WHITE PAPER

The most sustainable solution for water purification in green hydrogen production

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Introduction

According to United Nations, water scarcity is an increasing problem on every continent. There are many different reasons why, but growing populations and increasing economic activity, along with climate change, are considered the main drivers. This results a in higher demand for clean water.

In the same context, there is an urgent need for decarbonization and to keep the global temperature increase below 1.5 °C, as stated in the Paris Agreement, and to reach Net-Zero by 2050. To reach the Net Zero target – no net emissions of greenhouse gases – various solutions like, mass-electrification, increased energy efficiency, and clean molecule alternatives will be needed. That is where clean hydrogen come in to play a key role.

Clean hydrogen will be especially important within the so-called 'hard-to-abate' sectors. These are areas where it is difficult to electrify, primarily heavy industry and heavy transportation sectors, and where there is no other commercially viable solution today to abate the carbon emissions, like ammonia and steel production. In fact, clean hydrogen is expected to correspond to as much as 20% of the total energy demand by 2050.

One of the main ways to produce clean hydrogen is through water electrolysis. This is when electricity is used to split pure water molecules into hydrogen and oxygen using an electrolyser. Using renewable power, this process does not emit any carbon, hence the name 'green' or 'renewable' hydrogen.

But as water scarcity is already an issue, we need to consider how we can continue to scale up green hydrogen to support the energy transition without exacerbating the problem. Let´s look into some facts:

How much water is needed to produce hydrogen?

9 kg of ultra-pure water is needed to produce 1 kg of green hydrogen. Or, to put in another way, 55 m^3/day of clean water is needed for every 10 MW of electrolyser installed.

With that information readily available, it is possible to come to some conclusions. If, as the UN has predicted, the total amount of water needed in the public and private sectors goes up to 1.4 trillion m^3/year by 2040, green hydrogen will account for less than 0.001% of global water consumption. For example, in a scenario where 240 GW of electrolyser is installed, 0.5 billion m^3/year of pure water will be needed. So, the amount of water is not the problem. It is more a case of process efficiency, where purification can make clean hydrogen production as environmentally friendly as possible and preserve the existing clean water sources. It is also important to remember that green hydrogen plants will many times be built in places where clean water demand is high so to preserve the existing water resources is crucial to not increase the scarcity problem.

The total amount of water needed for green hydrogen is NOT the problem, but preserving existing clean water sources is. So, how can we make sure that water purification does not increase the water scarcity?

The answer is energy efficiency. As mentioned above, one of the key elements to achieve the Net-Zero scenario is energy efficiency and making the most out of every process step. Excess heat, generated in almost all industrial processes, is a major source of energy but very much neglected in most industries today.

Looking at the electrolysis process specifically, we know that 20-40% of the energy used becomes excess heat in the AWE and PEM electrolyser technologies. Removing this excess heat from the process is crucial for maximizing the process efficiency and extending the equipment lifetime. This excess heat can be seen in two different ways. The first, and most common way to look at it in the industry today, is as waste. In these cases, the heat is just cooled down by air or water and deposed. The other, more sustainable way to see it, is as an opportunity. By adding technologies to capture this excess heat and reuse it to other purposes, excess heat become an important heat source for process applications like, in the case below, pure water production.

Alfa Laval HyDuo™

The most sustainable solution for water purification in green hydrogen production

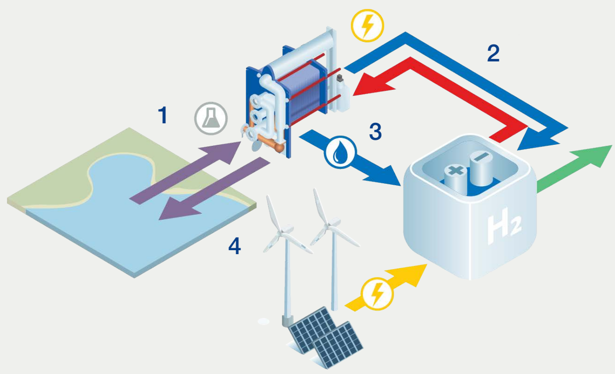
With Alfa Laval HyDuo™, two processes can be done at the same time: electrolyser cooling, ensuring the right temperature of the hydrogen production process and water purification, producing the right water quality for the electrolysis.

