LARGE SCALE GREEN HYDROGEN PRODUCTION

Water as a driver for sustainable regional development

White Paper

A case study on how water used for hydrogen production can become a sustainable element in a Hydrogen Valley.

Leeuwarden, January 2023 - The energy transition has begun. The world is switching from fossil fuels to green energy sources, such as green hydrogen. African countries lend themselves well to the production of green hydrogen due to favorable geographical conditions, mainly lots of wind and hours of sunshine. At the same time, in these regions, fresh water is not abundant; whereas large amounts of water are needed for the production of hydrogen.
CEW and Impact Hydrogen are joining forces to ensure that water can be used in a sustainable way during the production of green hydrogen, but also in such a way that the use of water can function as a circular element within a Hydrogen Valley. In this way, hydrogen contributes to more than energy and becomes a real Sustainable Hydrogen Valley. This case study will explain how.

Green hydrogen is expected to play an important role in the world's energy transition from fossil fuel to a sustainable renewable energy supply. Organising Hydrogen Valleys and the entire hydrogen chain, which consists of: generation, production, storage, transport, and use in one geographical area, will make a key contribution in abandoning fossil fuels and moving towards a CO_2 neutral world. The reason for this is that production and off-take of hydrogen are organised at the same time and that offers possibilities to accelerate the energy transition.

Hydrogen Valleys can be a vehicle for more sustainability. Namely, the hydrogen value chain offers the possibility of integrating circular systems into it. One of these systems is a water cycle management system.

Green hydrogen is produced through the process of electrolysis of water using green electricity from wind or solar, and this is a highly water intensive process. Production costs of Green hydrogen are subject to the costs of power. It is expected that in the future world-market, the price of hydrogen will be around $ 1,800/ton H_2. In order for this to be feasible, the costs of (green) electricity should be as low as approximately $ 25.00/ MWh. This is the reason why large scale production of hydrogen will be placed on locations where green power can be produced at the lowest costs. These are areas with above average wind and/or solar conditions and abundant space available for green power generation.
Additionally, clean water availability also has to be taken into account, since electrolysis requires large quantities of fresh water.

On the African continent, many regions are well suited for the H_2 production process as they do meet the requirement of sufficient wind/solar and space. However, secured water supply is not to be taken for granted. Often, there are already fresh water shortages which increase, due to the effects of climate change. Moreover, the basic requirements for clean water and sanitation for local populations are often not met. If there is competition for water between human consumption and food production, versus energy production, this is not sustainable.

How can the world's energy transition based on green hydrogen contribute to regional development and contribute to the Sustainable Development Goals? What should be a minimum contribution as benefit for regional societies? When this process is organized in the energy-water-food nexus, regional development can be sustained.

In many arid regions, fresh water systems are under pressure. If a local community can benefit from the opportunities of green hydrogen production where green hydrogen production benefits from the local circumstances of power generation and space, an exchange is possible.
This white paper is looking at a virtual case study of a 1 GW green hydrogen plant near a community of 50.000 inhabitants with a lack of fresh water supply and poor access to clean water & sanitation. Seawater or saline groundwater, on the other hand, is available.

State of the art electrolysers require ultra-pure water. This is a very clean quality of fresh water which needs to be produced industrially. For every kg of hydrogen, 9 kg of ultra-pure water is required. In areas that experience shortage of fresh water supply, desalination of sea-, or groundwater is technically and economically feasible. As long as sufficient water is available, the costs of water for green hydrogen production will be around $ 10-20 /ton hydrogen, and this is less than 1% of the production costs of hydrogen. For 1 GW electrolysis (85% full load hours), typically 1,500,000 m3/y of ultra-pure water is required, and this can be produced out of 3,300,000 m3/y of seawater. Such a plant will produce approximately 155.000 ton hydrogen annually.

Green hydrogen is relatively sustainable compared to fossil fuels since no carbon dioxide is produced and both green electricity and water are considered renewable. However, how sustainable is a process if only 11% of the raw material required is transferred into the product? With electrolysis, eight times as much oxygen as hydrogen is produced and around 30% of the green electricity is transferred to heat.

A community of 50,000 inhabitants with small and medium businesses and public services requires about 2,200,000 m3/y of potable water and will produce around 1,750,000 m3/y of waste water. Total costs of clean water & sanitation will be around 7M $ /y. However, in many cases the community is not yet that well developed and inhabitants and businesses cannot afford this amount of money. When there is no revenue model for clean water & sanitation, basically, nothing will happen.

Figure 1 (next page) shows the base-case with a standalone green hydrogen plant without technical and financial cross overs to regional society.

As shown in figure 1, apart from the requirement of green power, sea water and production of green hydrogen, oxygen and heat are also produced. If national and regional authorities include a water paragraph in the concession for a private energy corporation for harvesting wind/solar and mining of water, the demand for clean water & sanitation can be tackled.
From the perspective of the energy-water-food nexus, several cross overs can be distinguished.

