VATTENFALL

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Vattenfall's views on hydrogen

its contribution to move towards a fossil-free society & the EU legislative prerequisites

Executive summary

Vattenfall´s vision

Vattenfall actively supports the move towards a fossil-free society within one generation. We believe in a future where electrification is one of several efficient tools to realize emission reductions in our society and to meet the Paris Agreement objectives, f.i. through the electrification of transport and industry processes.

The conversion of electricity into another energy carrier can, in specific cases, extend the reach of electrification and, through this, reduce CO_2 emissions. Hydrogen is one of these energy carriers. Vattenfall believes hydrogen produced from fossil-free electricity will be important as;

- an **energy carrier** to reduce CO_2 emissions in certain sectors,
- a **fossil-free feedstock**, replacing fossil-based feedstock in industrial processes, and
- a provider of **fossil-free flexible electricity** to support a system with high volatility, facilitating the integration of high shares of renewable energy sources like wind and solar.

Market requirements

We identify three prerequisites for the take-off of fossil-free hydrogen:

- **Sufficient supply (availability) of affordable and fossil-free electricity,**
- **Demand** for fossil-free hydrogen to expand and mature the market, and
- **Infrastructure,** such as storage facilities and gas and electricity infrastructure.

EU regulatory requirements

Five regulatory components at EU level are paramount for the scale up of fossil-free hydrogen applications:

- **Carbon pricing**, via a well-functioning EU ETS for the power sector and industry sector under the ETS. In addition, a corresponding CO_2 price incentive is needed in the non-ETS sectors (transport, non-ETS heating and non-ETS industry) sectors for instance through changes of existing national levies and taxes.
- **Incentives** to use green hydrogen in the transport sector by counting its renewable content towards the renewable energy targets in European and national legislation. (Specifically referring to the Renewable Energy Directive post-2020).
- A **guarantees of origin** system to stimulate customers to pay a premium for CO_2 free products produced from green hydrogen.
- A legal framework in the upcoming **EU Gas Package** proposals to further facilitate sector coupling, to provide guidelines on the feeding in of hydrogen in the gas grid and to broaden the gas storage definition.
- In the allocation of **national and EU funding**, a focus on projects that position hydrogen as a partner to advance the energy transition.

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Introduction

As part of its corporate strategy, Vattenfall is working actively to reduce CO_2 in its generation portfolio, by investing in renewable energy and fuel switching. At Vattenfall, we believe in a future where electrification is one of several efficient tools to realize emission reductions in our society, for example through the electrification of transport and industry processes. The conversion of electricity into another energy carrier can, in specific cases, extend the reach of electrification and through this reduce greenhouse gas emissions. Hydrogen is one such energy carrier, for which Vattenfall envisages it has an important role to play.

Hydrogen can be produced in different ways. Two common practices to produce hydrogen use either natural gas or electricity. This paper elaborates on these two practices and distinguishes four additional categories:

- **Natural gas based hydrogen** production follows one of three chemical processes; auto thermal reforming (ATR), steam methane reforming (SMR), or partial oxidation (POX). Today in Europe, practices with natural gas are commonly applied in e.g. refineries[1]. These processes emit CO_2 into the atmosphere and the hydrogen produced in such a process is called **grey hydrogen**. To reduce CO_2 emissions, this process can be combined with carbon capture and storage, or -utilization (CCS/U). We then speak of **blue hydrogen**.
- **Electricity based hydrogen** is produced via a process called electrolysis, which uses electricity to split water into oxygen and hydrogen. Electricity can be used from e.g. the electricity grid or a single connected source. The levels of CO_2 emissions in the entire process depend on the energy mix, or source of the electricity. Hydrogen produced from electricity based on fossil fuel sources is also categorized as **grey hydrogen**. Whenever the electricity used for production of hydrogen excludes fossil fuels, we refer to **fossil-free** or **green hydrogen.**

Vattenfall's vision of the future role of hydrogen

Vattenfall sees an important role for fossil-free hydrogen in three applications addressing significant challenges of the energy transition:

- **Hydrogen as an energy carrier** to decarbonize processes that are difficult to electrify through the direct use of electricity. In this regard, one application is to use hydrogen as **transport fuel in fuel cells**[2] for heavy, long-distance modes of transport that are not cost-competitive to electrify via the direct use of electricity as energy carrier. The replacement of conventional transport fuels with fuel cell technology in train or heavy duty transport can provide a fossil-free solution for the heavy transport sector. For smaller passenger cars, the fuel cell technology will most likely not be competitive, in comparison to battery electric vehicles.[3]
- **Fossil-free hydrogen as feedstock**, replacing carbon-based feedstock in industrial processes. Industrial processes can be decarbonized by substituting carbon based feedstock, like f.i. coke in steel production, with fossil-free hydrogen. Such applications can revolutionize industry processes and can significantly reduce the carbon footprint of these sectors. Furthermore, certain industries like refineries today use grey hydrogen for their processes. In these cases the demand for hydrogen is already present and can be replaced by fossil-free hydrogen, decreasing the carbon footprint.