Available to adapt for different water capacity needs, the Alfa Laval HyDuo™ solution consists of two options:

- HyDuo MEP
  – capable of producing up to 2000 m³/day
- HyDuo AQUA
  – capable of producing up to 60 m³/day

Depending on electrolyser efficiency, around 50 m³/day of clean water is needed for each 10 MW electrolyser.

The principle of this product is that the heat coming from the electrolyser will be used to evaporate sea water, brackish water, or river water. The vapours formed in the evaporation process can then be cooled down in a condenser, and fed back into the electrolyser as clean water.



Utilizing the waste heat as an energy source in the water purification process comes with many advantages like, a lower dosage of chemicals, a smaller footprint, more reliability, and less electricity consumed. Let´s see how to achieve those advantage.

How excess heat can be used to produce pure water

First, feed water enters (1) the evaporation section of the plate pack, where the plates are warmed by the hot water that comes from the electrolyser (2). This causes the water to evaporate at around 30-65°C in a vacuum of 75-99%, which is maintained by the brine/air ejector. (The exact temperature and vacuum ranges depending on the Freshwater generator (FWG) model and electrolyser hot water temperature).

This means that only clean freshwater vapour reaches the condenser section of the plate pack, which is cooled by a flow of seawater. Here the vapour is condensed into fresh water (3), which is pumped out of a freshwater generator.

The vapour that was produced in the evaporation stage rises into the separator section, where any droplets of entrained seawater are removed. Gravity causes these droplets to fall back into the brine sump at the bottom of the freshwater generator (4).

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How water is used in green hydrogen production:

It is important to understand all the streams of water that are used in this process. Let´s have deep dive in each stream.

1. Water inlet

Inlet water that comes from sea, river, or brackish water sources has two purposes: First as a cooling agent in the condensation process and second as a feedstock for the evaporation section. The total amount of flow will depend on the water inlet temperature, as the lower the water temperature, the lower the flow will be.

Out of the total sea water flow, around 10% will be used as feed water and 20-30% will be evaporated in a process under vacuum.

2. Hot water loop

This is where the electrolyser cooling happens in a closed loop. The hot water coming from the electrolyser is cooled down and sent back to maintain the electrolyser temperature. This hot water can vary from 57°C to 85°C depending on the electrolyser type.

3. Ultra-pure water

The vapor formed in the evaporation section is then condensed and converted into pure water to feed the electrolyser. Distilled water out of the Freshwater generator (FWG) has a maximum conductivity of 2 µS/cm, so in certain cases where lower distilled conductivities are required (i.e. to comply with ASTM D1193-91 – Type I), a final polishing post treatment may be required.

4. Brine

The water that gets sent back to the ocean is called brine and is a combination of the water used for condensation and the water that has not been evaporated in the evaporation section. The condensation stream will have a higher temperature compared to the inlet sea water (around 10-12°C above or any other value needed due legislations), butthe same concentration. The stream coming from the evaporation part, on the other hand, will have a higher concentration (in general 1.3% above the inlet concentration) as well as a higher temperature.

The brine that is produced from these two streams increases in salinity and temperature as it goes back into the ocean, but only marginally. Salinity usually increases by 0.3%, while the temperature can increase by 10-12°C.

How easy is it to operate the system?

Chemicals: Another important point to address is the chemical dosage in the water purification process. Traditionally in desalination systems, a membrane-based solution is used where different types of chemicals are vital to be able to guarantee a smooth operation (e.g. biocides, activated carbon, anti-scaling). This is because membranes are very sensitive to water impurities variation.

