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Smart Electric Power Alliance

Insight Brief: Clean Hydrogen for the Electric System

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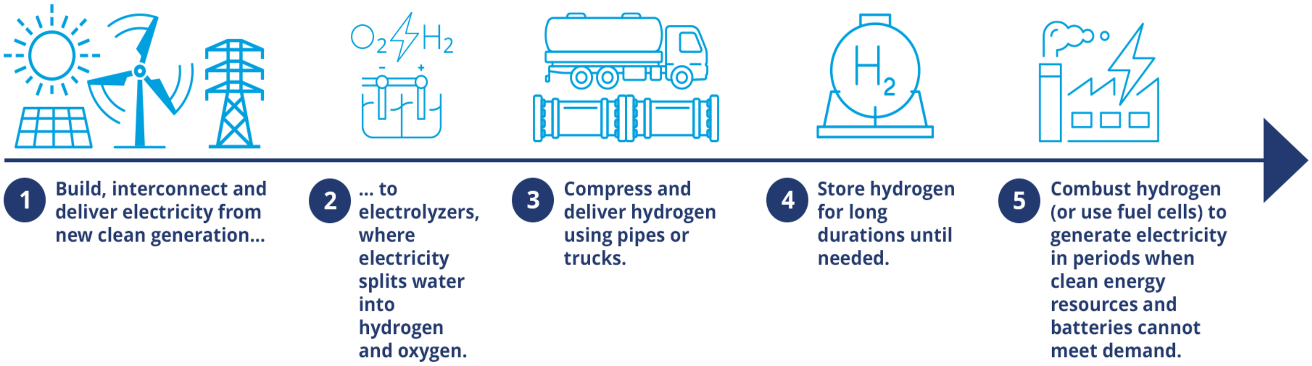
Highlights

In this first issue of SEPA's new Insight Brief series, we team up with Energy Innovation to investigate how the production, storage, and use of electrolytic hydrogen can support the rapid decarbonization of the U.S. power sector. We will explore the crucial role of utilities, grid operators, and technology providers in building the nascent clean hydrogen industry and unpack how their decisions may affect load growth, consumer rates, grid reliability, and communities.

- **Hydrogen's value stems from its decarbonization potential, which must remain central to the industry's growth to maintain policy support.** Hydrogen can increase or decrease net greenhouse gas (GHG) emissions depending on how it is produced, transported, and used. Actions that worsen climate pollution are likely to erode support for federal investments and incentives needed to develop the hydrogen market and make it competitive on its own.
- **New electrolytic hydrogen production will increase gross electricity loads, and electric utilities will play a key role in planning for and managing these loads.** However, electrolytic hydrogen production brings opportunities to integrate higher shares of variable renewable energy and support grid reliability to the degree that federal policy, state policy, and utilities can support electrolyzers in acting as flexible, price-responsive demands.
- **In the long term, utilities can leverage hydrogen as a critical source of long-duration energy storage, though other applications are unlikely to pencil out.** Electrolyzers can draw on excess clean energy to produce hydrogen, which can be stored for use across seasons and years. However, the low roundtrip efficiency of electrolyzing hydrogen and burning it for power means electrolytic hydrogen cannot compete with the direct use of clean energy or lithium-ion batteries. This paper does not examine other hydrogen end-uses.
- **Successful production, transport, and use of hydrogen will depend on protecting and engaging early with communities hosting or surrounding this infrastructure.** While ideally, hydrogen will be a net benefit for any community, developers and utilities must take care to control for any public health, safety, consumer electric rate, and water consumption impacts.
- **By planning ahead for success, utilities can ensure electrolytic hydrogen supports — rather than harms — utility operations and decarbonization goals.** This will require research, development, and deployment initiatives that account for the above factors.



1. **Build, interconnect and deliver electricity from new clean generation...**
2. **... to electrolyzers, where electricity splits water into hydrogen and oxygen.**
3. **Compress and deliver hydrogen using pipes or trucks.**
4. **Store hydrogen for long durations until needed.**
5. **Combust hydrogen (or use fuel cells) to generate electricity in periods when clean energy resources and batteries cannot meet demand.**

Source: SEPA. 2024

The Hydrogen Opportunity

Hydrogen molecules can be produced without emitting GHGs and can replace fossil fuels throughout the economy, whether used as a chemical feedstock, combusted for heat, or run through a fuel cell to generate electricity. As governments and companies seek to meet their decarbonization goals, hydrogen has gained recent attention for its ability to serve applications that are difficult or impossible to electrify, such as steelmaking, chemical production, aviation, and marine shipping.[1]

The U.S. currently produces approximately 10 million metric tons (MMT) of hydrogen, primarily to refine oil or make chemicals like ammonia and methanol.[2] However, nearly all of this hydrogen is made through steam methane reformation (SMR), which splits hydrogen from methane while emitting roughly 10 kilograms of carbon dioxide per kilogram of hydrogen (responsible for nearly 2% of U.S. net GHG emissions in 2022).[3]

