Economic and environmental sustainability of a photoelectrolysis cell for hydrogen production

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The energy crisis, the impact on the transition

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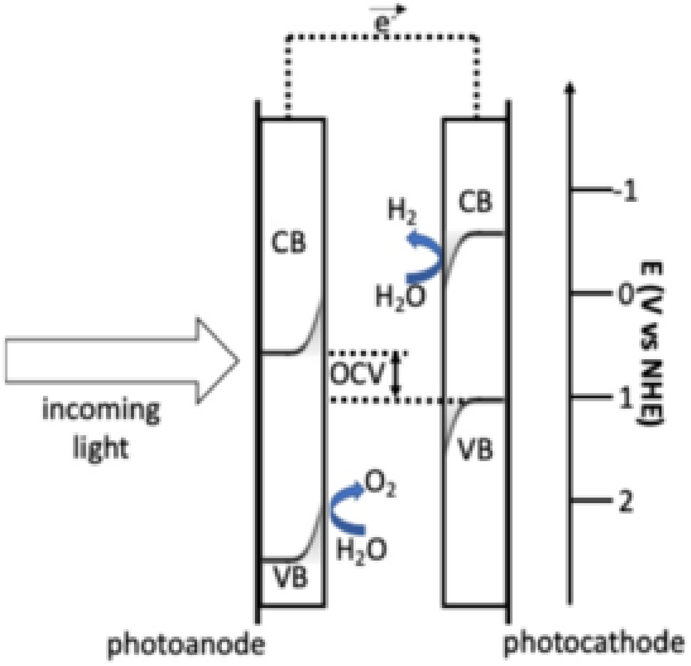
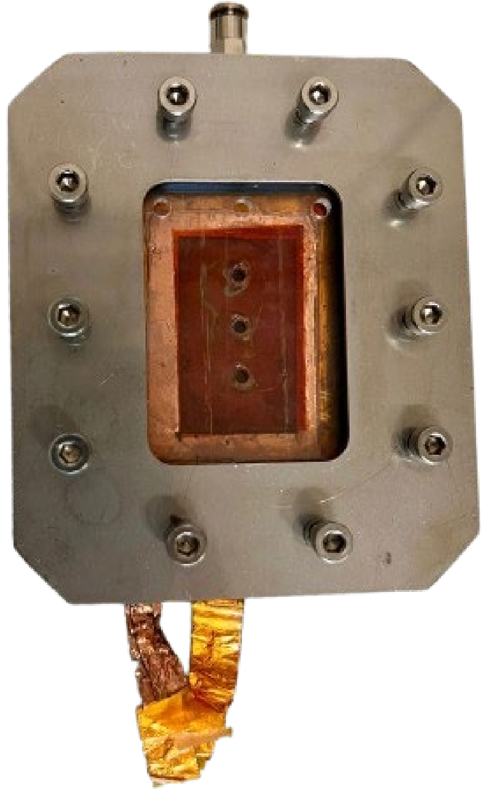
Consiglio Nazionale delle Ricerche

NOVEL PHOTOELECTROLYSIS CELL FOR HYDROGEN PRODUCTION

RdS
RICERCA DI SISTEMA

«Piano triennale di Realizzazione 2022 - 2024 della Ricerca di Sistema Elettrico Nazionale»





A novel concept consists of a tandem photoelectrolysis cell architecture with an anion-conducting membrane separating the photoanode from the photocathode, allowing the use of low-cost metal oxide electrodes (Fe2O3, CuO) and nickel-based co-catalysts

