VOLTA CHEM

Electrification of the Chemical Industry

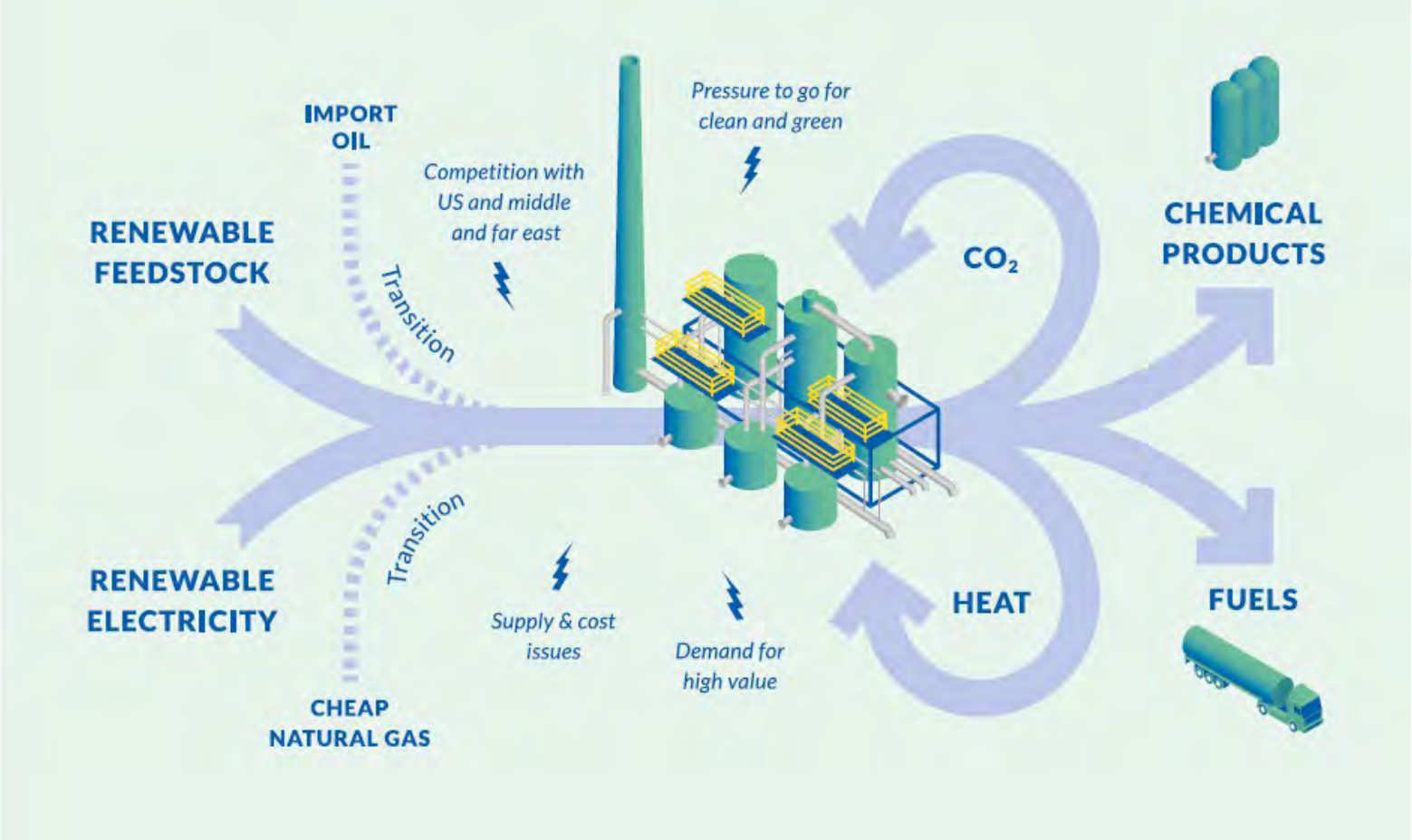
Electroreduction of CO_2

"Towards an economically feasible system"

Elena Perez Gallent, Susan Turk, Carlos Sanchez Martinez, Anca Anastasopol, Earl Goetheer