A variety of technologies can reduce or eliminate the emissions intensity of hydrogen production. Carbon capture and sequestration (CCS) can mitigate emissions from the SMR process. Most notably for utilities, electrolyzers are an alternate technology that uses electricity to split hydrogen from water molecules, with oxygen as the only on-site byproduct. The final GHG emissions intensity of electrolytic hydrogen depends on how electrolyzer development and power requirements impact utility or power market operations. Electrolytic hydrogen's lifecycle emissions may range from 0 to 50 $kgCO_2/kgH_2$ contingent on the degree to which fossil fuel power plants ramp up to serve the new demand.[4]

Relative to fossil fuels, hydrogen is much more expensive to produce,[5] trickier to handle, transport, and store, and not as readily suited for use in most applications it could theoretically serve.[6] Instead, it is hydrogen's decarbonization potential that drives its policy support and public acceptance. To create a truly clean hydrogen ecosystem that can compete with fossil fuels (absent subsidies), the hydrogen industry will need to grow sufficiently to fall in cost, deploy midstream infrastructure, and support the deployment of equipment that accommodates hydrogen. It is critical to ensure the pursuit of electrolytic hydrogen production results in a low GHG emissions intensity product.

In the U.S., three federal policies are spurring the growth of clean hydrogen production:

- The Infrastructure Investment and Jobs Act (IIJA) includes $8 billion for the creation of **regional clean hydrogen hubs,** intended to test different ways of producing and using hydrogen while building connective midstream networks. In October 2023, the U.S. Department of Energy (DOE) announced its preliminary selection of $7 billion in awards for seven Regional Clean Hydrogen Hubs (H_2Hubs) that are expected to collectively produce 3 MMT of hydrogen per year (Figure 1)**.**[7] Utilities are among the partners in these H_2Hubs and will play a large role in shaping the H_2Hubs' growth and success.[8]
- The Inflation Reduction Act (IRA) includes the **"Section 45V" Clean Hydrogen Production Tax Credit**, which is meant to scale clean hydrogen deployment. The credit is worth up to $3/$kgH_2$ for hydrogen with an upstream and production GHG emissions intensity below 0.45 $kgCO_2/kgH_2$. In December 2023, the U.S. Department of the Treasury released draft rules for how producers can earn the credit.[9] The 45V credit could spur on the order of 10 to 26 MMT of annual electrolytic hydrogen production by 2032.[10]
- The U.S. Environmental Protection Agency (EPA) proposed new **Clean Air Act rules regulating GHG emissions from fossil fuel-fired power plants** in May 2023 and finalized aspects of them in April 2024. These rules are performance standards. EPA set the standards for new natural gas generators based on emissions reductions achievable with CCS. However, generators have flexibility in how to meet the standards and could elect to use hydrogen as part of their compliance pathway.[11] While the rules may create new demand for hydrogen in the power sector by the 2030s, it is unclear to what degree utilities would choose to rely on hydrogen versus alternative options.

As of April 2024, key details related to the H_2Hubs,[12] the 45V tax credit,[13] and the aspects of the U.S. EPA power plant GHG rules for existing natural gas generators have yet to be finalized. Their final forms will drive how the hydrogen industry develops over the coming decades. Utilities will need to plan for managing the broader impacts of multiple scenarios, as this can improve the odds of success in reducing emissions, lowering consumer costs, and improving reliability.

Figure 1. Clean Hydrogen Hubs

Source: U.S. DOE. Regional Clean Hydrogen Hubs Selections for Award Negotiations.

BOX 1: SMR + CCS This brief primarily focuses on electrolytic hydrogen given its interdependence with the U.S. power system and ability to eventually reach an unsubsidized cost below SMR hydrogen. By comparison, sustained carbon pricing policy or subsidies will always be needed to keep the combined cost of SMR hydrogen with CCS below the cost of SMR hydrogen alone. This said, utilities with generation may still see a role for SMR hydrogen with CCS in complying with the future Clean Air Act power plant GHG rules. Compared to installing CCS equipment on certain natural gas generation units, it may be more economical to reduce the plants' GHG emissions by blending in SMR hydrogen produced with CCS. The economics of CCS improve with steady operations, so for SMR hydrogen with CCS to emerge as the economically favorable approach for supporting intermittent power generation applications, it would need to be produced around the clock and stored until needed.

Hydrogen Production: Planning for and Managing Electrolysis Loads

The 45V tax credit will be the primary driving force behind U.S. electrolytic hydrogen production. Where, when, and how project owners develop and power electrolytic hydrogen production facilities — and therefore, what the load profiles of any grid-connected electrolyzers look like — will depend greatly on the final rule design. As of March 2024, a primary uncertainty is how Treasury will choose to qualify hydrogen as "clean" and therefore eligible for incentives, namely how it may choose to implement the "three pillars" of clean electrolytic hydrogen production (Table 1).[14]