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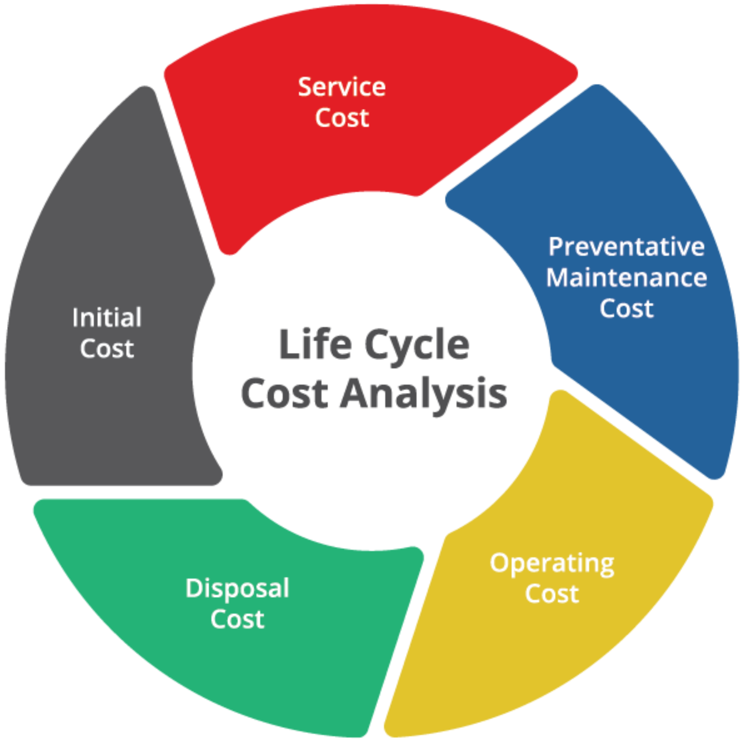
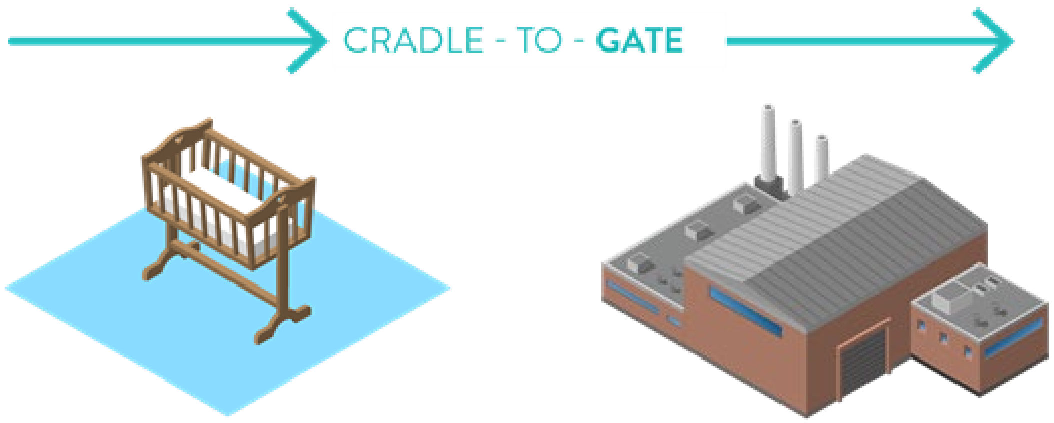
ELCC & LCC





