***OXYGEN FROM ELECTROLYSIS FOR MEDICAL USE: AN ECONOMICALLY FEASIBLE ROUTE***

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## Overview

Today, worldwide hydrogen production (around 70 Mt/year, in 2018) is almost exclusively (96%) derived from fossil fuels, with water electrolysis accounting for a residual share (4%) [1]. But, the conventional processes used for hydrogen generation – mainly, steam methane reforming (SMR) – are responsible for about 5% of the global carbon dioxide emissions [2]. By contrast, water electrolysis powered by renewable energy sources (solar, wind, etc.) is a mature and environmentally friendly technology for large-scale hydrogen production, whose main bottleneck for a widespread diffusion is still related to economic concerns [3]. In fact, according to the literature [4, 5], the production cost of hydrogen from electrolysis is at least 5–6 €/kg, which is not competitive compared with hydrogen production by SMR (ca. 1.5–2.3 €/kg [6]).

In our previous investigations [7, 8], we performed some evaluations of a system based on alkaline water electrolysis (180 kW) coupled with a photovoltaic plant (200 kW). These studies allowed us to demonstrate the economic profitability of the system when the extra revenues generated from the selling of the co-produced oxygen (usually vented into the atmosphere) are considered. Recently [9], we completely reversed the usual concept, and considered a photovoltaic-powered electrolysis plant whose main purpose was to satisfy the oxygen requirements of a hypothetical enterprise, while the obtained hydrogen could be sold to external users to achieve additional revenues. The obtained results evidenced that the proposed plant was economically attractive if compared to the case when the same enterprise buys the compressed oxygen from local gas distributors/resellers. In particular, by assuming a hydrogen selling price of 10 €/kg (a reference price for hydrogen as a fuel, at the pump), the economical sustainability (recovery of the investment within 20 years) is achieved if the market price of oxygen is at least 3 €/kg, whatever the size of the electrolyser (in the range from 100 kW to 10 MW).

Nowadays, the energy-health nexus is a key theme whose importance and priority cannot be neglected or postponed anymore. The availability and quality of energy supply affect the quality of primary healthcare, and some studies [10] evidenced that sustainable decentralized renewable energy technologies could bridge the gap for access to healthcare in medical centres located in remote areas. In addition, due to the current COVID-19 pandemic, the demand for oxygen increased – e.g., in parts of Italy, oxygen consumption has tripled [11] – and this has exacerbated the shortage of medical oxygen in many developing countries [12].

Based on these considerations, in this work we consider an electrolysis plant devoted to gaseous oxygen generation for a typical medium-size hospital (200-250 beds capacity) and, assuming that the hydrogen produced from the plant is sold at 3 €/kg (a price competitive with hydrogen from fossil fuels), we perform some calculations to estimate what should be the (market) price of oxygen to achieve economic profitability within 15 years through the oxygen self-production from the proposed system.

## Methods

The core of the examined system consists of an alkaline electrolyser powered by a renewable energy plant (photovoltaic); besides, compressor and storage units are also included in the economic analysis. The plant is assumed to supply oxygen to a hypothetical hospital located in the South of Italy. On this basis, and considering an efficiency typical for an alkaline electrolyser (70%), we estimated that the size of the electrolyser should be in the order of 1 MW (coupled to a 1.25 MW PV plant). In fact, such size allows to produce about 160,000 Nm3/year of gaseous oxygen; an amount able to satisfy a 200–250 beds hospital [9, 13].

The method applied to verify the economic profitability of the plant is based on the calculation of the net present value (NPV), following the approach proposed by Kuckshinrichs et al. [14], and adopted in our previous works [7-9]. In particular, investment costs (CAPEX), operative and maintenance costs (OPEX), and taxes have been included in the economic evaluation. Positive cashflows are those associated with the selling of hydrogen and the avoided costs for non-purchased (self-produced) oxygen. Assuming a discounted payback period of 15 years, the corresponding oxygen price is determined, and the economic feasibility of the plant is then evaluated.

## Results

By considering the 1 MW electrolyser plant, and assuming a hydrogen selling price of 3 €/kg, the results derived from the economic evaluation indicate that an oxygen (market) price of about 3.3 €/kg warrants a null NPV after 15 years. This represents the so-called discounted payback period, i.e. the number of years to break-even the initial investment; the project is expected to generate a profit only after this period.

Since the surface area needed for a PV plant is typically 7–8 m2/kW, the above mentioned system (1.25 MW PV) requires a large area of about 1 hectare. Therefore, we also performed a calculation assuming an electrolyser of 500 kW coupled with a 625 kW PV plant, determining that in such a case the oxygen price to warrant a break-even after 15 years is 4.4 €/kg. This condition could be a feasible choice for smaller hospitals (< 150 beds [13]) having an oxygen consumption in the order of 80,000 Nm3/year or, in the case of larger ones could warrant a share (e.g., according to our estimations, about 30% of the oxygen needs for a 300 beds hospital) of their oxygen requirements.

## Conclusions

An economic analysis has been carried out to evaluate the attractiveness, for a medical centre that needs gaseous oxygen for healthcare, to produce it by a proprietary plant based on water electrolysis. The obtained results evidenced that the on-site production of this gas could be an interesting alternative compared to purchasing from the local gas resellers, if the market price of oxygen is higher than 3-4 €/kg. Since in literature market prices of gaseous oxygen up to 7 €/kg are reported [15], we can conclude that the use of medical oxygen from on-site electrolysis plant should be considered as an economically feasible route for hospitals and medical centres. For this purpose, even if it is based on a different technology (oxygen concentrators with molecular sieves), it is remarkable the case of Venaria Reale hospital (Piedmont), where a saving in the cost of oxygen in the order of 80% has been obtained through oxygen self-production [16].

In our case, the self-produced oxygen has a threefold advantage: (i) it is economically convenient; (ii) it is obtained by a carbon-free technology; (iii) the hospital is (partially or fully) independent from external gas suppliers.

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