BLACK & VEATCH

Water Resilience in the Hydrogen Economy

Four Things Hydrogen Developers Need to Know

Introduction

Hydrogen is a promising clean, low-carbon energy (LCE) carrier with the potential to reduce worldwide dependence on fossil fuel resources. Global investment in hydrogen infrastructure is rising and, along with the growth of LCE, demand for the water supply needed to generate the LCE is also expected to intensify. Water is a critical element of hydrogen production. As water scarcity threatens many areas of the globe, water-intensive decarbonization processes will need local sustainable water supply solutions.

Based on our expertise and experience in water management, hydrogen and sustainability, Black & Veatch outlined four water supply considerations to support hydrogen project development. Through these insights, developers can plan sustainable and equitable low-carbon hydrogen production infrastructure projects that align with community and environmental water needs.

Water's Critical Role in Hydrogen Infrastructure

Hydrogen can be produced through various methods, including electrolysis, natural gas reforming with carbon capture, and biomass gasification. Water is a necessary element of these processes, performing several functions:

- Critical feed for production
- Plant cooling and domestic water
- Disposal of reject water from treatment processes
- Salt cavern solution mining for geophysical hydrogen storage

For water electrolysis, 9 liters (L) of ultra-pure water is required to create 1 kilogram (kg) of hydrogen. However, depending on the configuration of the hydrogen plant, total plant water use may require between 18 to 36 L (4.8 to 9.5 gallons) of water per kg of hydrogen.[1] A large-scale hydrogen facility -- approximately 1 Gigawatt (GW) -- is projected to use roughly 7 to 15 million L (2 to 4 million gallons) per day.[2] When considering the local level impacts this is a large quantity of water, especially in water-stressed areas. To put it in perspective, that amount of water is more than the entire demand of many medium-sized U.S. cities. The quantity of water required for hydrogen production varies depending on these factors:

- Production process used
- Type of plant thermal management system
- Time of the year and associated local climatic conditions
- Level of water treatment
- Quality of raw water available

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Four Things Hydrogen Developers Need to Know

Water is central to the LCE transformation and developers confronted with climate risks and competition for access to reliable water supplies need to focus on water planning to value every drop. That said, Black & Veatch wants you to know these key things before the shovel hits the dirt.

1 Site Selection Starts with Water Supply and Demand

Understanding the water demand is important early in the planning process. Many factors impact the estimation of water demand and viability of a potential plant location, including:

- Hydrogen production method
- Thermal management approach
- Power generation capability
- Land area for renewable generation
- Storage, transport and power infrastructure

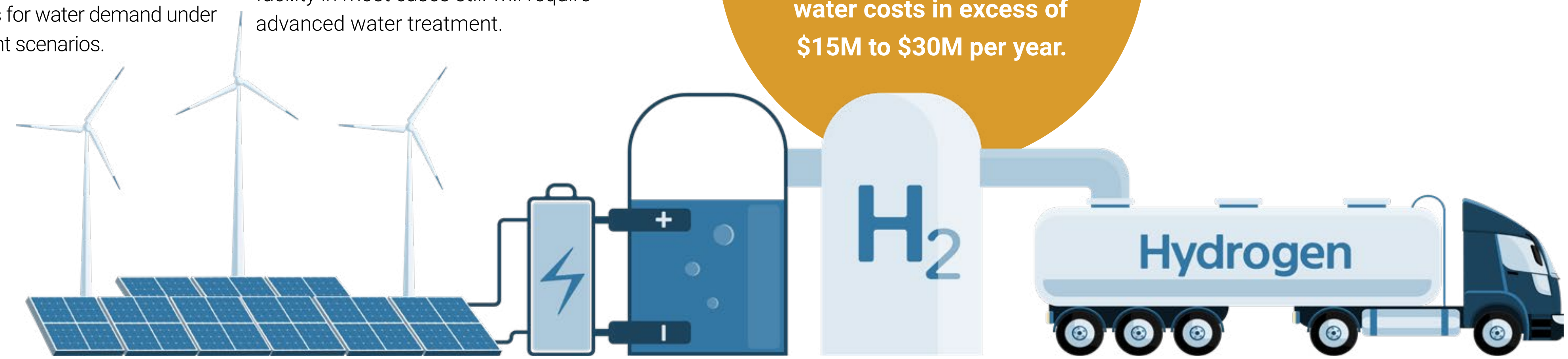
However, even prior to the initiation of preliminary engineering studies, it is prudent to develop conceptual estimates for water demand under various operational and thermal management scenarios.