Table 1. Three Pillars of Clean Electrolytic Hydrogen

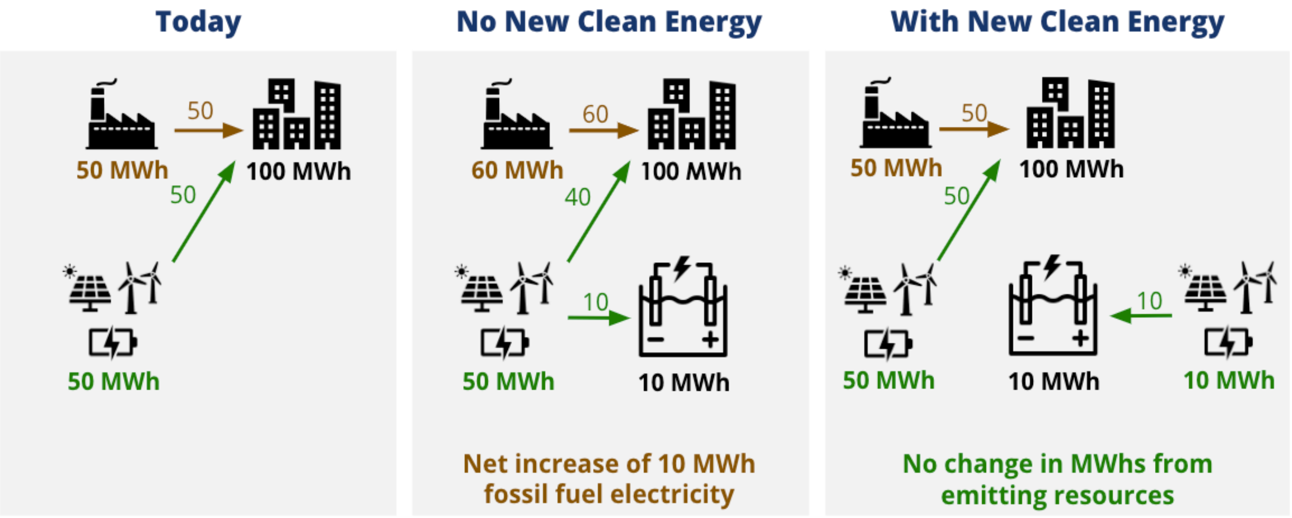
Pillar[A]	Definition
Incrementality	Incrementality refers to the use of electricity generated from new carbon-free generation sources that were recently commissioned specifically for hydrogen production. Treasury's draft rules allow the use of clean energy from projects that begin commercial operations no earlier than 36 months before an electrolyzer's placed-in-service date.
Temporal Matching	Temporal matching refers to the use of electricity in the same time intervals that it is being generated by a clean energy resource. Treasury's draft rules allow annual matching of electricity production and use through 2027 before switching to an hourly matching requirement, with all projects needing to comply with hourly matching beginning in 2028.
Deliverability	Deliverability refers to the use of electricity in the same transmission area as where it is being generated by a clean energy resource. Treasury's draft rules establish regions that match the DOE's National Transmission Needs Study.[15]

Notes:

A. This table paraphrases the general principles of the U.S. Department of Treasury's proposed implementation methods for the "three pillars." See U.S. EPA December 2023 memo (https://home.treasury.gov/system/files/136/45V-NPRM-EPA-letter.pdf) and U.S. Department of the Treasury Notice of Public Rulemaking (https://www.govinfo.gov/content/pkg/FR-2023-12-26/pdf/2023-28359.pdf). As of April 2024, the U.S. Department of Treasury is considering exemptions and changes to each of these pillars following a request for comments and a public hearing.

To put 45V's impact on load growth into perspective, consider a situation where electrolyzers collectively produce 10 MMT of electrolytic hydrogen by 2032. Given a standard electrolyzer efficiency of 50 kWh/kgH_2, this level of production would add 500 TWh of new load to the U.S. power grid in less than a decade, or about 12% of total generation in 2023.[16] A higher production volume of 26 MMT H2 would imply 32% load growth by 2032, strictly from electrolysis.[17] How and where this load growth shows up will depend in large part on the final design of Treasury's 45V rules. Figure 2 illustrates interactions possible with and without an incrementality pillar.

Figure 2. Illustrative Depiction of the Role of Incrementality



In the "No New Clean Energy" case, a new electrolyzer appears to draw power exclusively from clean energy resources but causes a fossil fuel power plant to ramp up, creating new GHG emissions. In the "With New Clean Energy" case, the electrolyzer draws power exclusively from new clean energy resources: so long as deliverability and time-matching principles are also met (presumed to be true in this situation), this arrangement will not affect other plants' output.

Source: Energy Innovation Policy & Technology LLC.

A hydrogen framework under 45V with no pillars would allow the new electrolyzers to buy energy attribute credits (EACs) from any existing clean energy resource in the U.S. on an annual basis.

