National Research Council of Italy

Electrolytic oxygen, only a by-product?

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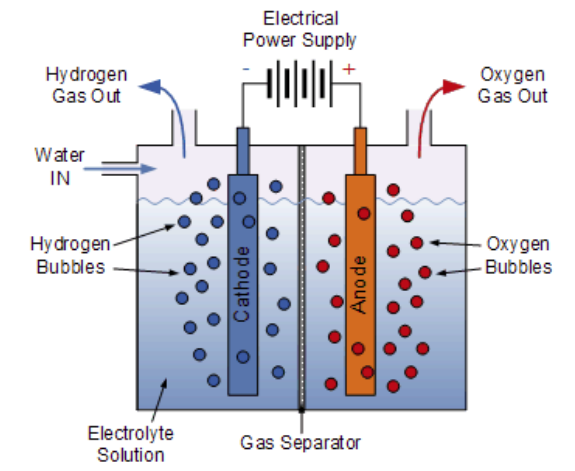
HYDROGEN PRODUCTION

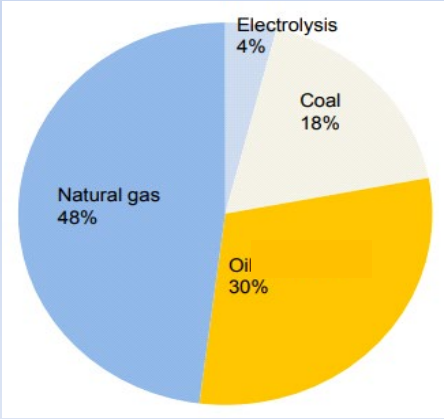


Water electrolysis utilizing electricity derived from RES (wind, solar, geothermal, hydro) is the most environmentally friendly approach for **hydrogen** production.

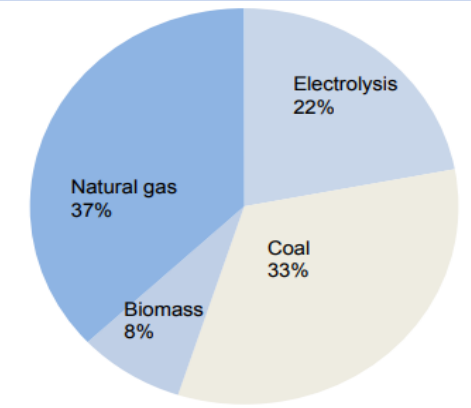
Current worldwide production: 50 Mt H_2/year.

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

TODAY



2050



A NEW VISION

Oxygen co-produced by electrolysis (8 kg for each kg of hydrogen) is usually vented to the atmosphere

Why?

- The attention is mainly focused on centralised mass production of hydrogen by SMR (no oxygen production).
- Use of hydrogen as an energy carrier (fuel for mobility, chemical feedstock, etc.) is emerging as a key solution for decarbonisation, and storage of surplus energy from RES.

We reverse the usual approach:
oxygen co-produced by electrolysis
is considered the **main product**

OXYGEN MARKET

Oxygen produced by electrolysis can be placed on the market

Industrial applications:
- Steel industry (blast & electric arc furnaces, stainless steelmaking)
- mining & metal refining
- pulp & paper industries
- glass industry
- food industry
- thermo-chemical processes (e.g. biomass gasification) to produce chemicals (i.e., hydro-methane and methanol)

Technical gases market:
- small and medium enterprises
- craft industries (e.g., blowtorches)
- research centres

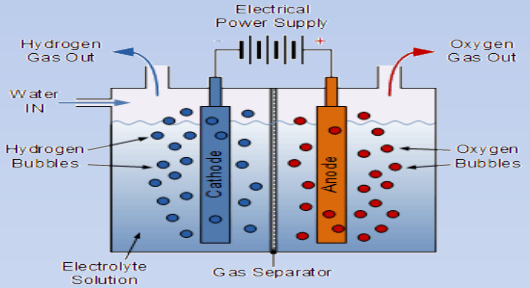
Medical applications:
Mainly used for the prevention and treatment of respiratory failure (hypoxemia, pulmonary vasoconstriction, etc.), both for hospital and homecare use

THE CASE-STUDY

The research aims to assess the **return on investment** and the **profitability** of an alkaline electrolysis system for the production of oxygen to be placed on the market of technical and/or medical gases

1 MW PV plant

800 kW electrolyser



THE CASE-STUDY

Table 1: Plant characteristics

Parameter	Value	Note
PV plant peak power	1 MW	
Total power generation by PV plant	1,300 MWh/y	PVGIS estimate[a]
Electrolyser power	800 kW	Alkaline electrolyser
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	
Oxygen output	502.9 kg/day	128,456 Nm^3/year
Hydrogen output	63.3 kg/day	256,913 Nm^3/year