- The presence of a fresh water industry (desalination) can contribute to an affordable clean water supply of the local community.
- If a community has access to affordable clean water, a stable waste water flow is produced. Waste water contains valuable components for e.g. agriculture. With anaerobic treatment, organics can be transferred to biogas and macro-, micro nutrients and trace elements can be captured into a hygienised digestate which is a broad-spectrum

fertilizer for agricultural use.
- Treatment of wastewater requires heat for capturing the valuable components and considerable amounts of oxygen, e.g. aeration steps, ammonia removal etc. Both heat and oxygen are byproducts of green hydrogen production.
- Treated and clean waste water can be a source for ultra-pure water for hydrogen production.

The integration of water supply for hydrogen production and clean water & sanitation for the local community offers some interesting solutions.

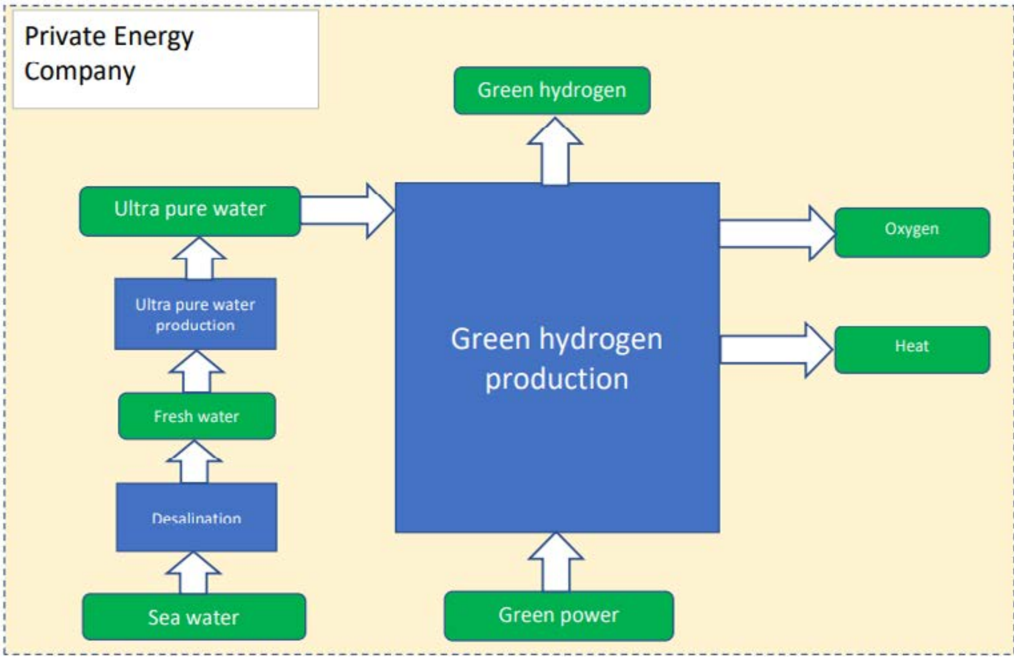

Figure 1. Base case stand alone

Figure 2 (below) shows the integration of hydrogen production and clean water & sanitation.

In this case study, the desalination plant owned by a private energy company produces fresh water that is supplied to a local water corporation at a reduced price. This makes drinking water available and affordable for people and small and medium businesses. Since clean water is available, waterborne diseases will occur less. With waste water collection and -treatment, biogas can be produced using the excess heat of the green hydrogen production plant. Biogas can be sold in common gas bottles for green cooking. Due to the thermal treatment, pathogens are killed and a hygienised digestate, a broad spectrum fertilizer is produced. By producing this type of fertilizer locally, money that would otherwise be spent on industrial fertilizers can be saved. Additionally, the depletion of spore elements in soils can be prevented. This is a valuable asset in the process of sustaining regional food production.

After digestion and dewatering, the fluid is treated aerobically. In general, this is a very energy intensive process. By blowing large amounts of compressed air through the fluid, oxygen is added for treating waste water. However, with a green hydrogen plant as neighbor, plenty of pure oxygen is available which considerably reduces the costs of wastewater treatment. Finally, the effluent produced is sold to the private energy company. By collection and treatment of wastewater, the sanitation problems with associated