When using a thermal solution, the need for chemicals dramatically decreases and is only needed for anti-scaling. This is because:

- The high-grade titanium plates are robust enough to work with sea water.
- The distillate quality does not change if the composition of the inlet sea water varies.
- Less sensitivity to sea water inlet variation;

But that is not all. In some cases, the anti-scaling chemicals can even be avoided if operations run using lower hot water temperature.

Variable production: Green hydrogen production uses renewable energy as a source, which is often an intermittent way to produce electricity. This means that the production of hydrogen and the water purification process will vary in correlation with supply intervals. Let’s use a windmill as an example:

If the wind is lower, less hydrogen will be produced and less water will be used in the process. Since the HyDuo solution is a 100% thermal driven process, the water produced will be proportional to the excess heat produced. Since excess heat is a biproduct of the hydrogen production, the water purification process will automatically match what is required.

Is the heat available sufficient? Does the lifecycle of the electrolyser have any influence?

The excess heat produced in the electrolyser process will vary over an estimated 10-year lifecycle. In general, it will produce 20% in the first year and 40% at the end of the 10th year. The HyDuo is always sized according to lowest heat availability so that it is always capable of producing the right water amount and quality. So, when excess heat is raised to 40%, extra heat exchangers can be easily added to the system. Some electrolysers might present different waste heat profiles depending on their lifetime and/or if they are working on a partial load.

Efficiency is not just about recovering excess heat

Electricity consumption

By using the heat as main driver for water purification, The HyDuo system offers two benefits in one. It can cool down the process and produce the right water quality with the same pump system. In general, 2-5 kWh/m^3 will be used for the full cooling and water purification system, which is up to ten times lower than other technologies with combined water purification and cooling capacities.

Footprint

The HyDuo minimizes the electrolyser footprint, making it the perfect solution for both on and offshore installations. This is possible since the plate technology utilizes less space than RO and also does not need a secondary cooling system.

