Oxygen from electrolysis for medical use: an economically feasible route

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Summary

Acknowledgement

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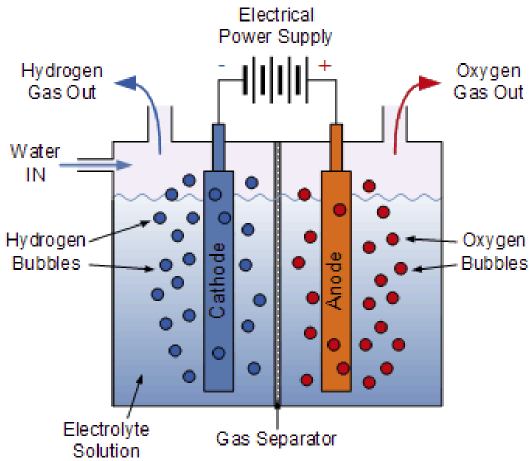
For more information: www.itae.cnr.it www.newcomersh2020.eu

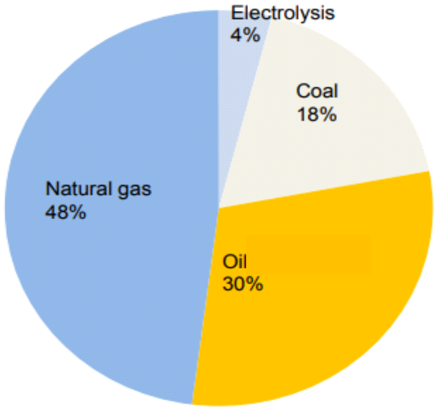
GREEN HYDROGEN PRODUCTION

Water electrolysis utilizing electricity derived from renewable sources (wind, solar, geothermal, hydro) is the most environmentally friendly approach for **hydrogen** production.

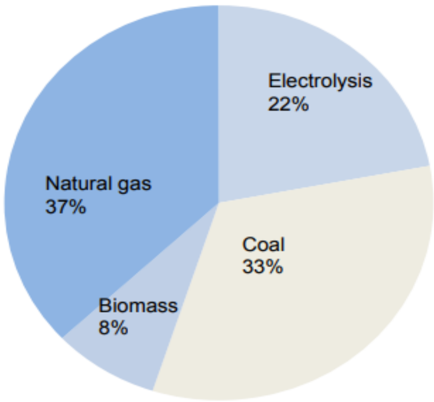


Current Worldwide H_2 Production: 50 Mt/year.

TODAY



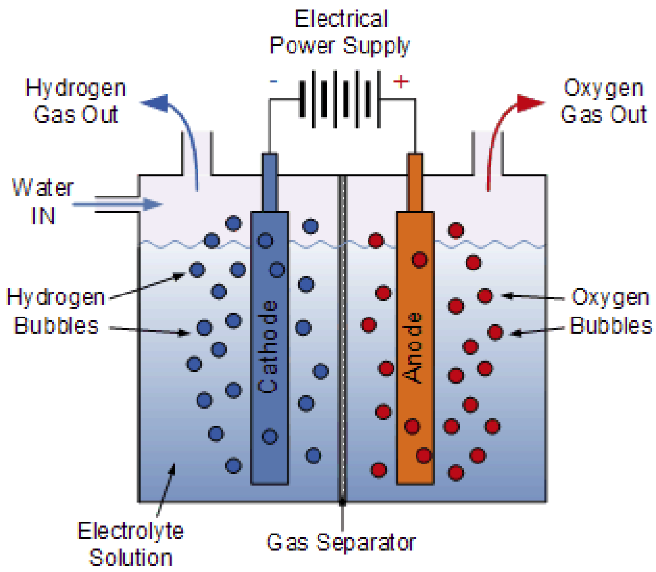
2050



Electrolysis currently account for only 4% of the hydrogen production, but a large expansion is expected in the next years.

Main issue: The cost of produced Hydrogen

Changing the approach



In water electrolysis for each kg of produced **hydrogen**, we have 8kg of **oxygen**.
Usually, oxygen is not considered and released in the atmosphere. WHY?

Buscar el levante por el poniente

"I should not proceed by land to the East, as is customary, but by a Westerly route, in which direction we have hitherto no certain evidence that any one has gone."

Cristoforo Colombo diary, 3 August 1492.

Looking at the Oxygen as driver product for having low cost Hydrogen.