- This form of electrolytic hydrogen would have a GHG emissions intensity of 2-4x that of SMR depending on which fossil fuel power plants ramp up or are built to serve load that was previously served by clean energy resources (now diverted to feed electrolyzers, e.g., Figure 2 above).[18] The emissions impact could undermine support for 45V and hydrogen more broadly.[19]
- Utilities could expect electrolyzer deployments at scale in the very near future and with near-baseload operating profiles, given the surplus of low-cost EACs that are not used to fulfill state clean electricity standards (e.g., from Texas wind farms or Pennsylvania nuclear facilities). That is, electrolyzers selling hydrogen at $1/kg (today's market price for SMR hydrogen) and earning a tax credit of $3/kg would be willing to buy power at a price up to at least $80/MWh.[20] Such producers' willingness to pay for power may be even higher if they are able to sell hydrogen at a premium or enter new markets.
- A "no pillars" framework also brings heightened uncertainty in the scale and duration of this load growth. This framework may incentivize projects and technologies that first maximize electrolyzer load factors in the subsidy period, then face challenges to operating flexibly post-subsidy when cheaper power (i.e., $20/MWh) is needed but only available intermittently.[21] Such projects may see their load factors plummet or could face early retirement. On the other hand, utilities must also consider the possibility of Congress extending the program, including for both new and existing facilities.

A framework with all three pillars as currently proposed would bring new, local, hourly-matched clean energy resources online roughly in parallel with the deployment of electrolyzers, and ensure low GHG emissions intensity hydrogen production.

- Utilities would see much lower net load growth. Much of the electrolyzer buildout might happen off-grid or through co-located projects (electrolyzers paired with new clean energy, where allowed) that show up either as smaller interconnection requests or sources of price-responsive clean generation. That is, co-located projects might (1) only sell excess electricity to the grid, reducing their interconnection request; or (2) submit an interconnection request for the full generation capacity and sell all available power to the grid when prices rise above the electrolyzer's break-even price (in the above example, $80/MWh). These arrangements can ease pressures on load growth and support grid reliability during the subsidy period.
- A policy with three pillars as currently proposed would incentivize new electrolyzer projects designed to ramp up and down to capture changes in renewable output. When 45V expires — after 10 years for a qualifying project and for any project beginning construction after 2032 — these electrolyzers will be better equipped to price-hunt for cheap power from the market, further supporting renewables integration and grid reliability by soaking up excess generation. Should Congress extend 45V, the net load growth impacts would be similarly low, reducing uncertainty for demand forecasts.
- Lastly, the inclusion of the three pillars would concentrate electrolyzer deployments in wind-rich regions of the country, where generation profiles are a better match for achieving higher electrolyzer load factors.

Given the current policy uncertainty around 45V, utilities may wish to assess scenarios representing a range of outcomes so as not to be taken off guard by the final rules.

- To stay on track to meet utility carbon-reduction targets[22] under a "no pillars" framework, utilities will need to find a way to serve the new load with low-carbon resources. This could require increasing and accelerating new clean energy interconnections, securing and expanding renewable energy power purchases, or avoiding new fossil fuel power plant development.
- Under a "three pillars" framework, utilities will face less-rampant load growth but may see value in quickly examining their tariff structures to facilitate the addition of flexible sources of clean generation (i.e., co-located renewable and electrolyzer arrangements described above) and demand (i.e., electrolyzers acting as price-responsive demands). In particular, utilities could consider reducing or eliminating fixed fees for electrolyzers, as doing so will enable them to

maximize the production of competitively-priced hydrogen while providing important grid services and supporting grid decarbonization.[23]

- Energy businesses able to build and own generation assets (i.e., vertically integrated utilities, generation & transmission utilities, and independent power producers) can also develop and operate their own electrolyzers to take advantage of these same benefits. This may be especially beneficial in concert with hydrogen storage to provide long-duration energy storage services, as discussed in the next section.

Hydrogen Use: Leveraging Hydrogen to Decarbonize Utility Operations

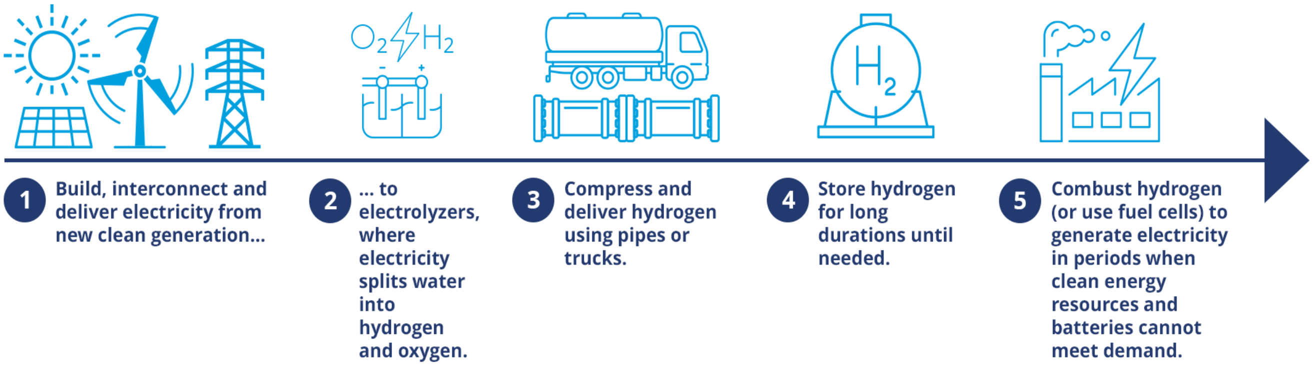
Electric utilities with carbon-reduction targets are taking a range of actions to decarbonize their operations.[24] While clean electrolytic hydrogen has the technical potential to support a variety of aspects, not all are currently economic or achievable. The most impactful use of electrolytic hydrogen for electric utility carbon reduction is as long-duration energy storage to firm generation in the “last mile” of the transition to a carbon-free electricity system. Up to that point, electric utilities should continue to prioritize a range of other strategies with broader and deeper carbon reduction potential, including deploying or procuring utility-scale clean generation in place of fossil-based generation, deploying shorter-duration battery storage, and supporting beneficial electrification, distributed energy resources, and strategies to align and shift customer demand to provide grid services and carbon reduction. Below, we elaborate on the hydrogen opportunity in the context of these other activities.