Maintenance

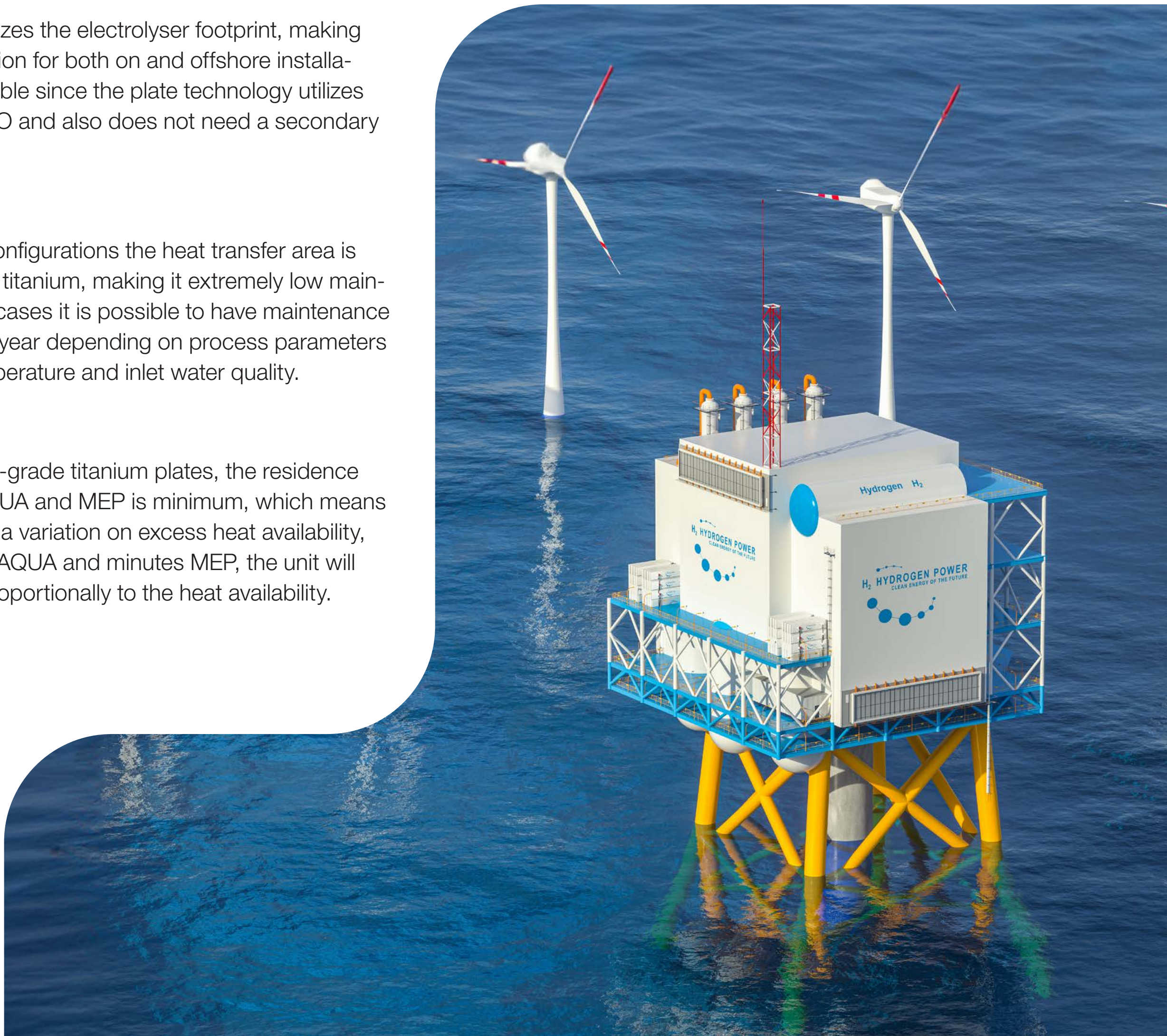
TIn both HyDuo configurations the heat transfer area is made from robust titanium, making it extremely low maintenance. In many cases it is possible to have maintenance once or twice per year depending on process parameters like hot water temperature and inlet water quality.

Response time

Due to use of high-grade titanium plates, the residence time inside the AQUA and MEP is minimum, which means that when there is a variation on excess heat availability, within seconds in AQUA and minutes MEP, the unit will start producing proportionally to the heat availability.

Energy efficiency and water scarcity are two critical challenges that require immediate attention. Addressing these issues is crucial for sustainable development and the well-being of our planet. Energy efficiency plays a vital role in mitigating water scarcity by reducing the energy-intensive processes involved in water treatment, distribution, and wastewater management. By implementing energy-efficient technologies and practices, such as efficient desalination techniques, and water recycling systems, we can significantly reduce the strain on both energy resources and water supplies.

Furthermore, promoting awareness and education about the importance of energy efficiency and water conservation can encourage individuals, businesses, and governments to adopt sustainable practices that conserve water, reduce energy consumption, and mitigate the impact of water scarcity. By taking decisive action now, we can pave the way for a more sustainable and resilient future, ensuring that both energy and water resources are utilized efficiently and equitably for generations to come.



This is Alfa Laval

Alfa Laval is active in the areas of Energy, Marine, and Food & Water, offering its expertise, products, and service to a wide range of industries in some 100 countries. The company is committed to optimizing processes, creating responsible growth, and driving progress – always going the extra mile to support customers in achieving their business goals and sustainability targets.

Alfa Laval's innovative technologies are dedicated to purifying, refining, and reusing materials, promoting more responsible use of natural resources. They contribute to improved energy efficiency and heat recovery, better water treatment, and reduced emissions. Thereby, Alfa Laval is not only accelerating success for its customers, but also for people and the planet. Making the world better, every day. It's all about *Advancing better*™.

How to contact Alfa Laval

Contact details for all countries are continually updated on our web site. Please visit www.alfalaval.com to access the information.