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Hydrogen, Water and the Energy Transition: a case study by Cannon Artes

The importance of optimized water treatment plants and water reuse for green hydrogen production

This is a decisive moment in the effort to tackle the climate crisis, dubbed by many the greatest challenge of our time: reaching Net Zero carbon emissions and limiting the rise in global temperature to 1.5°C.

The Energy sector accounts for more than 70% of the world's greenhouse gas emissions, around 34 billion tons of CO2 equivalent per year: to visualize what this astounding number means, imagine that it is the weight of a solid steel cube with a length of 15 football pitches.

Reaching Net Zero will require nothing short of a total transformation of the energy system that underpins our economies: a paradigm shift, the so-called Energy Transition.

Although fossil fuels will continue to play an important role in our energy mix in most of the Net Zero scenarios, the urgency towards identifying, researching, and developing alternative renewable sources is unprecedented.

The goal is the research and the development at scale of clean, renewable energy sources that allow the world to gradually phase out fossil fuels while guaranteeing sustainable and inclusive energy stability.

Some of the tools needed in the path to Net Zero for the energy sector are already well established and developed, like wind, solar, and hydropower. Others are still unproven and need further development or significant incentives to unlock their huge potential, like Carbon Capture, Utilization and Storage (CCUS), Direct Air Capture (DAC), and others.

Among this second group, hydrogen represents a very promising solution, which has the potential to help decarbonize several energy-intensive sectors, such as steel and cement, aviation, and shipping. As an energy vector, hydrogen is not found in its molecular form in nature and needs energy to be produced; it can have different labels based on the energy source employed and its carbon intensity, as reported in **Figure 1**:

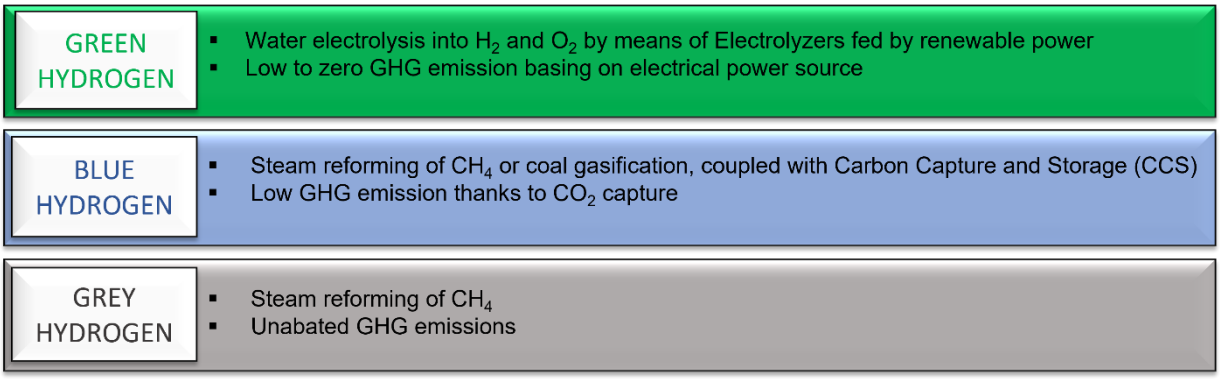

Figure 1. Classification of hydrogen types.

Green hydrogen, in particular, could represent a valid substitute for fossil fuels: it is carbon neutral, non-toxic, and has a very high energy density.

Green hydrogen is produced by electrolysis, an electrochemical process that splits water into hydrogen and oxygen according to the following reaction:

$$2H_2O \rightarrow 2H_2 + O_2$$

The oxidation-reduction reaction occurs when electricity is in the presence of ions. Two electrodes are immersed in water and connected to an electrical energy source. The passage of the current enables the mobility of the ions in the water towards the electrodes with an opposite charge, thus allowing the water to be split into hydrogen and oxygen, as shown in **Figure 2**:

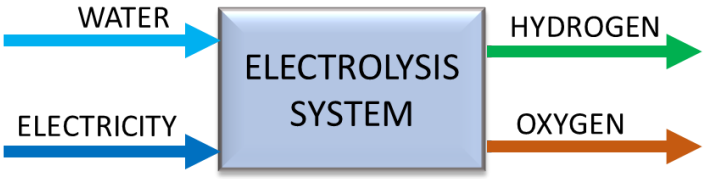

Figure 2. Schematic representation of hydrogen production by electrolysis.