Because clean electrolytic hydrogen emits no CO_2 when burned, it is a theoretically attractive option for decarbonizing combustion turbine operations. Analysis suggests that hydrogen’s role will be significant–albeit small in magnitude, relative to the existing U.S. fossil fuel generation fleet. One limiting factor is electrolytic hydrogen’s relatively low roundtrip efficiency as an energy storage medium. Producing hydrogen with electrolysis and then combusting the hydrogen for power has a roundtrip efficiency of approximately 30-35%, with the potential to achieve 60%-65%, assuming no losses during transportation or storage.[25] Thus, electrification served by low-carbon electricity is a more direct and efficient strategy for decarbonizing end-use loads that are today served by fossil fuels. Additionally, 4-hour lithium-ion batteries can ramp instantaneously and have roundtrip efficiencies of 85-90%, making them a better option for intraday energy storage than hydrogen.[26]

As mentioned in Box 1 above, hydrogen produced via SMR with CCS uses far less power than electrolysis and could therefore also serve intermediate or baseload power generation needs. Theoretically, this could be accomplished by blending this hydrogen with natural gas in the interim or retrofitting facilities to run strictly on hydrogen. However, given that SMR uses natural gas and adds costs from there, this would only make sense under a regulatory requirement (like the EPA’s proposed power plant GHG rules), a carbon pricing program, or indefinite carbon capture subsidies, as one or more of these are needed to enable this hydrogen to economically displace the direct use of natural gas in power generation.

Once utilities have largely saturated early-decarbonization opportunities — such as through electrification, clean energy supply, and short-duration storage — hydrogen may be a cost-effective strategy for the emerging long-duration energy storage services needed for “last mile” decarbonization (Figure 3). Hydrogen can be stored for long durations and in massive volumes (e.g., salt caverns) to be drawn upon when needed months to years later. For example, hydrogen could store excess hydropower output in wet years and be drawn upon in drought years–a service that would be terribly expensive for lithium-ion batteries to offer.

Figure 3. Pathways to Clean Electrolytic Hydrogen for Electric Utility Carbon Reduction



1. Build, interconnect and deliver electricity from new clean generation…
2. … to electrolyzers, where electricity splits water into hydrogen and oxygen.
3. Compress and deliver hydrogen using pipes or trucks.
4. Store hydrogen for long durations until needed.
5. Combust hydrogen (or use fuel cells) to generate electricity in periods when clean energy resources and batteries cannot meet demand.

Source: SEPA. 2024

Overall, in planning for system decarbonization, utilities should first maximize the pace of clean energy deployment or procurement before adopting clean electrolytic hydrogen. This is especially true when designing a strategy to serve anticipated significant load growth in the collective wake of electrolyzers; data centers; onshored clean energy manufacturing; and the electrification of vehicles, buildings, and industrial processes.

BOX 2: ADVANCED CLEAN ENERGY STORAGE (ACES) PROJECT IN DELTA, UTAH: The ACES project plans to use over 220 MW of electrolyzers to produce and store as much as 300 GWh worth of hydrogen in on-site salt caverns. This hydrogen can then be used in an 840 MW natural gas combined cycle power plant (retrofitted from a coal plant) that is intended to be capable of burning 30% hydrogen by 2025 and 100% hydrogen by 2045.[a] The plant also includes access to a dedicated transmission line to Los Angeles.[b] If the electrolyzers produce truly clean hydrogen (i.e., satisfying the "three pillars"), the project will be capable of providing on-demand clean power to an otherwise constrained region. The project funding includes a $504.4 million loan guarantee from the U.S. Department of Energy Loan Programs Office.[c]

a ACES-DELTA. (n.d.) Advanced Clean Energy Storage Hub. (Accessed February, 2024)
b Power Engineering (2023). First hydrogen equipment delivery arrives at Advanced Clean Energy Storage Hub
c U.S. DOE Loan Programs Office (n.d.) Advanced Clean Energy Storage (Accessed February, 2024)

Hydrogen Impacts: Supporting Equity, Environmental Justice, and Community Engagement

