THE GREEN HYDROGEN AS A FEEDSTOCK: A TECHNO-ECONOMIC ANALYSIS OF A PHOTOVOLTAIC POWERED ELECTROLYSIS PLANT

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Overview

It is a common opinion that the renewable sources play a primary role to reduce the greenhouse gas (GHG) emissions and that, according to the IEA, solar may become the largest source of low-carbon capacity by 2040 by which time the share of all renewables in total power generation reaches 40%, led by China and India. In the European Union, soon after 2030, renewables will account for 80% of new capacity and wind power becomes the leading source of electricity, due to strong growth both onshore and offshore (IEA, 2017).

A key issue to be faced is that electricity generation from renewables is heavily weather-dependent and this entails fluctuations causing instability of the power systems. As a consequence, systems for storing energy are becoming increasingly significant. Among the various solutions that are being evaluated, hydrogen is currently considered to be one of the key enabling technologies allowing future large scale and long term green storage of renewable power to be combined, for instance, with the well established pumped hydro storage.

At present, hydrogen is mainly produced from fossil fuels: about 96% of the world's hydrogen production (Banerjee et al., 2017). Steam methane reforming (SMR) is the most widely used route for producing hydrogen from natural gas. Other thermo-chemical conversion technologies allow hydrogen production through different pathways starting from coal, oil, biomass-derived fuels, biomass and wastes (Lymberopoulos, 2007). However all these approaches are not GHG-free. The Power-to-Gas concept, based on water electrolysis utilizing electricity derived from renewable energies (wind, solar, geothermal, hydro) is the most environmentally friendly approach. This attractive method for hydrogen generation, based on a mature technology, currently accounts for only 4% of the hydrogen production but its large expansion is expected in the next few years: a share of 22% is predicted for 2050 (Cornell, 2017).

Given its multiple uses, hydrogen is sold as a fuel, as a means to produce electricity through fuel cells and as a feedstock in several industrial processes. Just the feedstock could be in the short term the main market of RES hydrogen. The hydrogen feedstock market has a total estimated value of USD 115 billion and is expected to grow significantly in the coming years, reaching USD 155 billion by 2022 (IRENA, 2018). In 2015, total global hydrogen demand was estimated to be 8 Exajoules (EJ) (Hydrogen Council, 2017). The largest share of hydrogen demand is from the chemicals and refining sectors. Other industry sectors also use hydrogen, but their combined share of total global demand is small (IRENA, 2018). But a problem arises if the hydrogen will continue to be produced mainly from fossil sources, because this will contribute to increase emissions that are estimated in around 500 Mt of CO_2. For this reason, the international community purpose is decarbonisation of the hydrogen production through carbon capture, electrolysis or the increased use of by-product. Hydrogen produced from renewable electricity could replace other fossil fuels as feedstock. It could replace carbon (from natural gas or coal) as a reducing agent in the iron-making process, and it could be used together with captured CO_2 to replace fossil feedstock in the production of hydrocarbon-based chemicals such as methanol and derived products.

Therefore, the large industrial sectors, as refineries and chemicals, are expected to be key early markets for power-to-hydrogen. Al-Subaie et al. (2017) have claimed that the hydrogen can be consumed instantaneously by the oil refining and chemical industries without the necessity for increasing FCEV (Fuel Cells Electric Vehicle) market penetration.

Methods

The case study that has been developed in this work concerns the techno-economic-financial evaluation of a system to produce green hydrogen to be sold as a feedstock for industries.

The system includes a 200 kW photovoltaic plant and a 180 kW electrolyzer and is located in Messina, a Sicilian town in the South of Italy.

The analysis was conducted from the perspective of an entrepreneur or investor who wants to assess whether it is advisable to invest in a new industrial activity aimed at selling hydrogen from renewable sources.
Two possible scenarios were hypothesised in the study:

- the installation of electrolyzer alone, connected to an existing PV plant;
- the implementation of whole system, both PV plant and electrolyzer.

To perform the economic-financial analysis, we adopted the method proposed by Kuckshinrichs, Ketelaer and Koj (2017). Thus, starting from cash flow (CF) data we used different metrics such as levelized cost of hydrogen (LCH) to carry out cost assessment, net present value (NPV) to evaluate the investment attractiveness and variable cost (VC) for analysis of market flexibility.

Results

According to our analyses, taking into account the current development of technologies, we have found out that the capital, invested in the realization of a hydrogen production system from RES, can be recovered after approximately 12 years, providing hydrogen at a competitive price compared to that produced from SMR. This result can be obtained, however, if, in addition to selling hydrogen, it also sells oxygen, which is the other product obtained through electrolysis. For each kilogram of hydrogen produced, 8 kg of oxygen can be obtained. Therefore, the sale of both gases allows greater revenues that allow to cover the capital costs and operating and maintenance costs.

Conclusions

Based on the results obtained through our analysis and taking into account the forecasts made by important international organizations (IRENA and Hydrogen Council) and those present in the literature, the production of renewable hydrogen for the technical gas market is, in the short term, an achievable opportunity.

It can be foreseen that an higher RES-electricity share and electrolyser cost reduction will increase the spread and use of these systems offering higher revenue and new market opportunities. We espect that all these aspects will create the basic conditions for a distributed hydrogen production.

References

Al-Subaie, A., Elkamel, A., Mukherjee, U., Fowler, M., 2017. *Exploring the potential of Power-to-Gas concept to meet Ontario's industrial demand of hydrogen.* 5th IEEE International Conference on Smart Energy Grid Engineering, SEGE 2017, art. no. 8052821, 336-340.

Banerjee, S., Musa, M.N., Jaafar, A.B., 2017. *Economic assessment and prospect of hydrogen generated by OTEC as future fuel.* International Journal of Hydrogen Energy 42 (1), 26-37.

Cornell, A., 2017. *Hydrogen production by electrolysis*. 1st International Conference on Electrolysis Copenhagen, 12-15 June, 2017. Available at: https://energiforskmedia.blob.core.windows.net/media/23562/5-hydrogen-production-by-electrolysis-ann-cornell-kth.pdf

Hydrogen Council, 2017. *Hydrogen scaling up – A sustainable pathway for the global energy transition.* Report, November 2017. Available at: http://hydrogencouncil.com/wp-content/uploads/2017/11/Hydrogen-scaling-up-Hydrogen-Council.pdf.

IEA, 2017. *World Energy Outlook 2017.* Published by the International Energy Agency, Paris, France.

IRENA, 2018. *HYDROGEN FROM RENEWABLE POWER TECHNOLOGY OUTLOOK FOR THE ENERGY TRANSITION.* Published by International Renewable Energy Agency, September 2018.

Kuckshinrichs, W., Ketelaer, T., Koj, J.C., 2017. *Economic analysis of improved Alkaline Water Electrolysis.* Frontiers in Energy Research 5 (FEB), art. no. 1.

Lymberopoulos, N., 2007. *Hydrogen from renewables.* In: Sheffield, J.W. and Sheffield, Ç. (Eds.), *Assessment of hydrogen energy for sustainable development*. NATO Science for Peace and Security Series C: Environmental Security, Springer, Berlin, pp. 51-57.