The most obvious disadvantage related to green hydrogen production is the high energy consumption of the process that, along with product yield, still needs significant improvement and R&D investment to make green hydrogen a cost-effective solution.

A less obvious problem is the need for a substantial amount of ultrapure water as feedstock for the process. The actual inlet water quality depends on the Electrolyzer technology, but **in any case, roughly 9 m^3 of pure water is required for each ton of hydrogen**.

This amount might not seem to be much, but according to a Rystad Energy study, almost 85% of the planned green hydrogen projects will be built in water-stressed regions like Spain, Chile, and Australia, amounting to roughly 520 million cubic meters of purified water per year.

A lack of access to purified water could spell the death of a potential green hydrogen project. Thus, it is necessary to keep a focused eye on optimizing the design of the Water Treatment portion of the project. ***With decades of experience in industrial water treatment for the energy sector, Cannon Artes' solutions can maximize the efficiency of water treatment plants and minimize or reuse the effluents, contributing to the successful development of these projects***.

Cannon Artes has been lending its expertise in process engineering and system integration to co-create tailor-made solutions for low or zero carbon emitting energy projects with the leading players in the field.

Reusing Produced Water as Feedstock for Green Hydrogen

In one such collaboration, **Cannon Artes worked with *io consulting***, a leading development consultancy and project architect focusing on solutions for the Energy Transition, created as a JV between McDermott and Baker Hughes. The project focused on a **feasibility study of a green hydrogen project in the Middle East**. It faced, among others, one significant technical challenge: its location in a Middle Eastern desert, far from the sea, meant water scarcity quickly became a critical issue.

The scope of the study, summarized in **Figure 3**, was a 2.5 MW Electrolyzer designed to produce 1 ton of hydrogen per day, and its ancillaries.