Indeed, Oxygen produced by electrolysis can be placed on the market

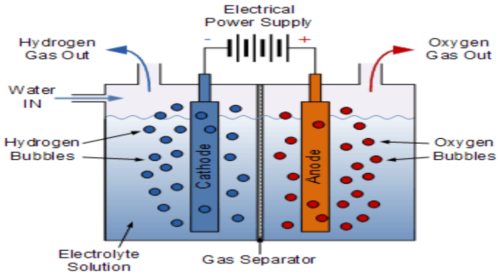
Food and drink industry Packaging with protective atmosphere. Fish farm tub oxygenation. Disinfection and sterilization (ozone).	Glass production and processing Increasing combustion efficiency and reducing NO_x emissions.
Chemical industry Raw materials oxidation, e.g. production of nitric acid, ethylene oxide, propylene oxide, vinyl chloride monomer and other bulk chemicals. Increasing the capacity and efficiency of waste incinerators.	Metal production and processing Air mixture over-oxygenation to increase the combustion temperatures. Increasing metal temperatures in electric arc furnaces for steel making. Oxy-fuel cutting, welding and heating of metals.
Oil industry Cracking catalysts regeneration. Increasing efficiency of sulphur removing.	Paper industry Increasing quality/efficiency of bleaching process.
Waste treatment Air enrichment for firing (lower pollution). Pyrolysis and gasification processes. Waste water purification.	Medical applications Reviving gas mixtures for anaesthesia and emergency. Long-term treatments of patients with respiratory failure.

The global Oxygen market size was about USD 43,5 Billion in 2019 and will expected to reach USD 50 Billion by 2025.
Font – marketstudy report

Oxygen market is already existing and well organised for both production and distribution.

Previous work (1)

200 kW photovoltaic plant



180 kW electrolyser

Compression and storage

Table 1: Plant characteristics

Parameter	Value	Note
PV plant peak power	200 kW	
Total power generation by PV plant	260,000 kWh/y	PVGIS estimate[a]
Efficiency of electrolyser	70%	Stolten & Emonts (2016)
Plant lifetime	20 years	
Stack lifetime	83,000 h	Koj et al. (2015)
Average daily operation	6 h/day	
Hydrogen output	12.7 kg/day	

[a] From http://re.jrc.ec.europa.eu/pvgis/apps4/pvest.php, for a building-integrated plant located in Messina.

"Green Hydrogen as Feedstock: Financial Analysis of a Photovoltaic-Powered Electrolysis Plant", by A. Nicita, G. Maggio, A.P.F. Andaloro and G. Squadrito; Int. J Hydrogen Energy 45, 2020, 11395-11408

Previous work (1)

2 HYPOTHESES

Installation of electrolyser alone connected to an existing PV plant

Implementation of the whole system: PV plant & electrolyser

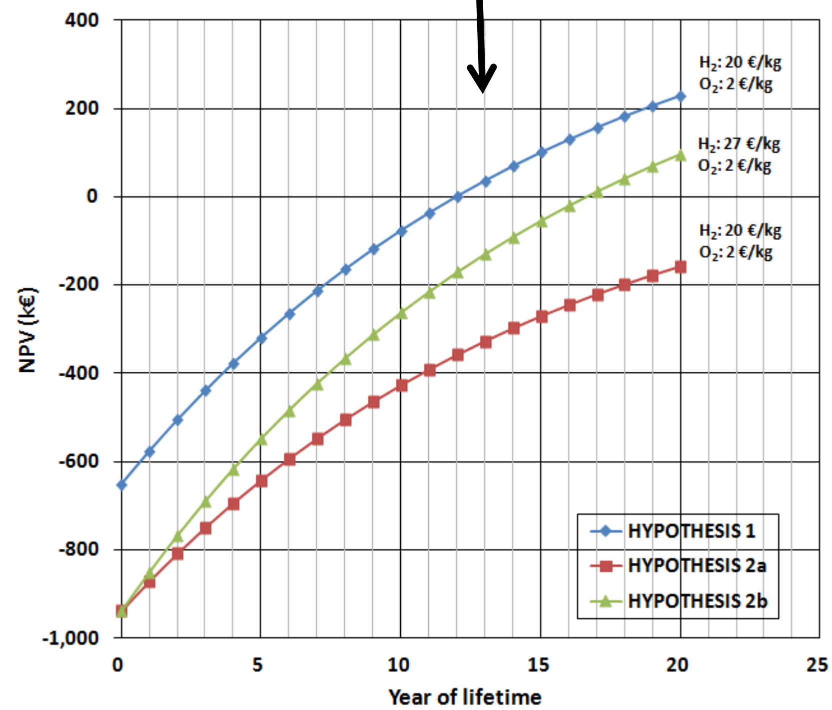
2 SCENARIOS

Sale the produced hydrogen only.

