WATER SAVING SOLUTIONS

Blair Garrett, BAC, USA, explores options to solve the challenges of water management in hydrogen production.

Consumption of our earth's resources is one of the most critical considerations for the future of hydrogen production. Water and energy are intrinsically tied together. To produce one is often at the expense of another, but both work in conjunction to power manufacturing processes around the world. As our understanding of technology develops, our means of production for the fuels that power our innovation continue to improve.

Both water and energy are required in the production of hydrogen, and its potential to power cars, rockets, and organic chemical production make it one of the most promising industries today. The big challenge with the production of hydrogen is the amount of water needed throughout the entirety of the process. From start to finish, water is consumed in high volumes, but there are key points along the way that can help reduce our water usage going forward.

Grey, blue or green hydrogen?

The three most popular types of hydrogen production all have different water consumption profiles. They all heavily rely on clean water, and the purification for clean process water uses additional water and energy. This purified water is obtained through reverse osmosis or distillation and accounts for a significant portion of the total water used throughout the process.

Because purification is a necessary first step for all forms of hydrogen, the opportunity to save water and energy will continue to develop as the technology and infrastructure for hydrogen evolves. Across purification, process water, and cooling, leading hydrogen production facilities will use 20 - 35 t of water to produce just 1 t of hydrogen.

Grey hydrogen

Grey hydrogen production will consume less total water than blue or green hydrogen using a process called steam methane reformation, but it does not utilise renewable resources and allows for the harmful release of approximately 10 t of CO_2/t of hydrogen produced. While it is efficient and cheaper to produce, the negative impacts include significant energy consumption, and increased carbon footprint contributing to climate change.

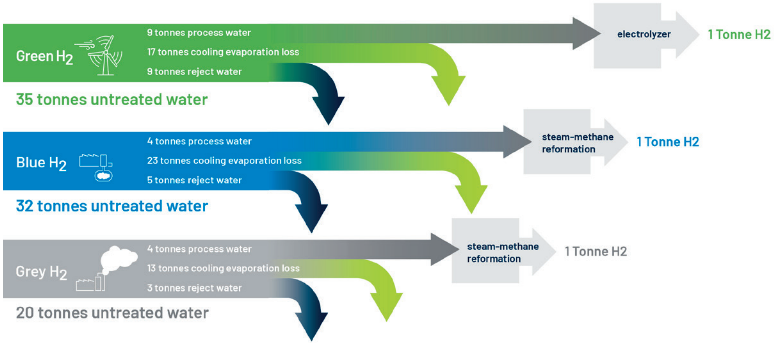

Figure 1. Tonnes of water per tonne of hydrogen (note: these water consumption profiles are based on evaporative cooling).

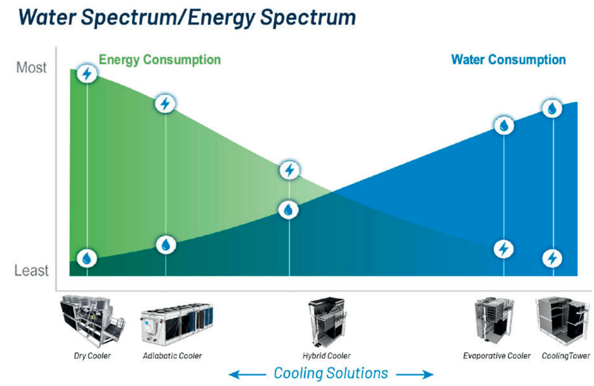

Figure 2. Water spectrum/energy spectrum.

In an increasingly eco-friendly environment, many hydrogen facilities are looking for cleaner solutions.