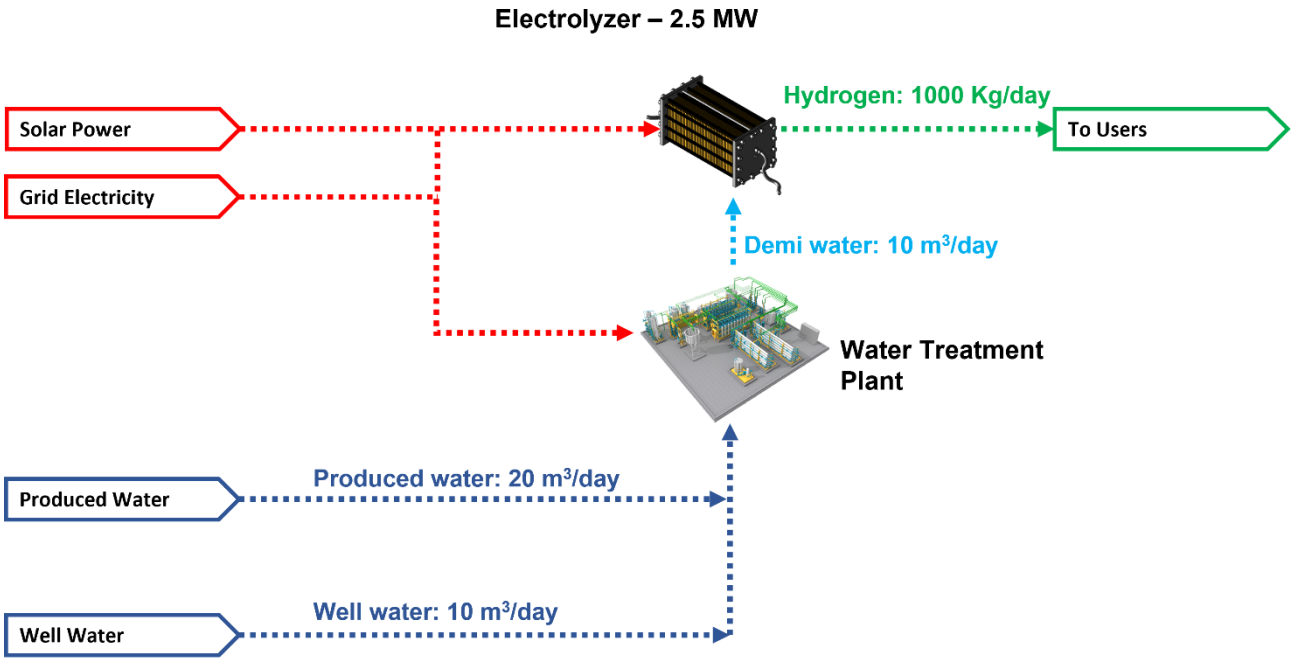

Figure 3. Scheme of the green hydrogen project in the Middle East.

One of the pillars of this scheme was the availability of 10 m^3/day of ultrapure demineralized water. While this is not a huge water demand, every drop counts in a desert environment. The only available source of clean water was a limited amount of high-salinity well water that, alone and at the net of processing losses, could not satisfy the demand.

To meet the site's needs, a second, unusual water source was identified in the produced water effluent from a nearby oilfield. Produced water is the formation water that gets extracted together with crude oil and represents one of the major waste streams in oilfields by volume. Additionally, it needs highly specialized expertise and technologies for its disposal or reuse due to its high salinity and presence of large quantities of hydrocarbons, fine suspended solids, heavy metals, and other pollutants.

Bridging the gap between the inlet streams composition and the required quality for the Electrolyzer feed was not an easy task, as noted in the water analysis in **Table 1**:

	Unit	Produced Water Inlet	Well water Inlet	Demi water ASTM D1193-91 - Type I
Flowrate	**m3/day**	20.0	10.0	10.0
Conductivity	**µS/cm**	132,100	39,500	< 0.056
Total Dissolved Solids	**mg/l**	102,000	26,500	< 5 ppb
Chloride	**mg/l**	63,100	15,500	< 1 ppb
Sodium	**mg/l**	30,900	6,790	< 1 ppb
Total Suspended Solids	**mg/l**	180	25	Nihil

Table 1. Summary of inlet and outlet water analysis

Leveraging an extensive track record in produced water treatment and effluent reuse on one side, and ion removal up to the part per billion level on the other, Cannon Artes designed a customized solution for the water problem. Once the technical side of the equation was solved, detailed CAPEX and OPEX budgets were defined as input for io consulting's master study.

The resulting water treatment plant's process, depicted in **Figure 4**, can be divided into three sections: Pre-treatment, Ion Removal, and Final Polishing.