Hydrogen projects, like other larger energy projects, can bring adverse impacts and heightened risks if not carefully designed with risk mitigation and community engagement at the forefront. These impacts and risks include:

- Air pollution can arise from hydrogen combustion, which emits nitrogen oxides (NOx) at levels that can be higher or lower than burning natural gas depending on the combustion method and pollution control equipment in place.[27] Hydrogen fuel cells do not emit NOx.
- Water consumption at new hydrogen electrolysis facilities can cause concern in regions with drought or water scarcity. In general, the process uses comparable amounts of water as SMR and less water than SMR with CCS.[28]

- Public safety is a risk due to hydrogen being highly combustible and therefore carrying the possibility of explosions. This danger can be mitigated by using the proper infrastructure (e.g., new, hydrogen-dedicated pipelines) and leak detection equipment.[29]
- Electric utility customer costs can rise depending on how hydrogen is produced and used. Namely, electrolysis that does not meet the "three pillars" standard can raise electric rates, as can the use of hydrogen in applications where alternatives like electrification would be more cost-effective.[30]
- Climate pollution is a risk from producing hydrogen in policy scenarios in which the "three pillars" are not employed and electrolysis induces fossil fuel power generation elsewhere on the grid. It is also a risk in hydrogen transportation, as hydrogen molecules are extremely small and inherently prone to leakage, and hydrogen gas is an indirect GHG with a 100-year global warming potential estimated around 8-14 times the impact of CO_2.[31] Dedicated hydrogen pipelines can use materials like plastic that minimize leakage, but most existing natural gas pipelines are not well-suited to carry hydrogen.[32]

When seeking to mitigate these impacts and risks, hydrogen developers have a responsibility to learn about communities' experiences, concerns, and needs. They must seek out communities' input, going beyond simple consultation to center justice and inclusion alongside technological advancement. This work requires early, consistent, and genuine engagement with communities, as well as taking responsive action to address concerns.

Hydrogen projects typically are industrial facilities, and developers will need to proceed with the awareness that many would-be host communities have long borne the brunt of legacy climate, health, and economic burdens of other heavy industries without seeing an equal share of its benefits. Communities may be willing to host hydrogen projects if the net benefits (including careers, economic benefits, and improved local air quality) outweigh the risks and if they contribute to real GHG emissions reductions. On the other hand, ignoring community concerns or "greenwashing" hydrogen's emissions impacts could revoke developers' social license to operate, which could take the form of communities thwarting projects or working to undo needed policy incentives for hydrogen.[33] Lastly, hydrogen may face pushback to the degree it is seen as a way to perpetuate fossil fuel infrastructure.

Such public opposition is already bubbling up. For example, some communities facing proposed hydrogen projects are raising concerns about regional groundwater withdrawals for electrolytic hydrogen[34] and the local air quality impacts of NOx emissions from hydrogen combustion.[35] Additionally, environmental justice organizations[36] and consumer advocates[37] are raising alarms about dirty electrolytic hydrogen production. For a clean electrolytic hydrogen industry to succeed, it must take serious steps to address — rather than dismiss — these concerns. Seeking input on clean hydrogen projects and accounting for community sentiment is critical. Communities will hold unique views about what benefits are useful, what risks and costs are acceptable (or unacceptable), and what a just and inclusive process for establishing community benefit will look and feel like. Today, we cannot singly summarize the varied input that individual groups may have about proposed hydrogen projects in their communities. Instead, we recommend the industry works actively to answer a variety of questions on these considerations, including but not limited to those listed in Table 2. Groups involved in the emerging clean hydrogen supply chain can show up at forums such as Regional EPA Administrator monthly roundtable calls[38] to learn more about the community groups engaged in this topic, learn what groups want for their communities and what they think about hydrogen, and reach out to them with information about proposed projects.

Table 2. Sample Questions for Community Engagement

Environmental impact of hydrogen projects on surrounding communities and the environment	Process for gathering and incorporating community feedback
▪ What kind of due diligence needs to happen to proactively prevent harm to the environment and frontline and fenceline communities? ▪ What, if any, extra precautions and approval processes are being taken for hydrogen hubs and individual hydrogen projects that have been proposed in non-attainment areas (e.g., St. James Parish, LA; Gulf Coast, TX)? ▪ What do those processes look like? ▪ What level of controls and monitoring (e.g., safety measures, clean air/water metrics) and emergency protocols (e.g., funding, community response, remediation plans) are in place to mitigate NOx emissions, hydrogen leakage, fire/explosion risks, and any other public health and safety risks?	▪ How can we best apply community-centered approaches that have been used in other energy applications (e.g., DOE's Consensus-Based Siting)? ▪ How can we engage minority-serving institutions in R&D? Small businesses in commercialization?[A] ▪ Can we leverage current programs and funding to address these or other questions (e.g., the Environmental Justice Thriving Communities Technical Assistance Centers)?[B] ▪ How can we use the environmental justice index and other metrics to measure and assign a cost to potential environmental harms?[C] ▪ How can we get feedback from people in the region on what they think about hydrogen? How can we engage early enough in the process to make meaningful adjustments based on input? ▪ How can we employ a community benefits plan?[D]

Notes:

A. Research could focus on developing and commercializing technologies as well as ways to increase domestic ownership of intellectual property. Commercialization could include the items needed along the supply chain like anion exchange membranes and thermochemical water splitting.