Blue hydrogen

Blue hydrogen is another viable process that takes advantage of carbon capture utilisation and storage (CCUS) to transport the CO_2 that would be released into the atmosphere in a typical grey hydrogen process. This steam methane reformation process combined with carbon capture systems, while environmentally beneficial, can add significant water and energy expenditure to the end product. The bulk of the water usage in blue hydrogen systems is lost due to evaporative cooling. With 22.6 t of water used to yield 1 t of hydrogen from evaporation alone, there are opportunities for water-stressed facilities to utilise less water-intensive cooling systems.

Green hydrogen

Green hydrogen on the other hand is a completely renewable process, yielding hydrogen without emitting CO_2. Typically powered by wind, solar, or hydroelectric energy, green hydrogen is breaking ground on a new method to produce truly renewable, emissions-free fuel.

The positives of green hydrogen are evident. It emits oxygen as opposed to CO_2, its energy source can be sustainably harvested, and electrolysers are getting more efficient by the day. The challenge with green hydrogen is in its substantial water demand.

Electrolysis requires a lot of water to operate, using twice the amount of process water that grey or blue hydrogen requires. It also needs an extremely high purity to prevent contaminants from fouling machinery, which adds to the total water consumed. Because of the level of purity needed for electrolysis, roughly double the amount of reject water is lost compared to grey or blue hydrogen production. With twice as much process water and twice as much purification reject water, green hydrogen facilities face massive utility requirements unless they take action to reduce water usage.

Methods of cooling and the reliance on water

Due to the high energy demands of hydrogen production, many facilities are being constructed close to renewable energy sources. However, these areas are often in water-stressed environments. To obtain the amount of water needed, the International Renewable Energy Agency (IRENA) has indicated that desalination of seawater is a viable option to procure the water necessary throughout the process. The initial investment may be higher for companies looking toward desalination as a means of getting water, but it is a sustainable alternative.

As of 2023, IRENA indicates that more than 12% of operational blue and green hydrogen plants are in water-stressed environments, but that number is set to climb dramatically in the coming years. More than a third of blue and green hydrogen facilities planned for construction will be in areas with significant water restrictions (per IRENA). This means that future hydrogen production needs to be increasingly focused on utilising water-saving solutions.

Evaporative cooling

The greatest opportunity to save water lies in the cooling process necessary to maintain systems. Evaporative cooling has been the gold standard for rejecting heat from manufacturing facilities for decades. It is extremely energy efficient and imperative to the process to prevent overheating and damage to machinery. Without proper cooling systems, facilities cannot operate optimally or safely, and the lifespan of equipment is significantly diminished.

The benefits that an evaporative cooling tower brings to temperature-sensitive manufacturing processes like hydrogen production cannot be overstated, and in an energy-conscious environment, cooling towers are the most efficient cooling technology available. However, it is not the only solution due to the growing problem of water scarcity. Just as methods of fuel production are becoming more innovative, so too are cooling units in the wake of energy and water conservation. Loss of water in evaporative cooling systems can account for roughly 15 t of water per t of green hydrogen produced. With nearly 44% of the total water required during the entire process being lost to evaporative cooling, alternatives are needed.

Dry cooling

Dry cooling is a hot topic among growing industries, such as data centres, and its application in hydrogen can be revolutionary going forward. A dry cooling unit does not use water to operate, and while air-cooled systems inherently use more energy, with modern wind and solar infrastructure, the additional energy load

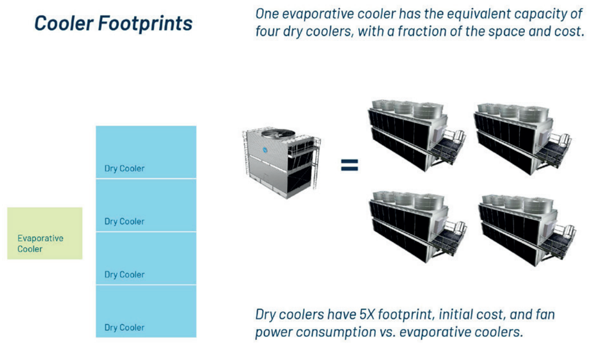

Figure 3. Cooler footprint.

