

Undertake independent life cycle analyses at national laboratories and research universities to clarify emissions intensities of various hydrogen systems, including upstream emissions and the impact of hydrogen leakage, under a variety of real-world assumptions. Various studies have aimed to quantify the emissions intensity of hydrogen production, both including upstream emissions and at the site of production. Additional research is needed, though, to consider hydrogen's emissions intensity under differing assumptions that mirror true realities, for instance, with higher-than-average methane leakage rates (comparable to Utah's), various carbon capture rates (reflecting real-world carbon capture capabilities), and a variety of hydrogen leakage scenarios (which can vary considerably depending on the infrastructure used and transportation methods involved). Expanding research on hydrogen leakage, in particular, is necessary to expand knowledge of hydrogen's warming impacts in the atmosphere, and to identify potential hydrogen system designs that minimize leaks.

INVEST IN INFRASTRUCTURE

Direct state and federal resources to establish alternative fueling stations along major freight corridors in Utah. Alternative fueling infrastructure is pivotal to achieving both the air quality and economic benefits that can come from expanding zero-emissions transportation. While efforts are ongoing to establish fueling stations in key locations through Project Beehive, these efforts must be supercharged to create full corridors that clean fleets and other vehicles can travel, especially along I-15, I-70, I-80, and I-84. Utah's state government should ramp up its efforts by funding grant and low-interest loan programs for hydrogen and other alternative fueling stations in priority corridors to better compete with surrounding states for clean fleet investments. California, for instance, announced in late 2020 that the California Energy Commission would direct up to $115 million to build 111 new hydrogen stations, aiming to deploy 200 public fueling stations by 2025.[74] Federal resources should also be leveraged to expand hydrogen infrastructure in Utah. Utah's state agencies and local governments should pursue funding made available through the bipartisan infrastructure law, including $3.5 billion in charging and fueling infrastructure grants, to install electric vehicle and alternative fueling infrastructure on public roads, fuel corridors, and in communities.[75]

Co-locate hydrogen infrastructure with other types of energy and related infrastructure to facilitate the growth of hydrogen hubs in Utah. The bipartisan infrastructure law provides for the creation of at least four hydrogen hubs across the country. Utah is already working closely with Wyoming, Colorado, and New Mexico on an application for one of these hubs. Utah's Office of Energy Development should channel available resources into ensuring this application is as competitive as possible. Integrating private sector and research partnerships into this application would also strengthen Utah's proposal; New York, Connecticut, Massachusetts, and New Jersey took this approach by announcing that nearly 40 additional partners will be involved in their hydrogen hub proposal, indicating strong demand and interest in the potential project.[76] Regardless of whether Utah receives this federal funding, though, the state can still work to establish such a hub. The recent announcement of a $504.4 million federal loan guarantee to build a green hydrogen hub around the ACES storage project near Delta, Utah, provides a natural starting point. Utah's Office of Energy Development and Office of Economic Opportunity should partner with the project and regional governments to attract new investors to the state that can complement and leverage existing hydrogen projects such as this one.

GROW AWARENESS AND DEMAND

Expand public-private partnerships to enable government and companies across the value chain to collaborate on hydrogen technology applications and combine their purchasing power. By using the government as a coordinating body, Utah can foster growth in hydrogen applications, both through its own procurement power and through fostering demand by end users. Utah government agencies such as the UIPA, for instance, could bring fleets that are interested in procuring zero-emissions vehicles together with clean vehicle manufacturers in a partnership that allows fleets to aggregate their demand in group product buys. To illustrate, Climate Mayors Electric Vehicle Purchasing Collaborative has brought together more than 250 buyers committed to purchasing over 4,000 electric vehicles, highlighting the success of this strategy.[77] Such a model can reduce upfront costs and increase confidence for potential hydrogen users, while providing benefits to the state through improved air quality from zero-emissions vehicles. Existing partnerships such as Project Beehive are an effective model for this collaboration that should be expanded for other hydrogen uses (e.g., industry or the power sector).

Develop a clearer national lexicon to describe hydrogen that allows the public to differentiate easily between hydrogen's life cycle carbon intensity. The bipartisan infrastructure law directs DOE and EPA to define a clean hydrogen standard, based on emissions intensity at the site of production, which would transition away from descriptive hydrogen colors toward a system focused on emissions reductions. While this is a positive advancement for public understanding, the federal government should build on this progress by establishing a clean hydrogen standard that considers hydrogen's full life cycle emissions, not only emissions at the production site. Further, complementary measures should be taken to enable demand for low-carbon products to be met: Product emissions labelling, for instance, would add transparency to hydrogen's emissions attributes and allow consumers to opt for the lowest-carbon option. Federal and state governments, along with the private sector, should collaborate to educate the general public on what "clean hydrogen" means and streamline product labelling across the industry.

Create state-level awareness programs that showcase Utah's existing hydrogen work, educate the public, and cultivate potential end users. As Utah moves forward on hydrogen, the need for public awareness about what hydrogen is, its safety, its potential applications, and Utah's ongoing leadership in hydrogen only grows. Utah government agencies, nonprofits, and companies can partner on awareness raising programs that educate stakeholders across the state about these topics, grow trust in the sector, and solicit interest in hydrogen from potential end users. This awareness raising could take the form of educational events, knowledge materials, road shows, and more.