Sale of the produced hydrogen & the co-produced oxygen

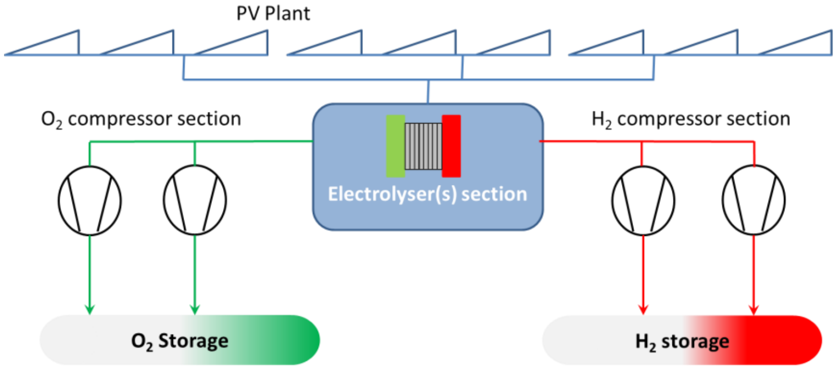
RESULTS

30€ < 1kgH2< 41€

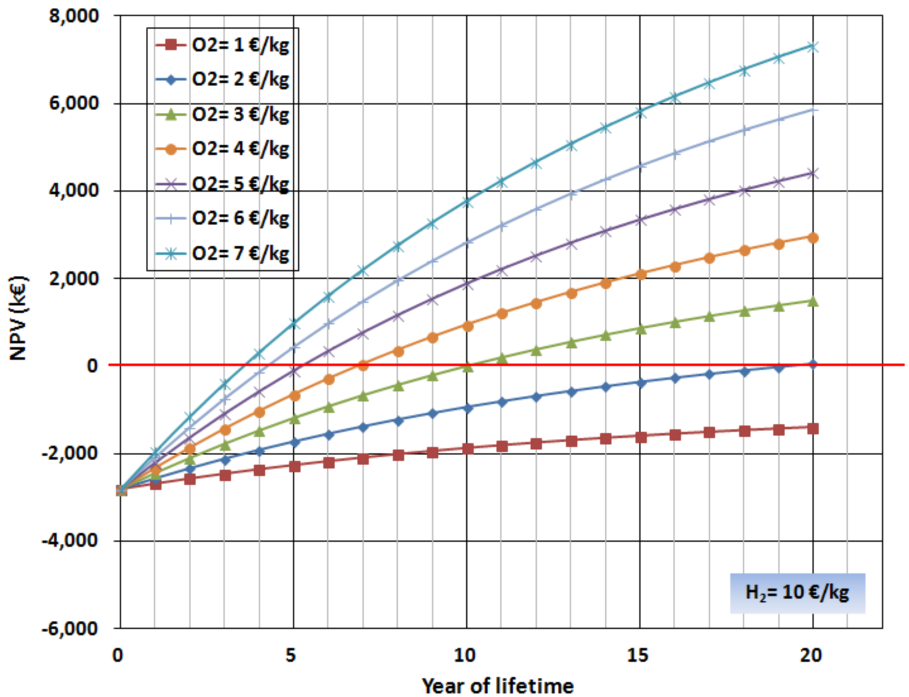


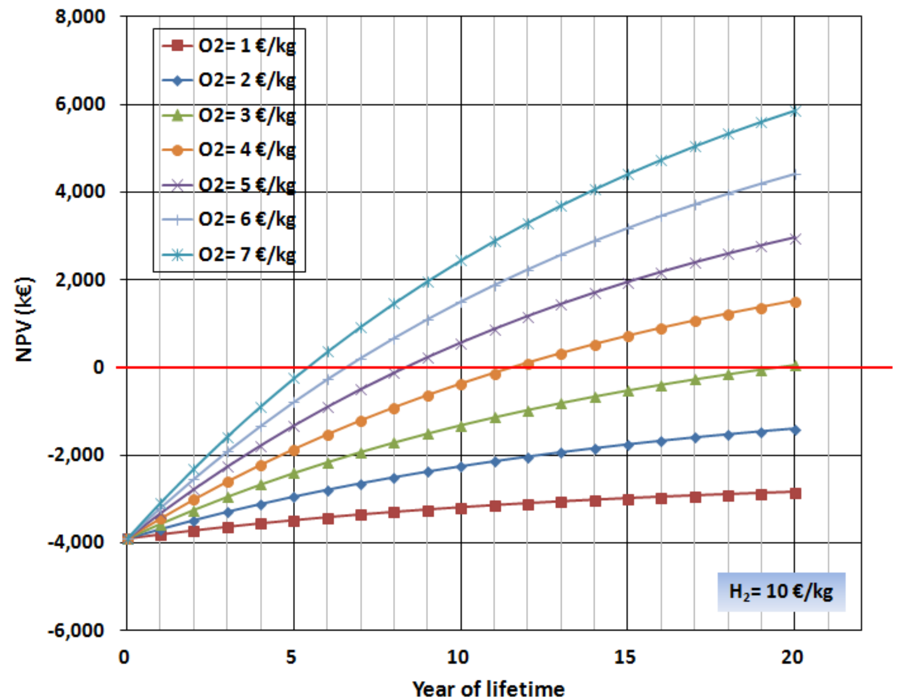
If Oxygen is sold at 2 €/kg, cost of Hydrogen is strongly reduced and the investment is profitable.