The straightforward approach to development is to utilize the existing infrastructure of a local municipality. In some cases, this is a viable solution near large population centers that have large, sustainable water supplies. In rural areas, where large land tracts are available, it becomes increasingly unlikely that the municipality can augment its current water production to supply the facility within the desired project construction timeframe. Additionally, the cost of buying water from a municipal provider may include industrial water rates dictated by a public utilities commission and have a rate scale that increases with level of consumption to promote industrial water efficiency. Industrial water also is considered a lower priority to domestic supply; thus, in times of water shortage, the municipality may restrict the volume of water to ensure that domestic supplies are met. Municipal water quality also will not meet the water quality required for most electrolyzers, so the hydrogen facility in most cases still will require advanced water treatment.

A 1 GW electrolysis-based water-cooled hydrogen plant could incur municipal water costs in excess of $15M to $30M per year.

Having an estimated range of potential plant water demand allows project developers to quickly make financial calculations of total plant costs under a range of water supply options. For instance, a developer may determine that buying agricultural water rights in a remote area is more cost effective than purchasing industrial water from the local municipality and using air-cooled technology.

The options for water supply beyond obtaining a municipal supply are listed on page 5. The selection of which water supply option is most favorable will be based on the local water resource conditions. Because there are different requirements for water in the hydrogen production plant, water supplies also can be selected based on specific water use. For example, a municipal water source may be feasible for the electrolyzer feed supply, whereas the thermal management water could be sourced from local groundwater.



Sites often will have access to either water supply or renewable energy – not both. Site evaluation determines the best approach for combining these two resources at a single source.

Water Supply Options

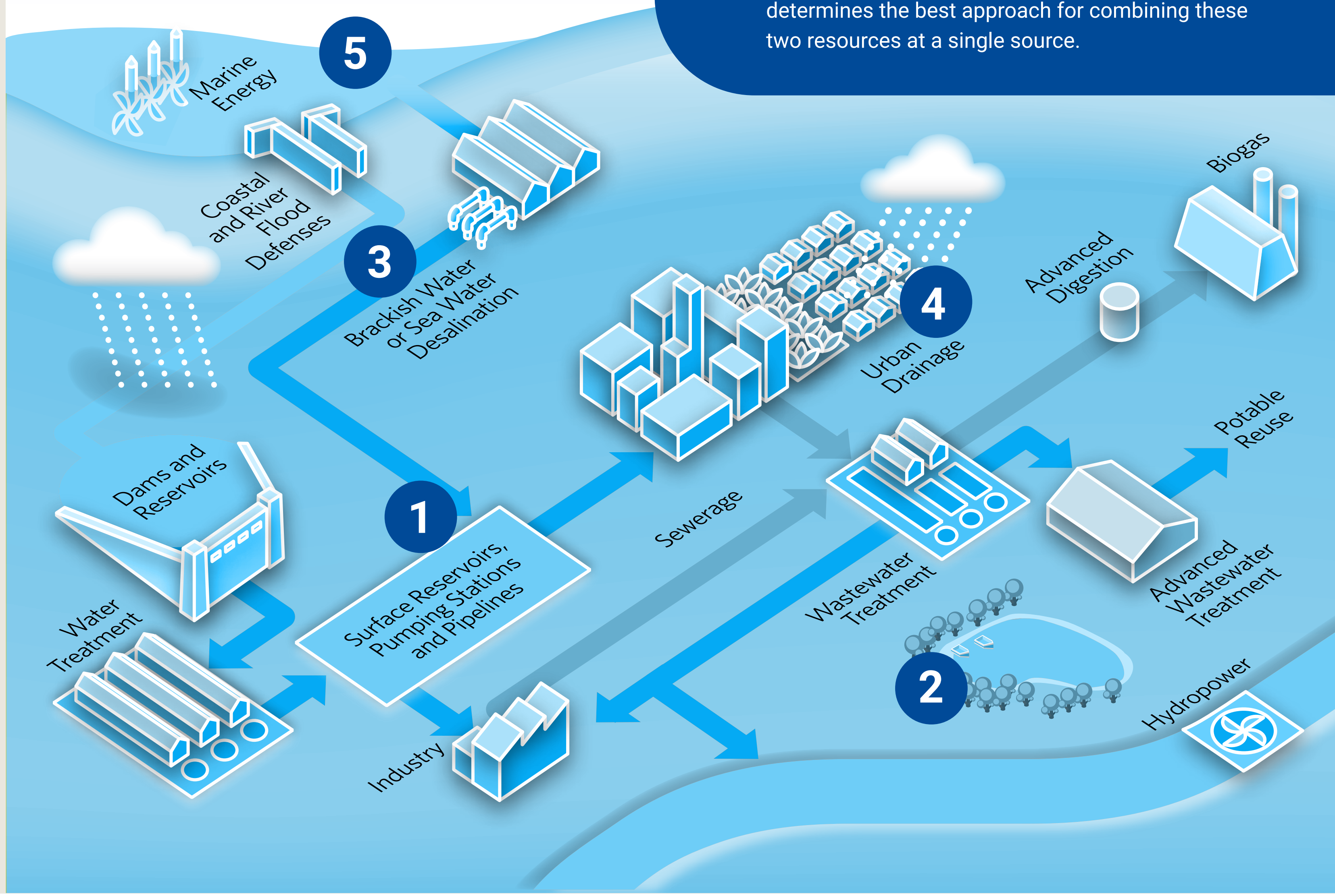
1. **Surface water** is an attractive option in areas where larger rivers are more common. However, surface water can be extremely hard to find in regions that lack access to large rivers, unless one acquires an existing senior water right. Even when a surface water right is identified, the intake structure may take many months of studies and permitting to show the water abstraction will not negatively impact stream ecology.