Figure 4. Case study units.

may be a necessary trade-off for operators that are forced to minimise water usage.

Aside from significantly higher energy consumption, another drawback of dry coolers is that they may require up to five times the upfront cost and footprint as evaporative cooling systems. However, in areas with little available water, dry cooling may be the best option, especially in areas where the ambient temperature is low.

Hybrid cooling systems

In addition to evaporative and dry cooling options, there is another alternative. Recently, there has been an increase in hybrid cooling systems, which combine the benefits of evaporative cooling with the need to minimise water consumption. With an increasing global demand for water and a constant need to reduce energy consumption, this is a great option for green hydrogen production in water-conscious environments.

Hybrid cooling provides a balance, combining the energy-saving benefits of evaporative cooling with the water-saving benefits of dry cooling, depending on water availability on a day-by-day basis. On hot days, hybrid coolers can efficiently drop temperatures by spraying water to cool process fluids, and on cooler days, cool ambient air is pushed over the dry finned coils to accomplish the same task while greatly reducing the water usage. Hybrid cooling can be useful for water-sensitive applications, and with a small footprint compared to dry coolers, it is an ideal system for water-challenged hydrogen production.

Adiabatic cooling systems

Another way to optimise water and energy usage is with adiabatic cooling. Instead of combining dry and evaporative cooling as two separate components, adiabatic cooling relies on dry finned coils as the primary heat transfer mechanism but uses water evaporation to cool down the incoming ambient air before it hits the dry coil. This is done by wetted pads that are fitted in front of the finned coil. The transfer of cooled air onto the coil maximises heat transfer capacity, reduces footprint, and minimises fan power consumption. Adiabatic units fit well on the spectrum between evaporative cooling towers and dry coolers, giving users a way to find balance between water and energy depending on the given circumstances.

An adiabatic unit's ability to switch to evaporative cooling during peak hours of the day and back to dry cooling when ambient temperatures drop can save up to 75% of water compared to traditional evaporative cooling. This solution allows for flexibility in climates with fluctuations in temperature throughout the year. With a smaller footprint, lower installation cost, and lower fan power consumption per unit than traditional dry coolers, it is a viable choice for future hydrogen production facilities.

Due to the large water demands of evaporative cooling in green hydrogen applications, many operators immediately turn to dry coolers as the primary solution. While the dry coolers will relieve much of the water requirements, the footprint and energy needed to accommodate these coolers may also be too much of an investment and may take away from using that energy toward the end goal – producing hydrogen. Considering a hybrid or an adiabatic solution can fill the niche for sites around the world that may have different needs based on geographic location, infrastructure, or financial support.

Case study

An end user based in Inner Mongolia, China – an extremely arid region without significant infrastructure or water resources – was concerned about the water usage of a planned green hydrogen production facility. Constructed in the desert with little surrounding population, this green hydrogen facility has the potential to produce 20 000 tpy of green ammonia, one of the most important compounds for reducing reliance on fossil fuels.

To cool a set of alkaline electrolysers with a combined capacity of approximately 25 MW, evaporative cooling towers would consume 500 000 t of water, which is not available at this location. Thanks to the hybrid cooling solution that was chosen, the evaporation loss has been limited to only 200 000 tpy of water, without making significant compromises on power consumption and installed cost. With an extreme shortage of water, hybrid cooling units have enabled this plant to seamlessly continue operations while balancing water and energy usage.

Conclusion

In summary, there are a myriad of choices to save water in regions lacking access to either freshwater or seawater. Cooling is the only part of the process where water is not essential, although it is beneficial to maximise production efficiency. It is also important to consider that the required amount of water may not always be available, depending on the site location.

With both evaporative and dry cooling working together, hybrid and adiabatic units can save millions of gallons of water, dramatically improve efficiency compared to dry cooler systems, and offer remote facilities a practical solution to a growing problem.