IMPACT CATEGORIES

TOTAL ECO COSTS

CARBON FOOTPRINT

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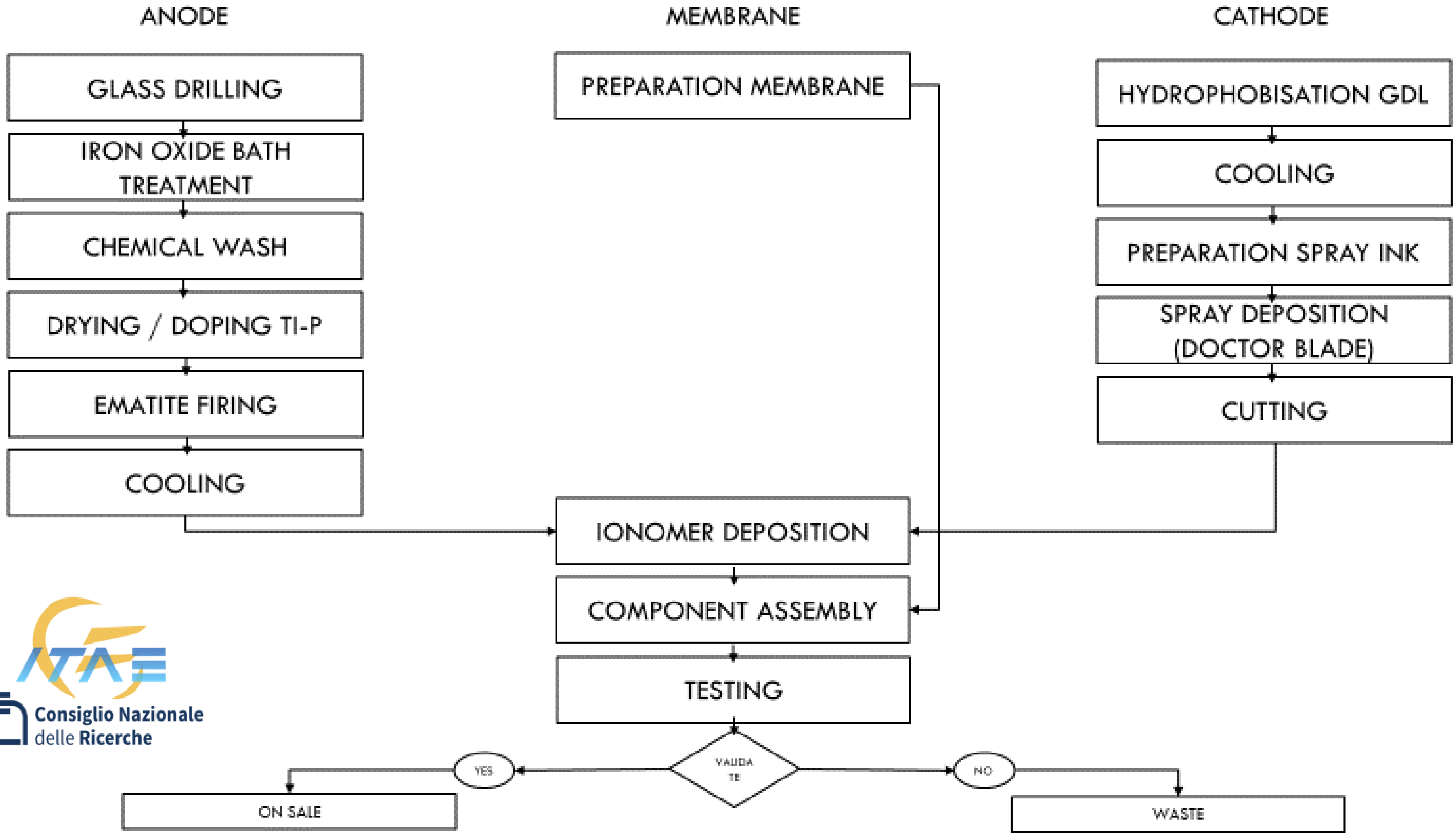
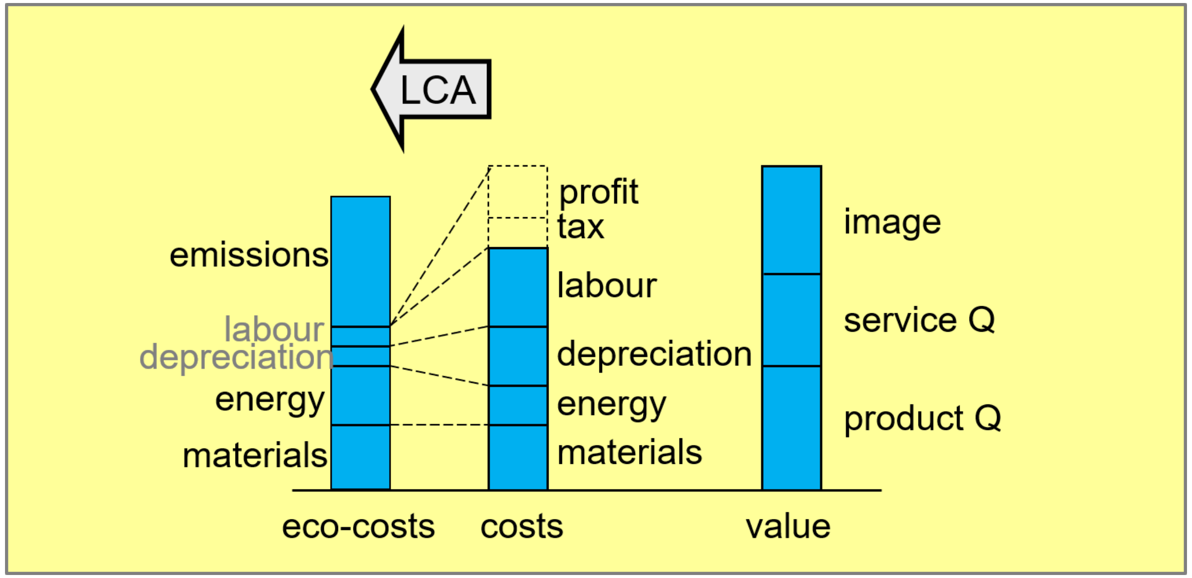
PRODUCTION FLOWCHART

