North Africa an alternative location for European hydrogen production?

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Overview

Hydrogen is increasingly seen as an important energy carrier for the energy transition in Europe. The technical potential for the energy carrier is substantial, as it can replace natural gas in heating, be used as a fuel for transportation and serve as energy input for industry. Hydrogen is called a secondary energy carrier, which means that it is has to be produced. Currently, almost all hydrogen production is based on Steam Methane Reforming, which is a process where natural gas (CH_4) is used to produce hydrogen. Besides hydrogen, carbon dioxide is produced and currently emitted. Hydrogen produced in this way is called 'grey' hydrogen. When the CO_2 is captured and stored, instead of emitted, the hydrogen is called 'blue'. Blue hydrogen is increasingly seen as a low emission energy carrier.

A different technique of hydrogen production is electrolysis, which splits water molecules (H_2O) into both hydrogen and oxygen (O_2). When the electricity used is produced by a renewable source, the hydrogen is produced without emissions and labelled as 'green'. Moreover, it can offer flexibility, both in timing and location, for the electricity system, which will experience an increasing volatile production. However, renewable energy production comes with some caveats. Solar panels, for example, only have an average capacity factor of 10-15% in Europe[1], making the electricity relatively expensive. Offshore wind parks have the problem of bringing the energy onshore, which is often accompanied by large costs. Therefore, it makes sense to explore alternative locations for producing hydrogen, in particular in areas with a better economic potential for renewable energy. It is estimated that the production of solar electricity in North Africa is 1.5-2.5 times more efficient than in European countries and hence, production of green hydrogen in North Africa is less expensive than in Europe[2]. However, with hydrogen production in North Africa and a potential hydrogen market in Europe, there is the need for the transportation of the hydrogen.

Proven and used hydrogen transport methods include compressed gaseous and liquid hydrogen by trailers or tankers and gaseous hydrogen by pipelines (Ball & Wietschel, 2009). Transport by pipelines is seen as the most suitable option for large quantities over large distances, with relatively high capital and low operational costs. The downside of the high capital costs can be lowered by reusing, if they exists, natural gas grids, which is more and more considered (Quarton & Samsatli, 2018). For small quantities and large distances, liquefied hydrogen is often seen as most usable, where compressed gaseous trailers are superior for small quantities and distances.

A relatively new, but promising hydrogen transport method is liquid ammonia as a hydrogen carrier (Cha et al., 2018). Hydrogen together with nitrogen reacts to ammonia, the so-called Haber-Bosch process[3], which is liquid at room temperature. At delivery, the ammonia can be used in fuel cells or converted back to hydrogen (Yin et al., 2004). In this paper, we will analyse the costs and benefits of these different types of hydrogen transport to evaluate the option of hydrogen production in North Africa designated for the European market.

Methods

In order to assess the economic outlook for different options of producing and transporting hydrogen, we estimate the minimal required hydrogen price for a plant to be profitable (or: the break-even price). This means that the price should cover all the variable and fixed costs of delivering the hydrogen to the market during the lifetime of a plant. To make the estimation for the costs of hydrogen production, we make assumptions (based on literature) on the costs of inputs, plant lifespan, investment costs per capacity unit, output capacity and efficiency. We make break-even calculations for the production with different techniques, different sources of energy and different production locations.

We compare the option of hydrogen production in Europe[4] with the option of producing and importation of hydrogen from North Africa. We calculate the break-even price of blue hydrogen produced in the European Union, green hydrogen produced at offshore wind parks at the North Sea and green hydrogen produced with solar energy in North Africa to deliver to the European wholesale market.

When analysing the production costs of green hydrogen, we assume that the electrolyser is directly connected to the renewable source and all electricity is used for hydrogen production. Hence, we take the electricity price investors in renewable energy require to recoup their investments and operational costs based on recent tenders or information on costs for investors. Moreover, there is no need to buy green certificates, as the source of electricity is

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[1] European Commission (2017). *EMHIRES dataset Part II: Solar power generation*
[2] GlobalSolarAtlas
[3] Haber-Bosch process: $N_2 + 3 H_2 \rightarrow 2 NH_3$
[4] We assume the price of producing hydrogen in the Netherlands to be a good estimation of the production price for Europe.

clear. For offshore wind parks at the North Sea, we set the required electricity price at 45 euro/MWh, based on recent tenders of offshore wind parks.