Previous work (2)



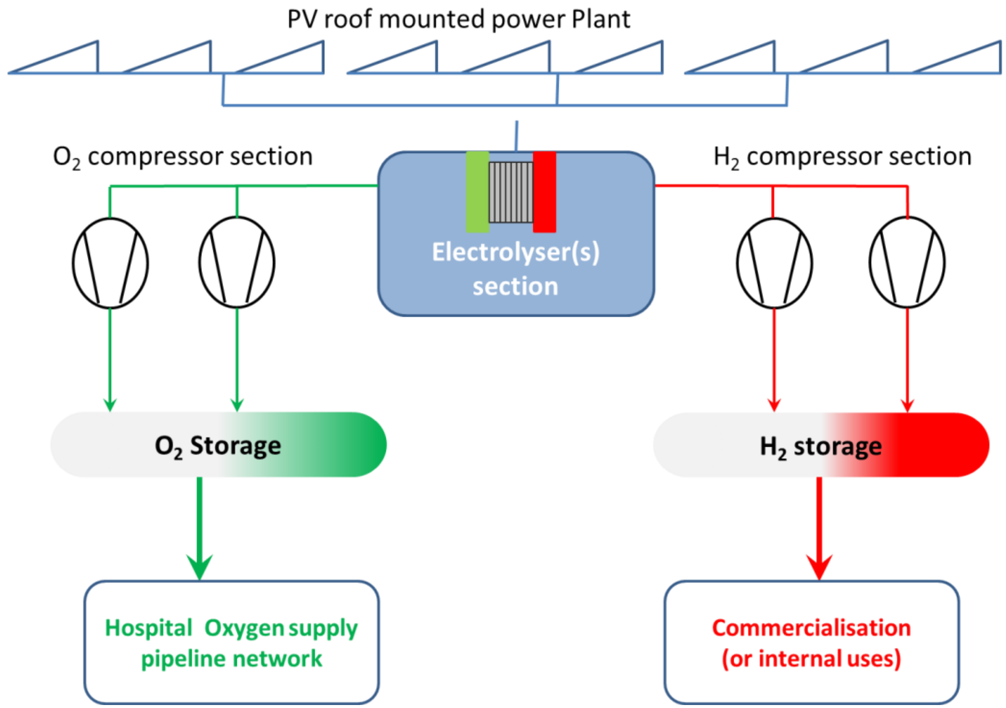
Plants in the range 0,1-10 MW were studied.
Again oxygen selling price is the main contribution to remuneration.





"A size-dependent financial evaluation of green hydrogen-oxygen coproduction", by G. Squadrito, A. Nicita, G. Maggio; Renewable Energy 163 (2021) 2165-2177

THE CASE STUDY



Question
Is RES based distributed Oxygen production for health purposes sustainable?

Yearly oxygen consumption [Nm^3/y] = 8.3 (No. Hospital beds)$^{1.814}$

Electrolyser size [MW] = (Yearly oxygen consumption [Nm^3/y]) / 160,570 [Nm^3/y MW])

160,570 [Nm^3/MW] is the estimated oxygen production in the selected location for 6h/day of electrolyser work with a PV field of 25% greather installed power

THE CASE STUDY - Methodological approach

Economic-financial analysis based on the method proposed by Kuckshinrichs et al. (2017)

FINANCIAL PARAMETERS & METRICS USED

- Weighted average cost of capital (*WACC*)
- Levelized cost of hydrogen (*LCH*)
- Net present value (*NPV*)
- Standard and modified internal rate of return (*IRR* and *MIRR*)

- not account for loan payments and interest on debt
- non-cash deductions (i.e., depreciation and amortization)

excluded

- neither fuel costs nor electricity costs

Taxes are included like for an SME, although we consider an hospital.