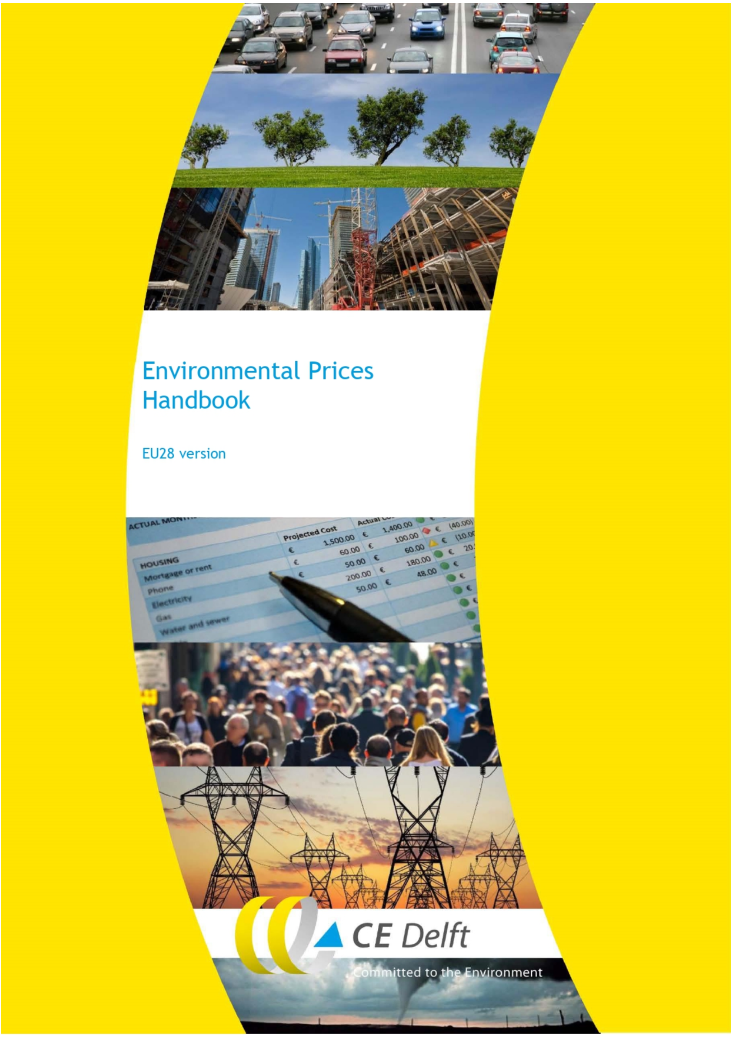


ECO COSTS VALUE RATIO «EVR»



MEASURING THE COST OF PREVENTING A SPECIFIC AMOUNT OF ENVIRONMENTAL DAMAGE

ENVIRONMENTAL PRICE «EP»