2. **Groundwater** is a common primary water supply, but factors such as natural recharge and aquifer storage may be subject to long-term water level declines. Groundwater regulations vary depending on the country and region.

3. **Brackish or slightly saline groundwater** is an attractive option for facilities due to its lack of competition for the resource but is subject to the aforementioned regulations.

4. **Reclaimed water** is ideal when the proposed facility is near a major metropolitan area that has large, centralized wastewater treatment facilities.

5. **Seawater** is a possible source when the facility is located near marine areas. Although there are challenges associated with treatment and regulatory permitting, desalination using renewable energy sources such as solar or wind power may be a viable option to produce fresh water that can be used for production.



2 Water Quality Impacts Water Quantity, Power and Your Bottom Line

Water quality has a significant impact on hydrogen plant water supply. A common measurement of water quality is total dissolved solids (TDS), measured in milligrams per liter (mg/L), which is a water quality parameter and indicator of the level of treatment that will be required for the plant, including impacts to both the process feed as well as thermal management. Electrolyzer manufacturers commonly specify that water quality meet ASTM Type I or Type II water.[3] Some electrolyzer manufacturers even are requiring the customer to certify that the water meets water quality specification because water quality is one of the most important factors in electrolyzer operations and long-term durability.

Membrane treatment removes the TDS; however, the higher the TDS concentration, the greater the volume of concentrate reject water requiring disposal, and the greater the electrical demand for the pumps to push the water through the membranes. This equates to a higher parasitic electrical demand for a LCE hydrogen facility, capital and operation costs for water treatment, and expensive reject water disposal.

The advantage of poorer quality water is that it generally is less expensive and has fewer conflicting demands. Poor quality, or brackish water, is found all over the globe and has not been extensively developed due to being unsuitable for crop irrigation or municipal supply. When calculating the costs of using a poor-quality water source, developers need not only include the treatment and power costs, but also the disposal costs.

Seawater is an attractive water source due to its almost limitless availability. A general drawback to seawater supply systems is typically related to the need for carefully engineered intake systems to avoid impingement effects on the marine ecology and disposal of the membrane concentrate. Slight changes in near-shore salinity can be toxic to the marine ecosystem and concentrate disposal may need to occur many miles offshore to mitigate these potential impacts. It's also important to note that seawater systems generally have exceptionally long permitting timeframes that are expensive and may require many years to obtain regulatory approval.

Brackish water sources generate concentrate which may contain elevated levels of metals, making it unsuitable for any use besides engineered concentrate disposal.

Concentrate Disposal Options

1. **Deep Well Injection** Requires extensive site investigation as part of the permit application process and could result in high operational costs to install and operate a disposal wellfield. Could cause induced seismicity (earth tremors) and contamination due to concentrate releases. Water that contains elevated concentrations of radionuclides often requires a Class I (hazardous waste) disposal well.

2. **Evaporation Ponds** Require a large surface area and long retention time, which can be challenging to implement in areas with limited space and water availability. High salt concentration can create corrosion and environmental concerns for surrounding infrastructure and ecosystems. System efficacy may be geographically limited. Evaporation ponds require routine maintenance to remove and dispose of precipitated salts.