[1] Refineries represent the second largest consumer of hydrogen within the industry segment, with a market share of 30% (2.1 Mtons of hydrogen demand annually). (CertifHy (2015): Overview of the market segmentation for hydrogen across potential customer groups, based on key application areas)

[2] Fuel cells generate electricity from hydrogen through a chemical reaction

[3] Fuel cell vehicles require more than twice as much electricity compared to battery electric vehicles (Agora Verkehrswende , Agora Energywende und frontier Economics (2018): The Future cost of Electricity-Based synthetic fuels).

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- **Hydrogen as a provider of flexible fossil-free electricity** to support a system with high volatility. As the volumes of variable renewable energy increase, more flexibility is required. Hydrogen has large **storage** potential and is therefore suitable to serve as flexible fuel in the power system. Hydrogen can be used to manage volatility and flexibility in the power system, whilst offering security-of-supply, removing the need for fossil-based back-up power capacity. Storage of hydrogen, produced from renewable electricity, in times when the demand for electricity is lower than the supply, could offer a solution to bridge the gap between electricity supply and demand and can play a role in alleviating curtailment of electricity, when electricity grid capacity is congested. As batteries have a lower storage efficiency over time, they will come into play for short-term storage solutions and both technologies or applications have a role alongside each other.

Market requirements

We identify three prerequisites for the take-off of fossil-free hydrogen applications:

- A **sufficient supply (availability) of affordable and fossil-free electricity.** As the production of fossil-free hydrogen is an energy intensive process, this represents the most important driver for its price.
- **Demand** for fossil-free hydrogen, to expand and mature the market, triggering economics of scale and efficiency gains. However the current higher price for fossil-free hydrogen - compared to grey hydrogen and other fossil-based alternatives - is a main bottleneck for the uptake of the demand.
- **Infrastructure,** such as large-scale storage facilities and gas and electricity infrastructure. Infrastructure is necessary for the (large-scale) storage of hydrogen and its transportation to the customer. The existing gas infrastructure in Europe could be investigated for this purpose.

The transition path

Vattenfall's ambition to realize fossil-free living by the time children born today have children of their own, requires a transition path. This path will differ per country or market, depending on the current structure and resources. For the development of hydrogen, the route to going fossil-free will a.o. be determined by the presence of the above mentioned requirements.

As the transition path requires new technologies, adapted processes and the development of new markets, blue hydrogen, can, in some markets, be an option from a cost, environmental and acceptance perspective. In situations where fossil-free electricity is not yet sufficiently available or where it is still too expensive for the market to develop, blue hydrogen can serve as an intermediate tool that supports and realizes the transition to fossil-free hydrogen based on e.g. wind power, whilst - already during the transition - reducing greenhouse gas emissions, compared to current technologies. Therefore, the role blue hydrogen can play during the transition should be investigated and, if found in support of the transition, utilized.

However, independent of the transition road chosen, Vattenfall maintains its ambition to become fossil-free, within a generation and fossil fuels are not a long-term alternative for a company and society that needs to achieve climate neutrality. Fossil-free hydrogen solutions fit in this perspective.

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Regulatory requirements

To facilitate the above outlined transition, we identify five policy drivers and opportunities that should be secured by the EU and its Member States, to realize the scale up of hydrogen and its subsequent effect on CO_2 reductions:

- **Disincentivize carbon emissions.** A well-functioning EU ETS will drive the economic rationale in the electricity sector for the further build-out of renewable capacity and green hydrogen options. Strong decarbonization incentives should also be put in place in the non-EU ETS sectors. For the latter, measures should be considered for instance the change of existing national levies and taxes to trigger financial incentives to avoid CO_2 emissions.
- **Incentivize the use of green hydrogen** in the transport sector. The Renewable Energy Directive post-2020[4] (RED II) sets green hydrogen at equal footing with other renewable transport fuels by counting the renewable energy content for producing green hydrogen towards the renewable transport target (Art. 7 RED II). The Directive puts forward the right intentions and this requires corresponding next steps:
    - Next to using the national or EU renewables share as reference for electricity imported from the grid, it should also be possible to fully green the electricity with power purchase agreements (Art. 25 para. 3a RED II). The underlying European methodology to be developed by the European Commission should take this into account.
    - These elements as laid down in the RED II should be fully respected when implementing this Directive at Member State level to create a demand for green hydrogen in the transport sector.
- **Introduce a guarantees of origin system for green hydrogen.** As encouraged in the RED II, a system of certified green premiums, like the existing guarantees of origin scheme for renewable electricity, can differentiate grey from green hydrogen and will generate a willingness of customers to pay more for CO_2 free products. In turn, this will trigger demand for these products and it will increase supply chain transparency, required to distinguish between different production processes.
- **Establish a legal framework for hydrogen and sector coupling** in the so-called Gas Package launched in 2019 by the European Commission. In the legislative proposals the European Commission should: further facilitate sector coupling, provide guidelines on the feeding in of hydrogen in the gas grid, and broaden the definition of a storage facility. The current definition of storage facilities (Art. 2 para. 9 Directive 2009/73/EC) focusses on today's principal applications with natural gas. Its scope should thus be broadened to also allow for hydrogen applications as well.
- **Support technological advancements.** To position hydrogen technology as a partner to advance the energy transition, public support is required. This support should aim to alleviate risks of projects with this objective. In the allocation procedures of national and EU public funding we encourage authorities to focus on green and blue hydrogen projects – the latter as a means to transition to fossil-free hydrogen. Support can come from EU funding programs such as the EU ETS Innovation Fund[5].