EXPRESS WILLINGNESS TO PAY FOR LESS POLLUTION

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STEPS TO DETERMINE ENVIRONMENTAL COSTS

1. DETERMINATION AND QUANTIFICATION OF INPUT MATERIALS

Input material	Amount (g/cm^2)
Glass/FTO	0.82
CuO	0.003
Potassium hydroxide	0.07
Ionomer	0.001
Fe_2O_3+Ti+P	0.0026
Sigracet® 35 BC	0.011
Distilled water	0.03
FEP	$7.7 \cdot 10^{-4}$
Polyvinylidenfluoride	1.78
Commercial membrane	0.006
NiCu	$0.8 \cdot 10^{-5}$

2. SEARCH AND DESCRIPTION OF DATA

Input material/resource	Input material in IDEMAT 2023
Glass/FTO	Float glass
CuO	Metalloid oxides
Potassium hydroxide	Potassium hydroxide
Ionomer	Ionomer
Fe_2O_3+Ti+P	Fe_2O_3 = Other non-metal oxides (n=2, std=0) Ti = Titanium (primary) P = Non-metal phosphates (n=1, std=–)
Sigracet® 35 BC	Carbon fibre (95%) PTFE (Teflon), chemical upcycled (5%)
Distilled water	Industrial reverse osmosis water Europe
FEP	PTFE (Teflon), chemical upcycled
Polyvinylidenfluoride	PVC (Polyvinylchloride emulsion polymerised)
Commercial membrane	PPS (Polyphenylene sulfide)
NiCu	Ni = Nickel (primary) Cu = Copper (primary)
Electricity	PV panel (irradiation 1,100 kWh per m^2)

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STEPS TO DETERMINE ENVIRONMENTAL COSTS

3. CALCULATION OF TOTAL ECO COSTS

Unit	Process	Total eco-cost (€/unit)	Quantity (unit)	Total eco-cost (€)
kg	Float glass	0.2280	0.0656	1.50E-02
kg	Metalloid oxides	0.5186	2.40E-04	1.24E-04
kg	Potassium hydroxide	0.3183	0.0056	1.78E-03
kg	Ionomer	3.2377	8.00E-05	2.59E-04
kg	Fe_2O_3 = Other non-metal oxides (n=2, std=0)	0.1543	2.08E-04	4.37E-03
kg	Ti = Titanium (primary)	20.7550		
kg	P = Non-metal phosphates (n=1, std=–)	0.1120		
kg	Carbon fibre (95%)	16.2236	8.80E-04	1.36E-02
kg	PTFE (Teflon), chemical upcycled (5%)	1.6762		
kg	Industrial reverse osmosis water Europe	0.0027	0.0024	6.53E-06
kg	PTFE (Teflon), chemical upcycled	1.6762	6.16E-05	1.03E-04
kg	PVC (Polyvinylchloride emulsion polymerised)	0.7653	0.1424	1.09E-01
kg	PPS (Polyphenylene sulphide)	4.5047	4.80E-04	2.16E-03
kg	Ni = Nickel (primary)	29.4569	6.40E-07	2.23E-05
kg	Cu = Copper (primary)	5.445		
MJ	PV panel (irradiation 1,100 kWh per m^2)	0.0057	30.420	1.72E-01
	TOTAL			**3.19E-01**

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STEPS TO DETERMINE ENVIRONMENTAL COSTS:

4. CALCULATION OF CLIMATE CHANGE EP – CLIMATE CHANGE ECO COSTS

Unit	Process	Carbon footprint ($kgCO_2$-eq/unit)	Carbon footprint ($kgCO_2$-eq)	Climate change eco-costs (€)	Climate change EP (€)
kg	Float glass	1.3715	9.00E-02	1.20E-02	5.13E-03
kg	Metalloid oxides	3.4538	8.29E-04	1.10E-04	4.72E-05
kg	Potassium hydroxide	1.7839	9.99E-03	1.33E-03	5.69E-04
kg	Ionomer	11.5819	9.27E-04	1.23E-04	5.28E-05
kg	Fe_2O_3 = Other non-metal oxides (n=2, std=0)	0.9644	6.45E-03	8.57E-04	3.67E-04
kg	Ti = Titanium (primary)	29.5599			
kg	P = Non-metal phosphates (n=1, std=–)	0.4687			
kg	Carbon fibre (95%)	87.8194	7.39E-02	9.83E-03	4.21E-03
kg	PTFE (Teflon), chemical upcycled (5%)	10.6690			
kg	Industrial reverse osmosis water Europe	0.0086	2.06E-05	2.74E-06	1.17E-06
kg	PTFE (Teflon), chemical upcycled	10.6690	6.57E-04	8.74E-05	3.75E-05
kg	PVC (Polyvinylchloride emulsion polymerised)	2.2200	3.16E-01	4.20E-02	1.80E-02
kg	PPS (Polyphenylene sulphide)	7.1664	3.44E-03	3.89E-04	1.96E-04
kg	Ni = Nickel (primary)	13.0955	1.11E-05	1.47E-06	6.31E-07
kg	Cu = Copper (primary)	4.1896			
MJ	PV panel (irradiation 1,100 kWh per m^2)	0.0250	7.60E-01	1.01E-01	4.33E-02
	TOTAL			**1.68E-01**	**7.19E-02**

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CALCULATION OF OVERALL COST AND AFFORDABILITY

$$NPV = -CAPEX + (1 - TR)\sum_{n=1}^{N}\frac{REV_n - OPEX_n}{(1+r)^n}$$

NPV is defined as the discounted value, at a discount rate, of all cash flows (negative and positive) generated over the life of the project.

CAPEX	Investment cost	€ 80,000
TR	Tax rate on profits	27.9 %
REVn	Annual profit generated	€ 935,826
OPEXn	Operating costs	€ 926,453
r	Discount rate	4.85 %

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CELL PRODUCTED PER YEAR 4,400

CALCULATION OF OVERALL COST AND AFFORDABILITY

CAPEX

Equipment	Cost (€)
Solar simulator	25,000
Electronic instruments	20,000
Tower oven (25 kW)	18,000
Little tower oven (15 kW)	10,000
Ultrasound bath	1,000
Heating plate	500
Automated drill press X-Y	5,500
CAPEX:	**80,000**

DEPRECATION RATE15%

OPEX

Item	Cost (€/y)
Materials	852,615
Labour	60,000
Electricity consumption	12,338
Other	1,500
OPEX:	**926,453**

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RESULTS

TOTAL ECO COST

MATERIALS	%
Electricity	54
Polyvinildenfuoride	34
Distilled water	0,002

% OF MATERIAL INCIDENCE USING THE TOTAL ECO-COST METHOD

CARBON FOOTPRINT EP & EVR

MATERIALS	%
Electricity	60
Polyvinildenfuoride	25
NiCu	0,001

% OF MATERIAL INCIDENCE USING THE CARBON FOOTPRINT EP AND ECO COST METHOD.