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

2 HYPOTHESES:

Installation of electrolyser alone connected to an **existing PV plant**

Implementation of the whole system: **PV plant & electrolyser**

METHODOLOGICAL APPROACH

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

FINANCIAL METRICS

- 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*)

ASSUMPTIONS:

1) **NO DEBT FINANCING: NO LOAN PAYMENTS & INTERESTS ON DEBT**
2) **NON-CASH DEDUCTIONS ARE EXCLUDED**
3) **NO FUEL & ELECTRICITY COSTS**

FINANCIAL ANALYSIS INPUT DATA

Table 2: Alkaline water electrolysis plant costs

Investment:	
Electrolyser[b,c]	960 k€ (1,200 €/kW)
Compression plant[c]	1,260 k€
Storage system[d]	124.5 k€
Total direct depreciable capital cost (ddcc)	2,344.5 k€
Indirect depreciable capital cost (idcc)	20%/ddcc
Fix O&M costs:	
Material	2.5%/ddcc
Labour	7.0%/ddcc
Variable O&M costs:	
See Table 3	

[b] Water treatment included.
[c] Electrics, gas equipment, safety system, and control system included.
[d] Outdoor installation.

Table 3: Demand and cost of upstream products

Product	Specific demand[e]	Cost[f]
Deionised water	10 kg/kg H_2	0.01 €/kg
KOH	1.9 g/kg H_2	2.5106 €/kg
Steam	0.11 kg/ kg H_2	0.01 €/kg
Nitrogen	0.29 g/kg H_2	0.2783 €/kg

[e] From Koj et al. (2017).
[f] From Kuckshinrichs et al. (2017).

Table 4: Financial and tax parameters

Parameter	Value
Equity rate of return	7.0%
Inflation rate	1.2%[g]
Tax rate on earnings	30%
System degradation rate	0.5%/year

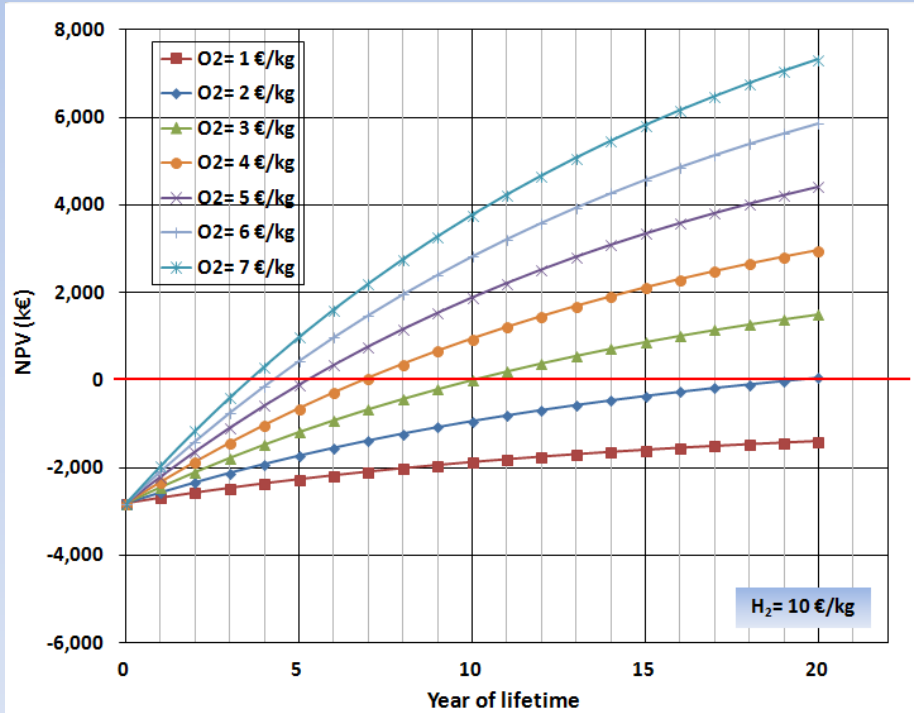
[g] ISTAT (2019), referred to Italy in 2018.