THE CASE STUDY - Financial analysis

For details of plant costs (CAPEX and OPEX) and financial analysis, please refer to "A size-dependent financial evaluation of green hydrogen-oxygen coproduction", by G. Squadrito, A. Nicita, G. Maggio; Renewable Energy 163 (2021) 2165-2177

Here a resuming of data is reported.

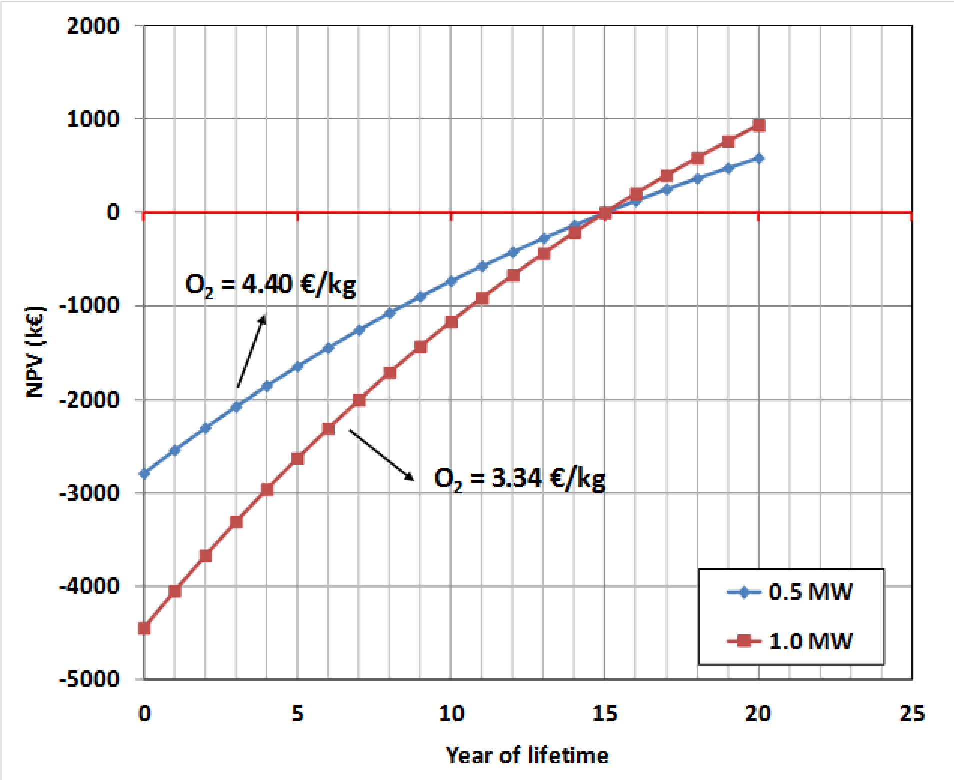
$$Electrolyser\ specific\ cost\ [€/\mathrm{kW}] = 1{,}200\ (P_{EL})^{-0.2}$$

$$PV\ plant\ specific\ cost\ [€/\mathrm{kW}] = \begin{cases} 1{,}800 & if\ \ P_{PV} < 20\ kW \\ 1{,}500 & if\ 20\ kW \leq\ P_{PV} < 200\ kW \\ 1{,}300 & if\ 200\ kW \leq\ P_{PV} < 1\ MW \\ 700 & if\ \ P_{PV} \geq 1\ MW \end{cases}$$

Parameter	Value
Equity rate of return	5.0%
Inflation rate	1.2%[a]
Tax rate on earnings	30%
System degradation rate	0.5%/year

Parameter	Ref. Value
Electrolyser nominal power, MW	1.0
Electrolyser specific cost, €/kW	1,200
Compression plant cost, k€	1,500
Storage system cost, k€	237.6
Labour cost for AWE plant, %/ddcc	5%
PV plant peak power, MW	1.25
PV plant specific cost, €/kW	700
Specific power generated by PV plant in the site, kWh/y per kW PV	1,300
Total power generation by PV plant, kWh/y	1,625,000