STRENGTHEN HYDROGEN PLANNING AND POLICY

Intentionally create synergies between hydrogen and the broader state energy system when implementing Utah's

energy strategies. Utah recently released an updated energy strategy, titled the Energy and Innovation Plan, which, among other goals, commits the state to supporting a clean energy future through investment in emerging energy technologies, including hydrogen.[78] The plan mentions hydrogen's ability to be dispatched to the energy grid, used in refining processes, or used to fuel cars. While the inclusion of hydrogen in the state's plan is a positive sign, Utah state agencies should better integrate their plans for hydrogen development with other energy strategies by planning for its synergistic use in the state's energy ecosystem. This integrated planning could help Utah take full advantage of its existing resources and infrastructure, while addressing energy challenges. For instance, Utah can increase energy system efficiency by leveraging excess renewable generation, flare gas, or methane-producing waste streams for hydrogen production. It should also explore a variety of potential end uses for hydrogen, including as a low-carbon fuel or feedstock in the industrial sector (beyond refining operations) or as a fuel for heavy-duty transportation specifically.

Strengthen state and federal regulatory frameworks for hydrogen to effectively govern its production, transport, storage, and use, both in Utah and across the country. Several gaps exist in federal hydrogen regulations that preclude the sector's responsible growth and weaken companies' confidence to invest in hydrogen infrastructure. DOE is currently conducting a regulatory assessment as part of its national clean hydrogen strategy and roadmap, which will identify regulatory barriers for hydrogen and suggest modifications. A central question to be answered in this process pertains to hydrogen blending in natural gas pipelines, which does not fall neatly into any one agency's jurisdiction.[79] At the state and local levels, Utah and municipal governments should collaborate on relevant hydrogen regulations, including any state-specific considerations for project decommissioning and locally specific building codes to govern hydrogen's residential and commercial heating applications. These state and local regulations, with supporting federal oversight, can ensure hydrogen development in Utah is safe and responsible and provides benefits to the state.

Consider hydrogen energy production in the state's water plans. If hydrogen production is to ramp up significantly in Utah, that production will have water implications, regardless of production pathway. In projecting for future water demands and crafting strategies for conservation (through the implementation of the Water Resources Plan and creation of a broader State Water Plan underway), Utah's state agencies should consider projections for hydrogen production in the state, coupled with broader energy system trends including the ongoing shift to cleaner fuels and electricity. Such strategic planning could also help identify sources of water that may not be suitable for other purposes but could be purified for hydrogen production (e.g., wastewater), as well as identify water conservation or replenishment strategies that hydrogen companies can use to responsibly manage resources.

Fund programs to identify and reduce leaked methane emissions at the state and federal levels. Given Utah's higher-than-average methane leakage rates in the Uinta Basin, combatting methane leaks will be essential to reducing emissions through hydrogen production. Federal action is already underway to reduce methane emissions through the EPA's pending rule to strengthen emission reduction requirements from the oil and natural gas industry.[80] In 2021, Congress considered creating a Methane Emissions Reduction Program, which would reward high performers and penalize excess methane polluters.[81] Passing such a program into law, either at the federal or state level, would be an effective way to spur innovation in reducing emissions. Several states have also taken initiative in combatting methane leaks. Neighboring Colorado, for instance, approved regulations in 2014 that required companies to routinely check both existing and new oil and natural gas wells and fix leaky equipment, resulting in a 75 percent drop in the number of sites with methane leaks detected.[82] Following suit by improving leak detection capacity and testing frequency and requiring or incentivizing methane leak reductions across oil and gas operations could help Utah's hydrogen better compete in low-carbon markets, while increasing production efficiencies.

Pass a suite of tax credits at the state and federal levels to support hydrogen projects, with incentives based on life cycle emissions intensity. Expanding the ITC and PTC provisions included in last year's Build Back Better Act would provide a strong starting point for incentivizing hydrogen production federally and encouraging innovation to maximize emissions reductions across hydrogen's life cycle. These provisions enjoy broad, bipartisan support from members of Congress and should be passed into law. While Utah currently does incentivize hydrogen production, it does not offer added incentives for low-carbon hydrogen. The state should strengthen its hydrogen incentives by ramping up tax credit values for lower-emitting hydrogen, reducing costs for clean hydrogen while maximizing the air quality and greenhouse gas emissions benefits for the state.

Prepare the hydrogen workforce by creating training programs to support new jobs across the full hydrogen value chain, with a focus on workers displaced by fossil plant closures. While existing energy workers have many skills that can be readily transferred to the hydrogen industry, hydrogen projects will also require new skills that necessitate training. To maximize the economic potential of hydrogen in the energy transition, Utah should fund workforce transition programs that help workers, especially fossil fuel workers, develop skills that can prepare them for work in a low-carbon future, including in hydrogen. Job placement and employer relationship building should be a central component of these programs to ensure training leads to long-term employment. Existing programs that can be leveraged to build out Utah's hydrogen workforce include services at the state's Workforce Development Division and the University of Utah's Coal Country Strike Team in Carbon and Emery counties.

ADDITIONAL RESOURCES

C2ES RESOURCES

Getting to Zero: A U.S. Climate Agenda

Investing in West Virginia's Future: Aligning Climate and Economic Development

Investing in Arizona's Future: Driving Equitable, Low-carbon, Economic Growth

OTHER RESOURCES

Utah Coal Country Strike Team

Going for the Green: How Utah Can Thrive in the New Climate Economy

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