3. **Zero Liquid Discharge (ZLD)** The cost of implementing a ZLD system can be high -- particularly for small-scale hydrogen production facilities -- and can be challenging to scale up or down. Additionally, the concentrated brine byproduct requires proper disposal or reuse to avoid potential adverse environmental impacts. Requires offsite disposal of crystalized salts as a waste stream.

4. **Offshore Concentrate Disposal** Used for seawater desalination systems to discharge membrane concentrate offshore. Extensive studies are typically needed to ensure that marine life is not impacted by high salinity. Seafloor discharge lines may extend miles offshore to avoid impact to near-shore ecosystems.

3 Water Availability Can Make or Break Your Project

Water availability relates to the physical, technical, regulatory and legal access (water right) to the water. Evaluation of water availability can be one of the most complex parts of siting a facility. While land leases/purchases, air permitting and purchase power agreements (PPAs) are all relatively straightforward, water rights and water regulatory statutes tend to have complex rules and regulations.

Surface water sources, groundwater sources, brackish water sources and even seawater all have different water rights and permitting processes. In general, there are different water right systems for both surface water and groundwater. In some jurisdictions surface water is predominantly "riparian right" based on reasonable use, whereas in other jurisdictions surface water is based on "prior appropriation" and beneficial use. There often are additional agreements or compacts between jurisdictions that address surface water and aquifers that cross jurisdiction boundaries.

It is important to note that there is not a single entity that oversees water rights. Each jurisdiction will require a separate evaluation of how water is acquired and used. Water issues are not limited to arid regions. For instance, in parts of the U.S. Great Lakes region, new water withdrawals require approval by the U.S. Supreme Court. [4]

In other jurisdictions, even stormwater can be subject to surface water rights as it is water that may have eventually reached a stream and therefore is owned by the senior surface water right holders. Additionally, making agreements or changes to water rights can be a lengthy and expensive endeavor. Establishing water agreements that include Native water rights or negotiation of minimum in-stream flow requirements with government agencies can cost millions of dollars in legal fees and take decades to resolve.

For a hydrogen infrastructure developer that will require feed water to produce hydrogen, it is often beneficial to identify an available water source first, then decide the location for the facility. One benefit in the development of industrial water supplies is that many water rights are conveyed with the purchase of the land. Therefore, a sustainable water supply may be included with the land acquisition or in close enough proximity that the water can be piped to the facility. Once a water supply is selected and secured, developing a sound sustainability and community relations plan is equally important.

4 Sustainable Water Management Practices are Key

As the use of hydrogen for energy applications gains traction, developers increasingly look to integrate sustainability into hydrogen production. With this mindset, developers construct facilities that operate with the community and their critical resources in mind.

Create a sustainability plan for all committed or expected water withdrawals to understand long-term sustainability goals. Evaluating historical water uses and supply, as well as applying quantitative tools such as numerical groundwater flow modeling, can help estimate long-term water supply availability. Modeling can be an iterative process using regional studies and site-specific field investigation data to improve the predictive sustainability estimates.

Some jurisdictions have sustainability built into their water rights allocation process. For instance, the U.S. state of Utah manages their water resources under the concept of “safe-yield,” in that the allowable water withdrawal from the system cannot exceed the amount of natural/artificial recharge. In concept, such an approach should ensure that the resource is available for perpetuity. Additionally in the U.S. State of Texas, Groundwater Conservation Districts (GCDs) have established Desired Future Conditions (DFCs) to manage aquifer sustainability. DFCs can be based on aquifer declines, and once the decline levels have been exceeded, the GCD can start to curtail groundwater withdrawals based on permitted allocation. The hydrogen producer relying on this groundwater needs to know the DFC limits and aquifer declines to understand if their water right will be curtailed.

Evaluate environmental and community impacts over the life of the project. In-stream flow depletions, ground subsidence, seawater intrusion and water quality degradation all can be traced back to overuse of the water resource. Given the expected life of hydrogen facilities (i.e., 20 to 50 years), it is important to include a monitoring plan to measure the impact of water withdrawals and develop contingency plans for mitigation or alternate sources of water.