THE CASE STUDY - Results of the financial analysis



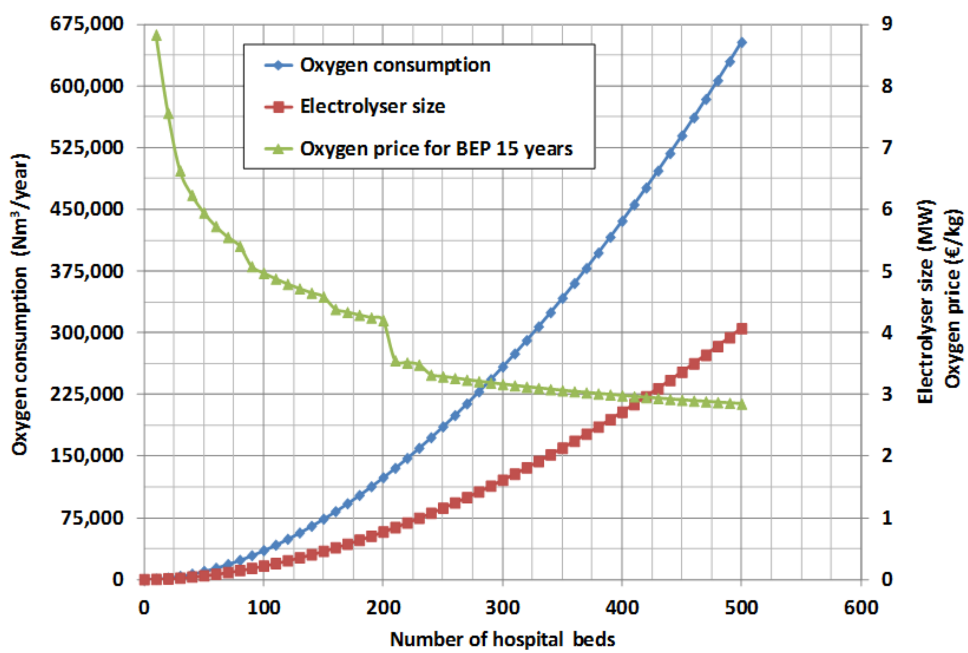
Assuming a hydrogen selling price of 3 €/kg,

- for a 1 MW electrolyser plant the results indicate that an oxygen (market) price of about 3.34 €/kg warrants a null NPV after 15 years;
- reducing the plant size to 500kW, the oxygen production cost for having the same result rises to 4.40€ /kg.

These costs are competitive with prices of medical oxygen reported by AIFA (the Italian drug agency)

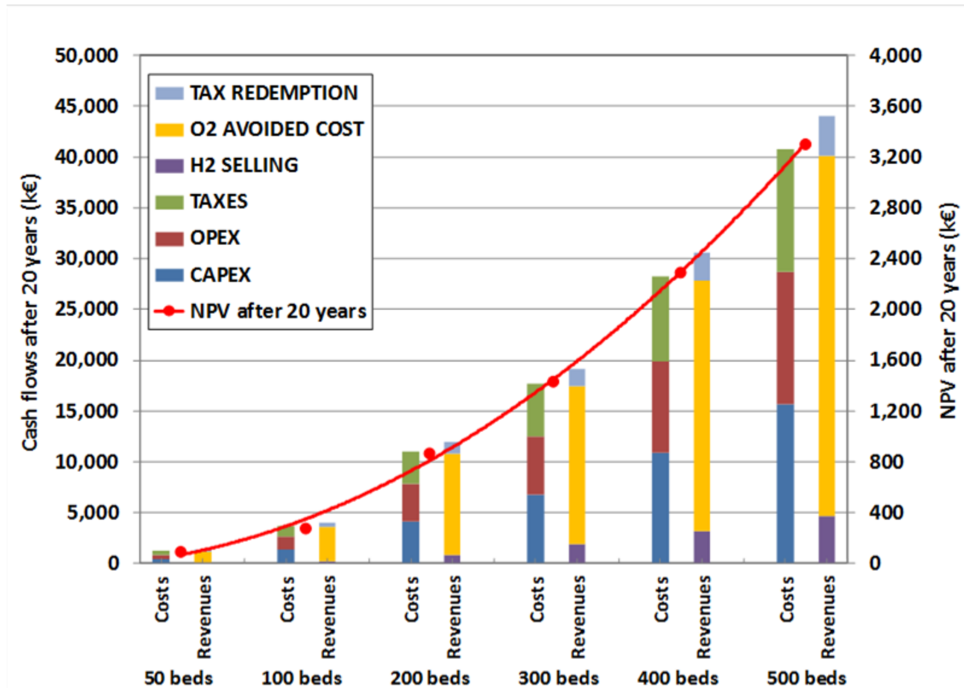
Source AIFA march 2021	Ex-factory prices		Retail prices	
	€/Nm^3	€/kg	€/Nm^3	€/kg
Cryogenic gas	4.20	2.94	6.55	4.59
Compressed gas at 200 bar	6.20	4.34	9.67	6.77
Compressed gas at 300 bar	9.30	6.51	14.51	10.16