Table 5: PV plant costs

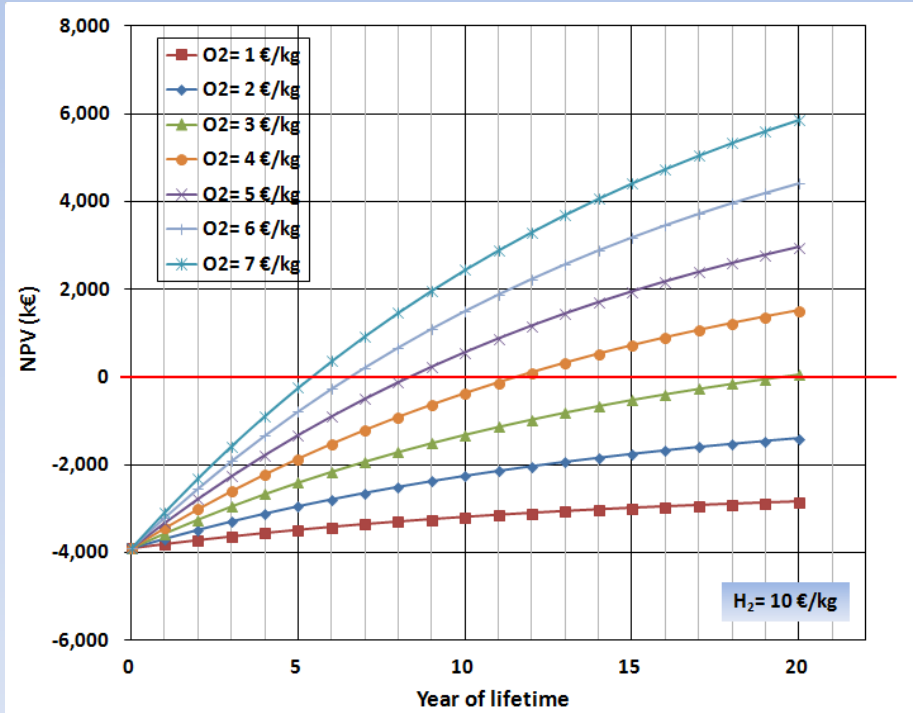
Investment:	
Direct depreciable capital cost (ddcc)	900 k€ (900 €/kW)
Indirect depreciable capital cost (idcc)	20%/ddcc
Fix O&M costs:	
Material	2.5%/ddcc
Labour	2.5%/ddcc
Variable O&M costs:	
None	

FINANCIAL ANALYSIS RESULTS

Proprietary PV plant



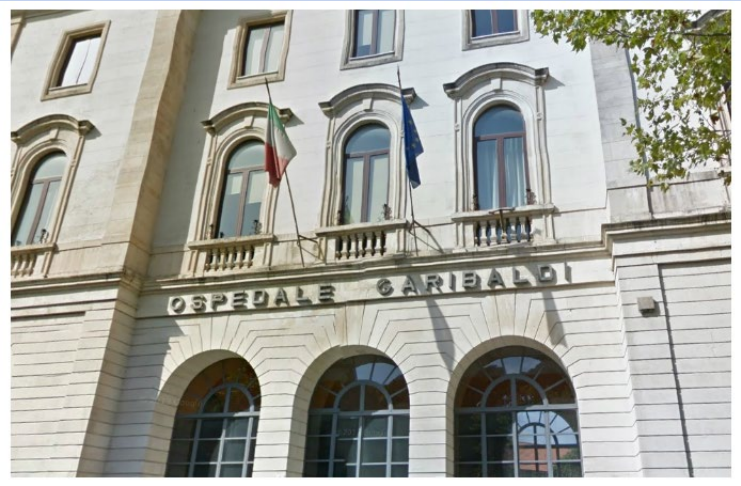
PV plant purchased



MAIN CONCLUSIONS

Preliminary results demonstrated that:

- Oxygen produced by electrolysis **can be placed on the market**
- It should be sold at **> 3 €/kg** to have economic profitability after 20 years



GARIBALDI-center hospital in Catania
(192 beds) uses **175,000 Nm^3/y**
of gaseous oxygen
(tender dossier, February 18, 2015)

CONSIDERATIONS & RESEARCH DIRECTIONS

A hospital can use a proprietary RES-based electrolysis plant to self-produce the **oxygen** for its medical needs.

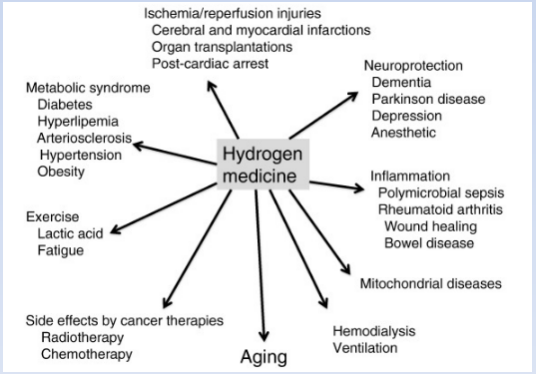
The **hydrogen** obtained by electrolysis can be:

Sold to third parties (research centres, industries, etc.)

Used or stored to generate **electricity** at a later time (gas turbines, FCs, etc.)

Used as a **fuel** to feed a park of fuel cell vehicles (cars, buses, ambulances, etc.) by a refuelling station serving the whole area of the hospital, a network of hospitals, and/or external users

Used for **medical applications** by the hospital: some studies evidenced that hydrogen acts as a "therapeutic and preventive antioxidant" for various diseases



S. Ohta, *Pharmacology & Therapeutics* 144 (2014) 1-11.

Thank you for your attention

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