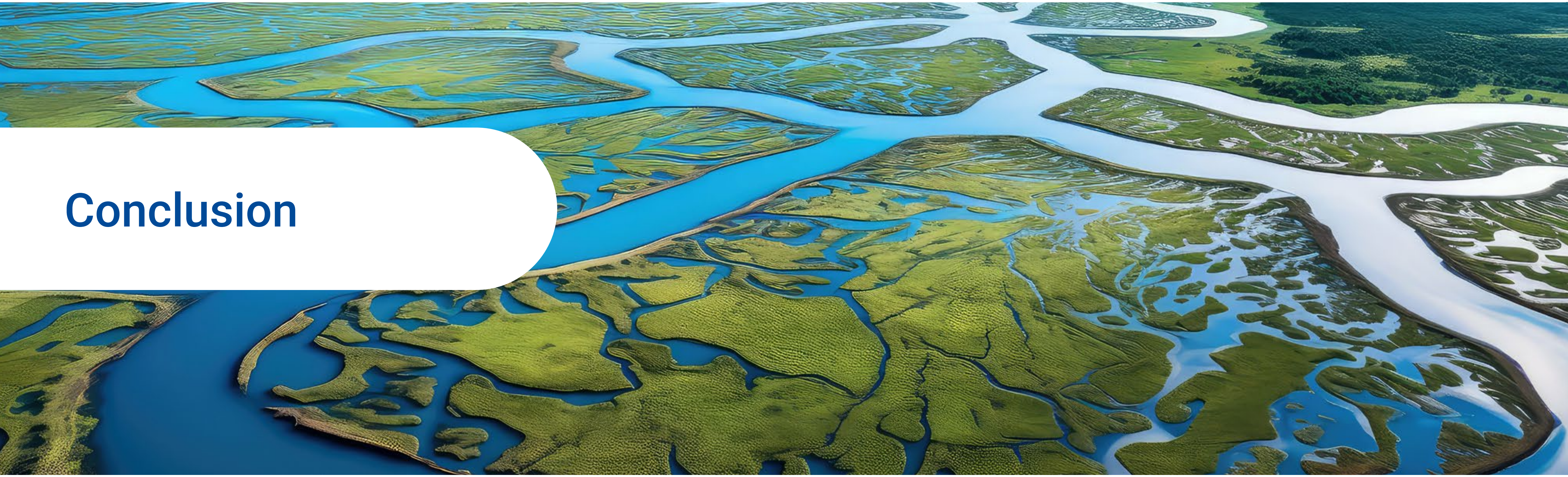
Engage with stakeholders to address concerns and build support. Due to the potential negative impacts, obtaining a new water supply can become contentious amongst the local community. A publicly favorable project will support communities, create employment opportunities, and contribute to the economic development of the region. Many projects have been delayed or cancelled by communities that were not included in the project development process. Don’t make this mistake. By involving the community, developers bring the project into alignment with the community’s values and priorities.

Developers should identify stakeholders that could be impacted by the project, particularly in communities that historically have experienced environmental injustices. Engage with the stakeholders to understand their concerns and priorities, and work to incorporate their feedback into the project planning process. Obtaining the services of a local public relations firm can be a way to leverage existing relationships and understanding the concerns of the local community. Through involvement, issues surface that enable the developer to mitigate concerns, making it easier to obtain permits and funding.

CASE STUDY

Low Carbon Energy Goes with the Flow

Along the U.S. Texas Gulf Coast, where fresh water is in short supply, Black & Veatch worked with a confidential client to provide water supply alternatives for several low-carbon energy projects, including a water demand evaluation for salt dome solution mining for hydrogen storage. Using a propriety water security workflow, our team of experts evaluated surface water, fresh groundwater, brackish groundwater, domestic reclaimed wastewater, sea water, conveyance, and water treatment options to provide the client with near-term and long-term water supply plans to meet the demands of the projects.



Conclusion

As the world seeks to decarbonize a variety of industries, hydrogen has the potential to become a large-scale, sustainable and clean energy resource. But water and energy are inextricably linked, and one cannot be devalued for the sake of the other. To achieve successful outcomes, Black & Veatch helps developers think about water comprehensively — from the supply and availability at the site through the technology processes at the facility, and to the community that partnered on decision-making from day one.

Black & Veatch understands the critical elements of a reliable, sustainable water supply for clean hydrogen production. Our proprietary water security workflow sequentially breaks down the water supply process to reach an end identification of the most appropriate water supply for an individual hydrogen facility.

Black & Veatch is an active industry advocate for the hydrogen economy, including membership in the Hydrogen Council, Fuel Cell Hydrogen & Energy Association, California Hydrogen Business Council, and the Ammonia Energy Association, as well as an executive member of the Center for Hydrogen Safety.

Ready to develop sustainable low-carbon hydrogen projects?

Contact us

Sources
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