B. U.S. EPA. (n.d.) The Environmental Justice Thriving Communities Technical Assistance Centers Program.

C. An example: Environmental Justice Index (EJI) Fact Sheet

D. RMI. (2024). Delivering Equitable and Meaningful Community Benefits via Clean Hydrogen Hubs.

Implications and Recommendations: Setting the Foundation for Success

Hydrogen has an important role to play in a decarbonized U.S. electric sector, but for the industry to grow quickly, achieve its intended benefits, and minimize adverse impacts, utilities and hydrogen developers will need to chart a careful path forward. Electric utilities should consider these recommendations:

- Plan now for how to approach different types and trajectories of electrolysis-driven load growth, which are today largely contingent on Treasury's final rules for the 45V tax credit.
- Explore how to enable the interconnection and beneficial use of electrolyzers capable of acting as flexible, price-responsive demands (such as through low- or no-fee tariff designs).
- Focus any hydrogen use case analysis on long-duration energy storage applications to smooth differences in renewable energy output across seasons and years (while first prioritizing the buildout of clean energy resources and lithium-ion batteries). Where possible, avoid scenarios that turn to hydrogen for supplying intermediate or baseload power, as this would otherwise generally be more expensive.
- Engage with communities at the earliest possible stage of hydrogen and other clean energy project development. Work to build trust and mitigate real risks (e.g., local air pollution, public safety, cost impacts), being as responsive as possible to communities' unique circumstances.

While most electric utilities may not need extensive long-duration energy storage services this decade, they can begin thinking about these issues now and setting up a glide path for deployment in the 2030s. Enabling flexible electrolyzer loads to soak up excess renewable generation can support grid decarbonization while growing hydrogen production to the scale necessary to supply future utility needs. Utilities can also run pilot projects to test and resolve operational challenges like NOx emissions from hydrogen combustion and how to safely and effectively link hydrogen supply, transport, storage, and use.[39]

Hydrogen policy in the United States has been a shifting, complex story in recent years, and it will likely continue to be for some time. Precise strategies and smart implementation will be critical to ensure that electrolytic hydrogen production provides net emissions and community benefits. Utilities and stakeholders can build on existing experience with other aspects of the energy transition to develop and align their clean hydrogen strategies with goals for an affordable, equitable, reliable, and enduring transition to a carbon-free electricity system. With the wealth of investments ahead and collaboration already underway, electric utilities have a unique opportunity to take an active hand in supporting and scaling clean electrolytic hydrogen for power system carbon reduction.

Endnotes

1. While hydrogen can theoretically replace fossil fuels in just about any application, it will likely only be competitive with alternative clean energy technologies in a small subset. This brief limits its focus to power sector applications. See: Liebreich, M. 2023. Hydrogen Ladder Version 5.0.
2. U.S. National Clean Hydrogen Strategy and Roadmap. Page 14.
3. Rhodium Group. (2023). Scaling Green Hydrogen in a post-IRA World.
4. Energy Innovation Policy & Technology LLC. (2023). Smart Design Of 45V Hydrogen Production Tax Credit Will Reduce Emissions And Grow the Industry. Figure 2.
5. Bloomberg NEF and The Business Council for Sustainable Energy. (2023). 2023 Sustainable Energy in America Factbook, page 55.
6. Energy Innovation Policy & Technology LLC. (2022). Assessing The Viability Of Hydrogen Proposals: Considerations For State Utility Regulators And Policymakers
7. U.S. Department of Energy (DOE). (2023). Biden-Harris Administration Announces $7 Billion For America's First Clean Hydrogen Hubs, Driving Clean Manufacturing and Delivering New Economic Opportunities Nationwide.
8. Edison Electric Institute. (2023). Clean Hydrogen Hubs Announced 17 EEI Member Companies Involved With Winning Projects.
9. Section 45V Credit for Production of Clean Hydrogen; Section 48(a)(15) Election To Treat Clean Hydrogen Production Facilities as Energy Property. 88 F.R. 89220 (Proposed December 26, 2023) (To be codified at 26 CFR 1).
10. Evolved Energy Research. (2023). 45V Tax Credit: Three-Pillars Impact Analysis. Figure 5.
11. U.S. Environmental Protection Agency. (2024). Greenhouse Gas Standards and Guidelines for Fossil Fuel-Fired Power Plants. Accessed April 25, 2024.
12. The hubs are in the "negotiation" phase, with the DOE estimating a timeline of 8-12 years over 4 phases for hubs to be fully operational. See also: U.S. DOE Office of Clean Energy Demonstrations (n.d.) Community Benefits Plans Overview.
13. Treasury's comment period for its draft rules closed on February 26, 2024. While final rules are expected this year, the precise timing is unknown.
14. The DOE has determined that these "three pillars" are "critical" to ensure electrolytic hydrogen production has a low-to-zero GHG emissions intensity as required by the IRA to earn the $3/kg credit. See: U.S. DOE (2023). Assessing Lifecycle Greenhouse Gas Emissions Associated with Electricity Use for the Section 45V Clean Hydrogen Production Tax Credit.
15. U.S. DOE Grid Deployment Office. (2023). National Transmission Needs Study.
16. This represents the lower bound forecast of the Evolved Energy Research study: 45V Tax Credit: Three-Pillars Impact Analysis, Figure 5.
17. *Ibid*, representing the upper bound forecast of the Evolved Energy Research study.
18. Energy Innovation Policy & Technology LLC. (2024). Comment : REG-117631-23 Request for Comments on Section 45V Credit for Production of Clean Hydrogen, page 3.
19. *Ibid*, page 6.
20. This assumes zero-cost EACs. In recent years, certified EACs have traded at approximately $2.5/MWh to $7/MWh. See: Evolution Sustainability Group. (2023). Reach Your Sustainability Goals With Renewable Energy Credits.
21. To continue producing competitively-priced hydrogen post-subsidy, electrolyzers that earn 45V credits would need to buy substantially cheaper power. It is also possible that the no-pillars framework could incentivize development of electrolyzers that can run 24/7 but which are relatively inflexible to ramping–as would be needed for post-subsidy price-hunting–risking their long-term viability. See: Energy Innovation Policy & Technology LLC. (2023). Smart Design Of 45V Hydrogen Production Tax Credit Will Reduce Emissions And Grow the Industry.
22. For example: SEPA Utility Carbon Reduction Tracker and 2030 Club.
23. Pursuing tariffs to attract electrolytic load is only beneficial for carbon reduction under a "three pillars" framework. During the subsidy period, low fees would facilitate new clean energy and electrolyzer deployments where they make the most sense on the grid, with the pillars keeping