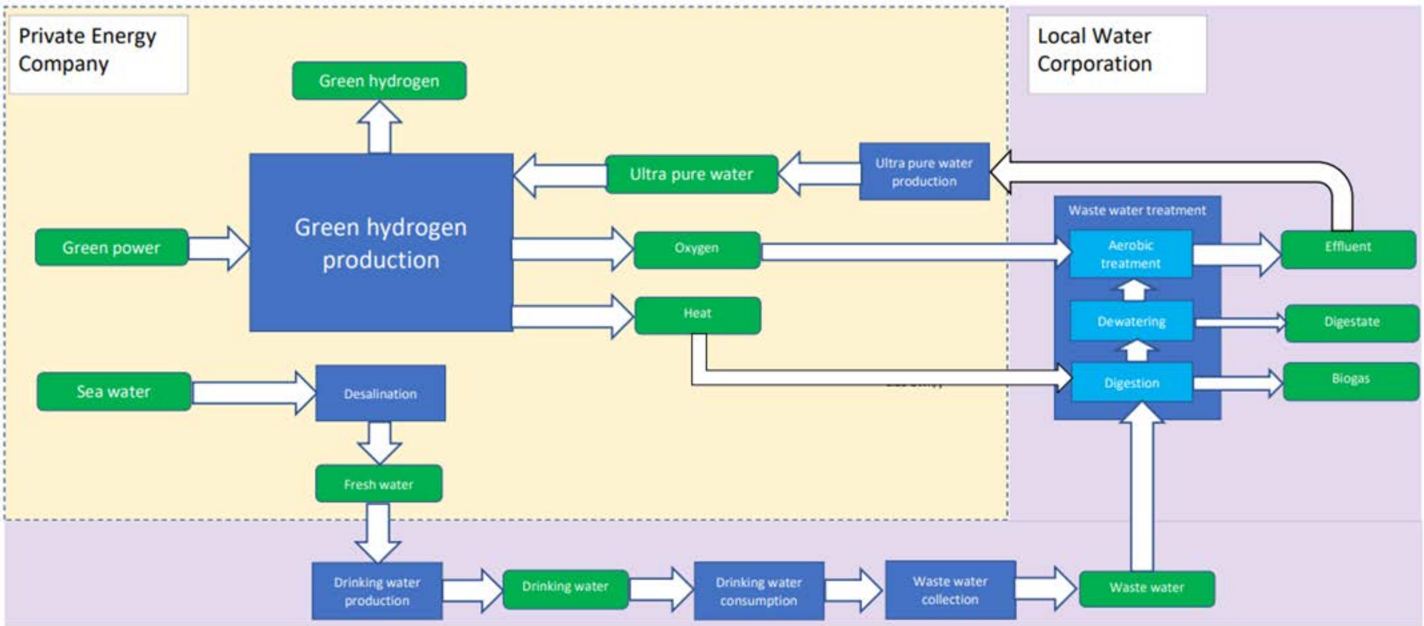

Figure 2: integration energy-water-food nexus

public health issues can be solved.
From a revenue perspective, the private energy company will serve society by means of providing it with affordable clean water, heat & oxygen and purchasing the feedstock for ultra-pure water production. In the stand alone situation, the costs of desalination and ultra-pure water production are calculated at $ 3,100,000/year ($ 20.00/ton hydrogen).
In the integrated situation, the total water related costs for the private energy company increases to $ 5,500,000/year, an additional $ 2,400,000/y ($ 15.50/ton hydrogen). The costs of clean water & sanitation for local society will be reduced from $ 7,000,000 /y to $ 1,300,000/y, which includes affordable biogas and a premium fertilizers for improving sustainable local food production and clean sanitation. This means a bottom-line benefit of €5,700,000 - €2,400,000 = €3,300,000.

It is important that such sustainable and circular water management is already taken into account when designing a hydrogen valley for a region. It is called: Impact by design. So that when the Hydrogen Valley is built, such water cycle management systems are a normal part of a hydrogen valley and people can really benefit from the production of green hydrogen, in different kind of ways.

Is the international society prepared to pay a small premium of less than 1% on sustainable green hydrogen which highly contributes to sustainable regional development in areas where Hydrogen Valleys are being build?

About the authors:

cew centre of expertise water technology

The Centre of Expertise Water Technology (CEW) conducts applied research for forward-thinking companies looking to take the next step towards a sustainable and circular economy. Every year, CEW deploys more than 300 students to bring fresh ideas, innovation and insight to their research projects. These students carry out the research, complemented by the knowledge and experience of CEW researchers and applied research professors. With CEW's support, technologies are developed and demonstrated from lab to launch. By conducting applied research, CEW accelerates innovation whilst training the future generation of water technology professionals.

IMPACT. HYDROGEN

Impact Hydrogen is a Dutch project development company that organises Sustainable Hydrogen Valleys that contribute to growth and prosperity in regions. Impact Hydrogen is based in the Northern Netherlands, home of the first Hydrogen Valley of the world. Impact Hydrogen operates in Europe, India and several African countries. Impact Hydrogen has a global partner network through which they mobilise technical expertise, knowledge and human capital. Together with trailblazing companies, they advise on how green hydrogen can contribute to sustainable development and they initiate Sustainable Hydrogen Valleys.

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