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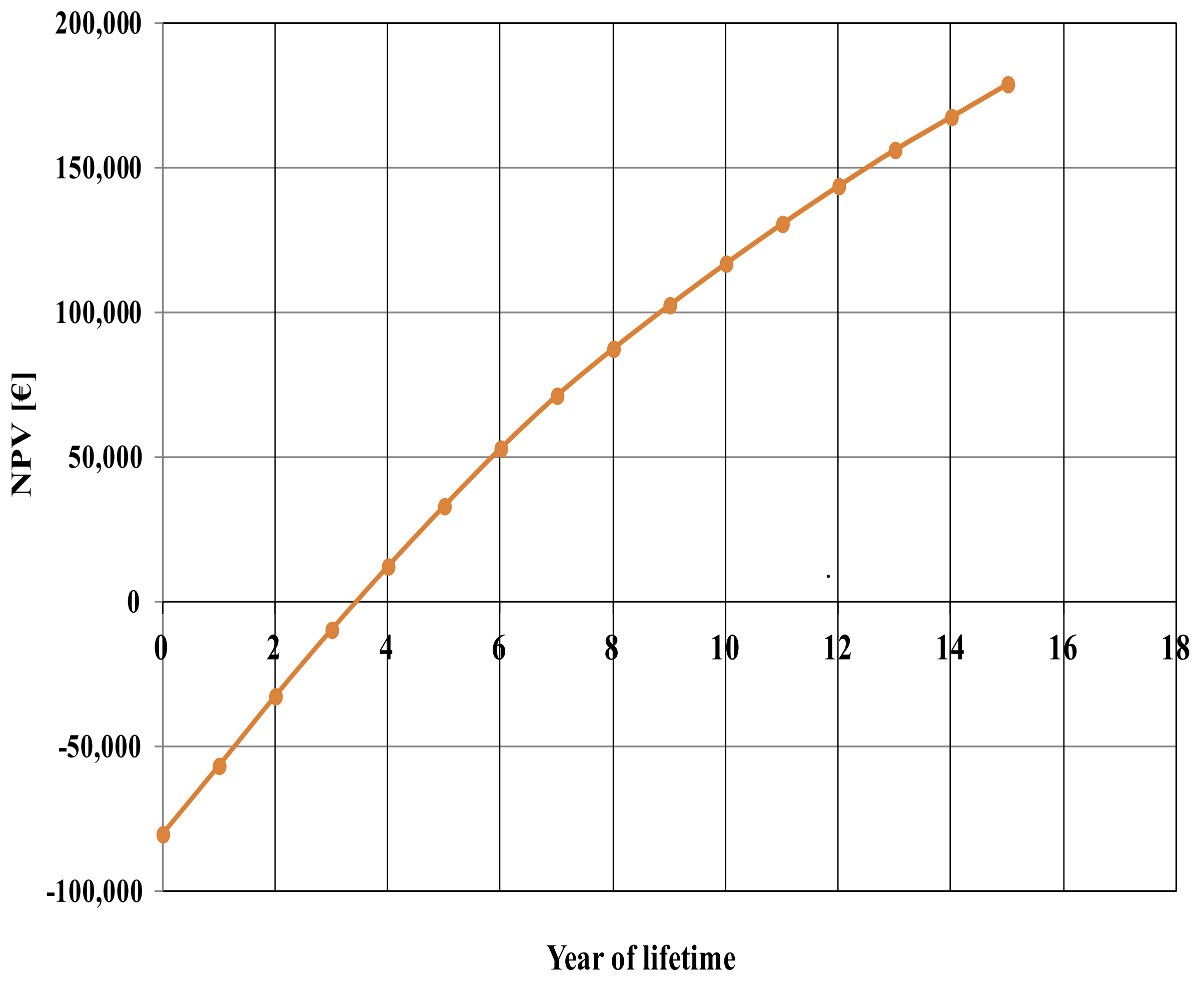
RESULTS

NET PRESENT VALUE EVOLUTION



Approach	External cost (€/y)
Total eco-costs	1,416
Climate change eco-costs	745
Climate change EP	319

EXTERNAL COSTS €/Y

Approach	CAPEX	OPEX	External costs
Total eco-costs	7.94%	91.92%	0.14%
Climate change eco-costs	7.94%	91.98%	0.07%
Climate change EP	7.95%	92.02%	0.03%

INCIDENCE OF COSTS ITEMS %

ESTIMATE PAYBACK PERIOD OF INVESMENT IS ABOUT 3.5 YEARS

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CONCLUSIONS

ENVIRONMENTAL IMPCATS:

PROS: THE PERCENTAGE ON THE TOTAL ECO COSTS IS NEGLIGIBLE

CONS: NO USE AND DISPOSAL ANALYSIS

ECONOMICAL RESULTS:

PROS: LOW INVESTMENT COSTS

CONS: HIGH OPERATIVE COSTS

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THANKS FOR YOUR ATTENTION

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