THE CASE STUDY - Results of the financial analysis



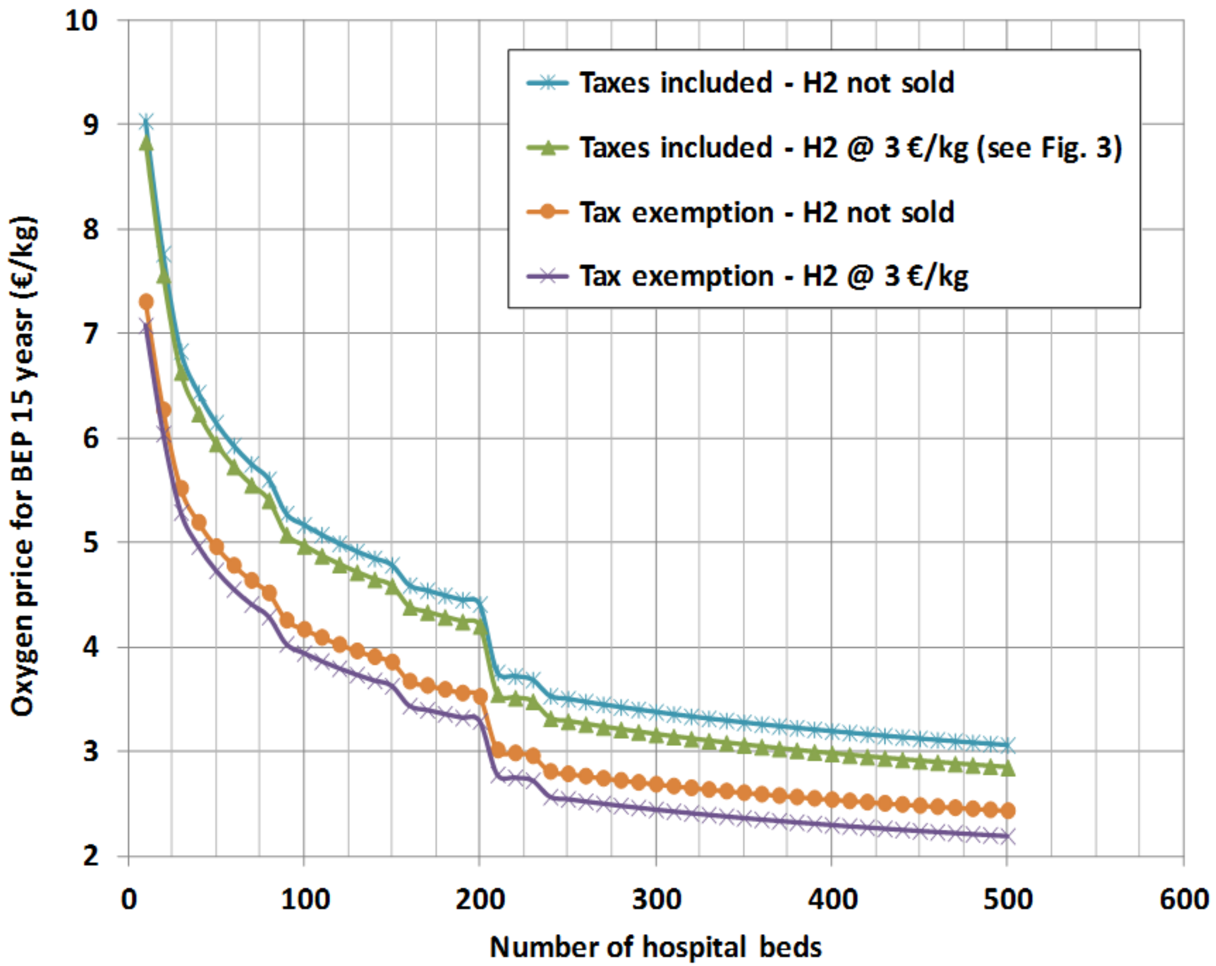
Oxygen consumption calculated according to Gómez-Chaparro M. et al. "*Analytical determination of medical gases consumption and their impact on hospital sustainability*" - Sustainability 2018; 10:2948.

RES-Based distributed Oxygen production in Hospitals is suitable for hospitals over 300 beds, and valuable for hospitals having 200-300 beds.