For the transportation of hydrogen, we consider several options. The first is transportation of pressurized gaseous hydrogen through both new constructed and reused natural gas pipelines. In the latter case, there are no costs for the construction of the pipelines, but there are costs for new compressor stations. Other transportation methods considered are hydrogen in liquid form and hydrogen converted into ammonia, both by ship.

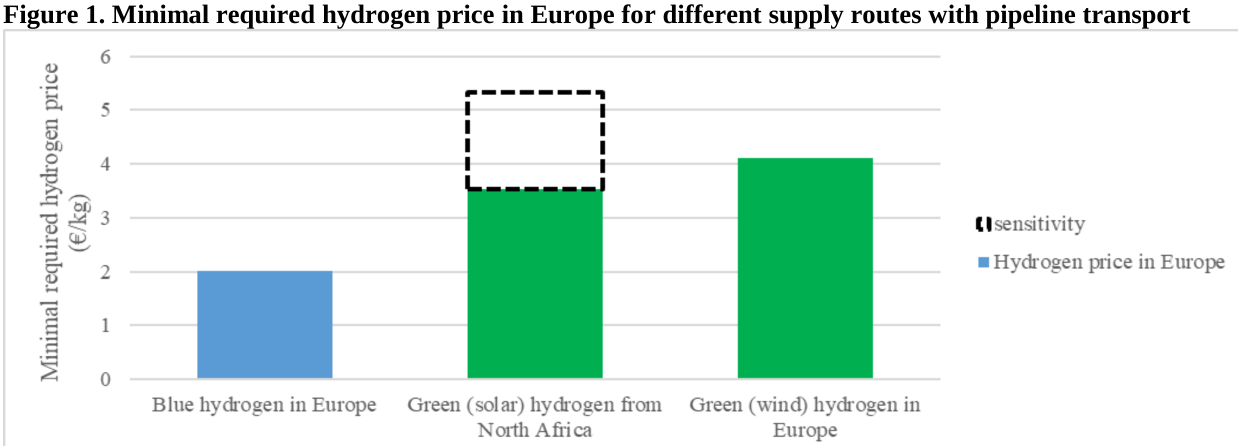
Results

Production of hydrogen by electrolysis, both in Europe and North Africa, is currently more expensive than the production of blue hydrogen, see Figure 1. Preliminary results show that green hydrogen production in Europe is less profitable compared to electrolysis in North Africa, where (solar) electricity is cheaper. Furthermore, the operation and maintenance (O&M) costs in North Africa are assumed to be lower, due to lower wages. In contrast, the capacity factor and hence, the efficiency of the electrolyser in North Africa is lower than in the Netherlands.

Transport costs for hydrogen from North Africa to the Netherlands by newly constructed pipelines is estimated to cost around 1.27 €/kg (Mulder et al., 2019). The possibility to use the existing natural gas grid in Europe could lower these costs. Transport in liquid form by tankers is found to be almost 9 times more expensive as pipeline transport and hence viewed as economically unfeasible, mainly due to the low temperature and large leakages.

The costs of ammonia as a hydrogen carrier depend on several inputs. The costs for the transportation of liquid ammonia is found to be lower than other hydrogen transport methods (Cha et al., 2018). However, the conversion of hydrogen into ammonia and possibly back to hydrogen in Europe bring additional costs. To properly compare the different hydrogen supply routes, the unit costs of these processes will be calculated.

Figure 1. Minimal required hydrogen price in Europe for different supply routes with pipeline transport



Conclusions

From the preliminary results on the different hydrogen supply routes we consider, it is clear that production of blue hydrogen in the EU has significantly lower break-even prices than green hydrogen. However, in case societies are averse of using natural gas, green hydrogen can be prioritized. Interestingly, the supply of green hydrogen from North Africa could be more feasible than green hydrogen production in the EU when the productive efficiency in this region is indeed 3 times as high as in Europe. This result, however, is influenced by assumptions on the efficiency and costs of the solar field and electrolyser. A proper sensitivity analysis as well as the estimation of other transportation methods will be conducted to draw precise conclusions.

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