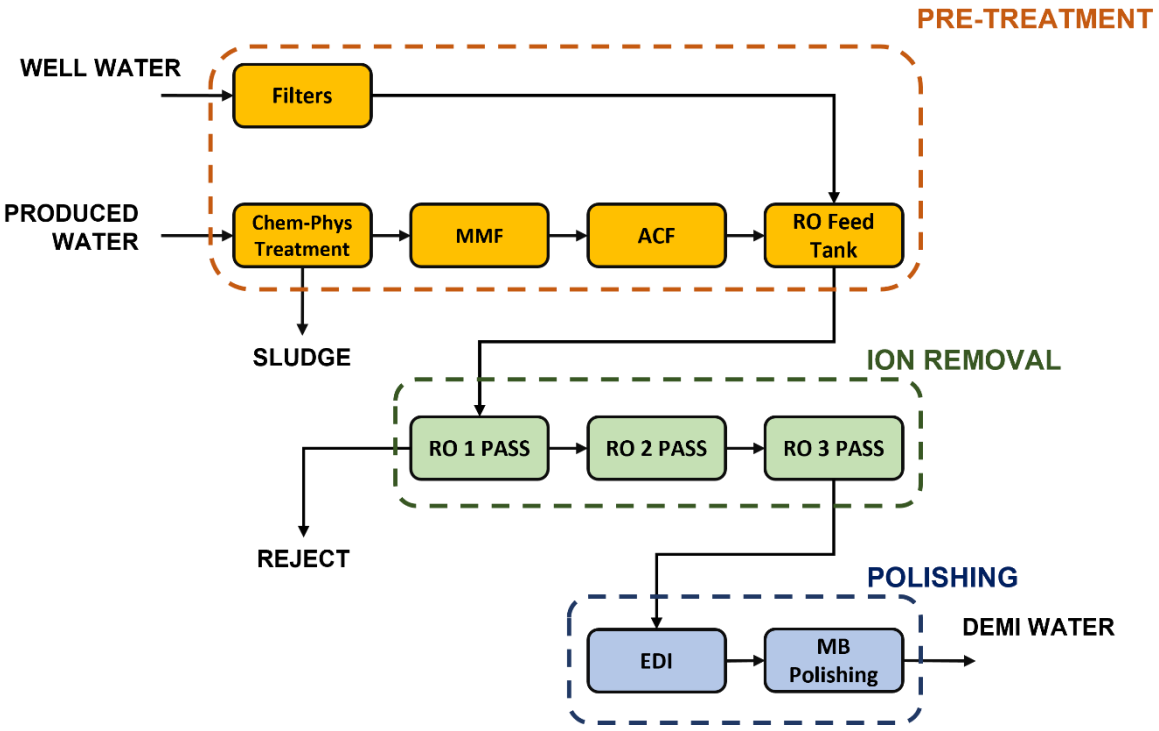

Figure 4. Scheme of the plant's process for water treatment used for hydrogen production.

The **Pre-treatment section** is functional for achieving, for each water source, a suitable quality for the downstream treatment. The process is straightforward for the well water stream, while it is extremely complex for the produced water stream due to its nature. After a deoiling and chemical-physical treatment for heavy metal and hardness abatement, the produced water is sent to fine filtration and an adsorption step to remove the remaining hydrocarbon. Afterward, it is mixed with filtered well water in the right ratio to allow the downstream system to operate.

The **Ion Removal section** is based on membrane technology, specifically on three passes of Reverse Osmosis (RO). RO membranes are semi-permeable, meaning that water subject to high pressure can pass through the membrane while salts and dissolved ions are blocked with a high retention efficiency. **The first pass of RO is the critical step in this section and needs special membranes capable of operating at more than 100 bar of pressure**, meaning 40% to 50% higher than the average seawater desalination. Integrating this type of water treatment plant requires multifaceted expertise, and process design is not the only, nor the major, complexity. For example, high-grade materials able to withstand both severe corrosion and the process conditions are needed in the system.

After the three RO passes, water conductivity is below 5 - 10 µS/cm, down from more than 100,000 µS/cm at the inlet. Still, it is orders of magnitude away from the target water quality.

For this reason, a Final Polishing section is needed before feeding the Electrolyzer. To reach the very strict requirements at the outlet and reduce the residual dissolved ions to the minimum possible level,

a sequence of Electro Deionization (EDI) and Mixed Bed with ion-exchanging resins is considered. In line with ASTM D1193-91 - Type I quality, the demineralized water at the package outlet can then be sent to the Electrolyzer as a feedstock for green hydrogen production.

Conclusions

An open-minded approach to problem-solving paired with deep expertise and vast experience in industrial water treatment allowed Cannon Artes to develop a customized solution to the study's problem. This meant removing a roadblock for this green hydrogen project and, possibly, the efforts toward the Energy Transition in the area.

Water is just one of the challenges that must be faced to develop green hydrogen at scale, but it is not necessarily the most important. At the present stage of maturity, financial aspects and government incentives play a much more crucial role. **However, it is safe to say that in this case, as in many others, tailor-made water treatment solutions can be enablers to reaching Net Zero**.

Cannon Artes strives to be a partner and an enabler in this process. As a major player in the water business, we are aware of the role and responsibilities that water treatment companies will have in the push toward Energy Transition and in the wider effort to build a sustainable world by closing the water cycle.