net load growth in check. When 45V expires, electrolyzers would only run at low prices (e.g., below $20/MWh), providing an important service on systems trying to integrate high shares of variable renewable energy.

24. See, for example: SEPA (2023). Utility Transformation Profile.
25. Roundtrip efficiency is the percentage of energy put into a process that is later usable. The higher the round-trip efficiency, the less energy is lost in the process. The lower range assumes a 50 kWh/kgH_2 electrolyzer (~80% efficient) and a standard simple-cycle gas turbine (~43% efficient). The higher range assumes a 41.5 kWh/kgH2 electrolyzer (~95% efficient) and a best-in-class combined-cycle gas turbine (~65% efficient). See: PCI Energy Solutions (2023) Power Plant Efficiency: Coal, Natural Gas, Nuclear, and More; New Atlas (2022) Record-breaking hydrogen electrolyzer claims 95% efficiency; GE Vernova (n.d.) 7HA Gas Turbine.
26. Lazard. (2023). 2023 Levelized Cost Of Energy+. Page 33.
27. For example, Georgia Institute of Technology and EPRI. (2023). NOx Production from Premixed Hydrogen/Methane Fuel Blends.
28. RMI. (2023). Hydrogen Reality Check: Distilling Green Hydrogen's Water Consumption.
29. *Ibid.*
30. Energy Innovation Policy & Technology. (2023). Consumer Cost Impacts of 45V Rules - Energy Innovation: Policy and Technology
31. "Global warming potential" (GWP) characterizes the climate-warming impact of a greenhouse gas over a given time frame. See: Sand, M. et al. (2023) A multi-model assessment of the Global Warming Potential of hydrogen.
32. Energy Innovation Policy & Technology. (2022). Assessing The Viability Of Hydrogen Proposals: Considerations For State Utility Regulators And Policymakers.
33. One example of "greenwashing" is calling electrolytic hydrogen "green" if its production is inducing higher GHG emissions elsewhere on the grid, as would occur if not meeting "three pillars" requirements.
34. For example, see: AZCentral (2024). Heliogen's 'green hydrogen' project in rural Arizona worries residents
35. For example, see: Clean Energy Group. (n.d.) Hydrogen Areas of Concern.
36. For example, see: Environmental Justice Organizations. (2023). Equity Principles for Hydrogen: Environmental Justice Position on Green Hydrogen in California, Environmental Justice Organizations. (2023). Letter to Senior Advisor to the President for Clean Energy Innovation and Implementation, et al.. Climate and Environmental Organizations. (2023). Letter to Senior Advisor to the President for Clean Energy Innovation and Implementation, et al., Midwest Advocates. (2024). Letter to Midwest Alliance for Clean Hydrogen (MachH2).
37. Consumer Advocates. (2023). Letter to Senior Advisor to the President for Clean Energy Innovation and Implementation, et al.
38. U.S. EPA. (n.d.) Environmental Justice in Your Community.
39. For examples, see: U.S. Department of Energy (2024). Biden-Harris Administration Announces $750 Million to Support America's Growing Hydrogen Industry as Part of Investing in America Agenda

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