Options for blue hydrogen to support the development of the market for green hydrogen. As described in the previous chapter, blue hydrogen can in certain conditions, offer the possibility to make tangible first steps towards the ultimate goal of a society free from fossil sources, during the transition phase. In such cases, these developments should also be supported by the regulatory framework.

[4] Analysis of the final compromise text with view to agreement of the Renewable Energy Directive post-2020 21/06/2018
[5] former NER-300 program

Annex Vattenfall & hydrogen projects in 2018

Vattenfall - committed to becoming fossil-free within one generation - is one of the largest producers of electricity and heat in Europe. We are active in all parts of the value chain: generation, distribution, trading and sales. In its core markets (the Nordics, Germany, the Netherlands and the United Kingdom) Vattenfall investigates collaborations through joint ventures, and partnerships to jointly develop decarbonized solutions with a focus on electrification. We have entered into mature partnerships in a wide range of sectors that explore the application of hydrogen:

- **Fossil-free steel - HYBRIT**
  The steel industry is one of the highest carbon dioxide emitting industries, accounting for up to 7% of global emissions. In Sweden it accounts for 10% of CO_2 emissions. To manufacture steel, the oxygen content of the iron ore must first be reduced. That is conventionally done with coke in a blast furnace where the oxygen is converted to carbon dioxide. HYBRIT, a joint-venture between Vattenfall, the steel manufacturing company SSAB, the mining company LKAB, explores the production of fossil-free steel, replacing today´s blast furnace process that uses coal and coke with a process based on hydrogen gas, to develop a process that emits water, rather than carbon dioxide. The project looks at fossil carbon reductions of 5.25 million tons per year.
- **Fossil-free hydrogen in fuel production - PREEM**
  Vattenfall and Sweden's largest fuel producer Preem cooperate in Sweden to investigate the use of hydrogen in the large-scale production of renewable fuel. More specifically, this process uses hydrogen to replace raw oil with residual products from the forest industry like lignin. Both parties share the same objective to significantly reduce emissions from road transport. The plant will contribute to reducing carbon dioxide emissions by 25,000 tons per year from the process, and emissions in the transport sector are expected to drop by about 230,000 tons per year when biofuels replace diesel and petrol. This is the equivalent of the emissions from 80,000 vehicles per year.
- **A power plant as super-battery - H2M**
  Vattenfall together with consortium partners Equinor and Gasunie explore the conversion of the flexible gas fired Magnum power station (Eemshaven / The Netherlands) from natural gas to hydrogen. The H2M project is focused on the production of blue hydrogen. The step to produce blue hydrogen, allows the consortium to build the hydrogen infrastructure now, whilst in parallel volumes of renewable electricity for green hydrogen become available. The Magnum power plant thus serves as a catalyst towards the ultimate objective; green hydrogen and a fossil-free society. The H2M project looks at a reduction of up to 2 million tons of CO_2 per year.
- **Green hydrogen for fuel cell trains - Wind2HyRail**
  About 50% of German railway tracks are operated by diesel trains and are not electrified. In an ongoing tender for emission free regional passenger trains in Northern Germany, a large scale application of green hydrogen in fuel cell trains is being investigated. The objective is to realize CO_2 free rail transport through the supply of 100% green hydrogen. Vattenfall - together with partners - develops the hydrogen supply chain in the region. This includes the sourcing of green electricity, the hydrogen production (electrolysis), and the logistics. European funding by the FCH JU has been granted to advance this development. In this project we look at a first application of 100% renewable hydrogen for mobility, deployed at scale and on its way to commercialize. Fuel cell trains supplied by green hydrogen, have great potential to replace today´s diesel trains in Europe and beyond.

Links to additional material:
Reducing industrial emissions - Vattenfall news
Hybrit – fossil-free steel
Swedish Energy Agency supports Preem and Vattenfall's planned hydrogen gas plant in Gothenburg - Vattenfall news
Vattenfall/Nuon takes another step towards fossil-free gas power production

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