It is expected that results are still valid for the whole Mediterranean area.

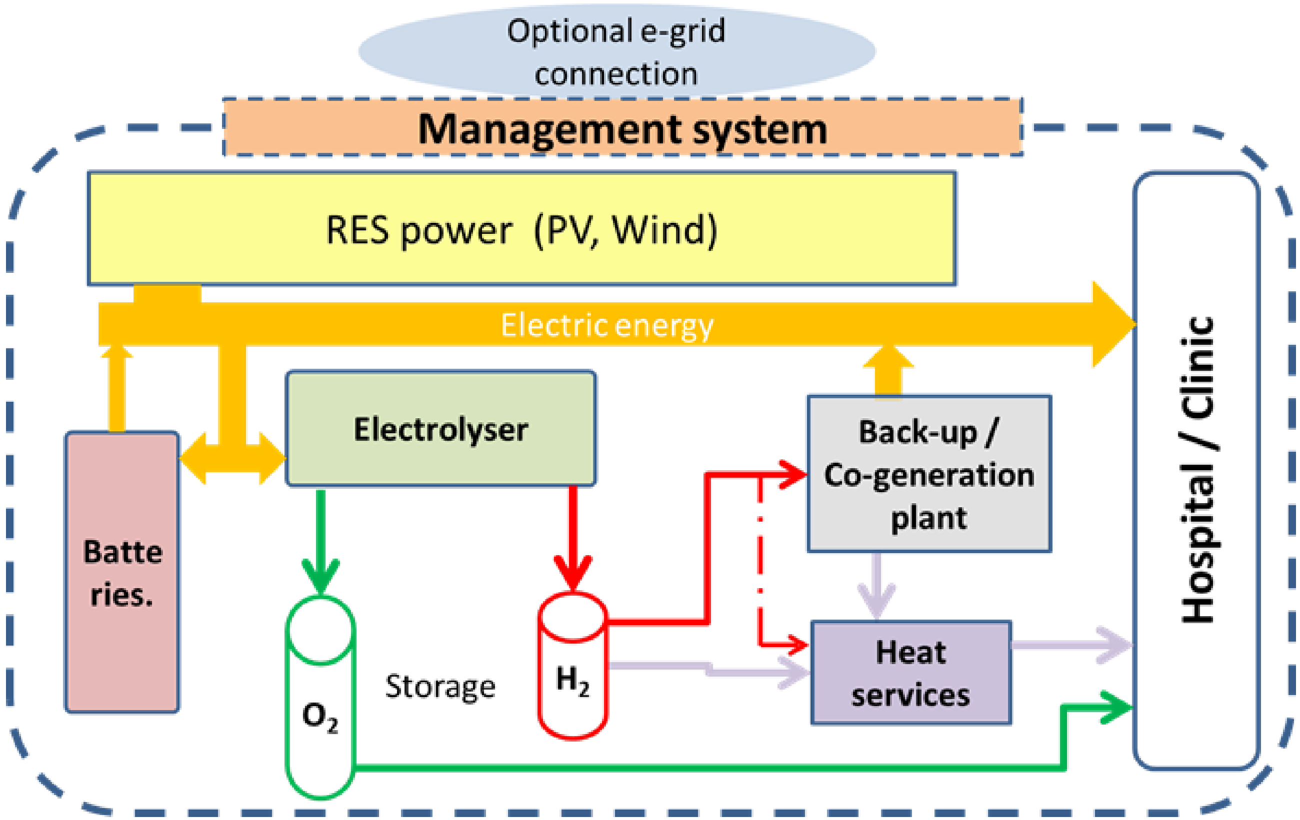
THE CASE STUDY – What is the taxes burden?



By the proposed approach the Green Hydrogen production cost target of 1,5€/kg is behind the corner!

Polygenaration system for hospitals and clinics.

Looking at the Energy-Health nexus



RES based polygeneration of different forms of energy and oxygen/hydrogen could be considered for resilient hospitals.

CONCLUSIONS

Distributed oxygen production in hospitals is a suitable and sustainable solution, at the least in Sicily (Mediterranean area).

If medical OXYGEN is the reference product, Hydrogen is produced at low cost.

The by-product Hydrogen could be used in many ways and is competitive.

- Energy backup fuel for cogeneration
- Fuel for ambulances and shuttle buses
- medical applications

A new concept of poly-generation from RES could be introduced: simultaneous production of different forms of energy and useful goods (in our case O_2/H_2).

The exposed results have been submitted for publication to a peer review journal.

Thank you for your attention

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