Powered by: TNO innovation for life ECN

Our vision on industrial electrification

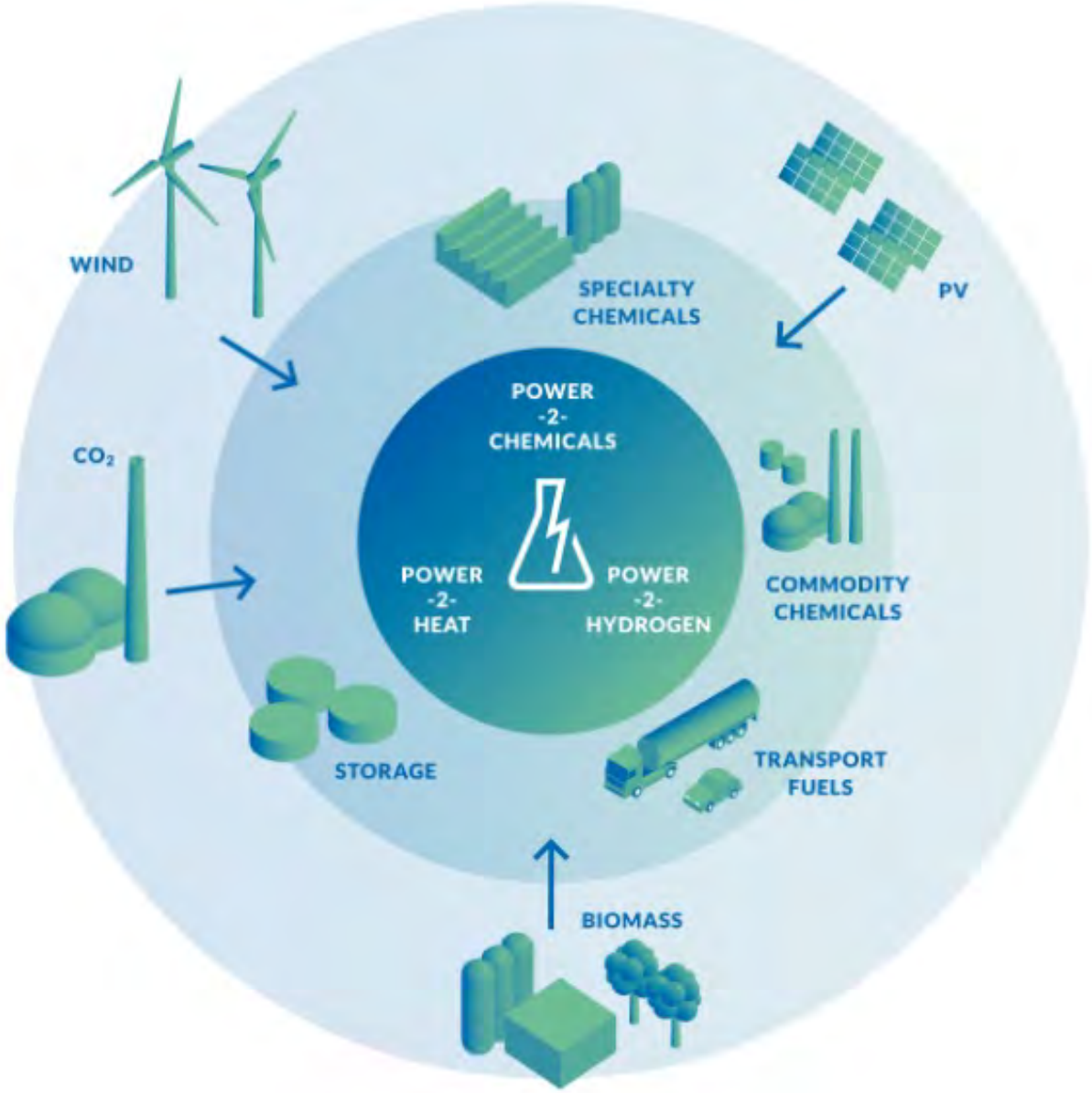


TOPSECTOR ENERGIE
Empowering the new economy

Topsector Chemie

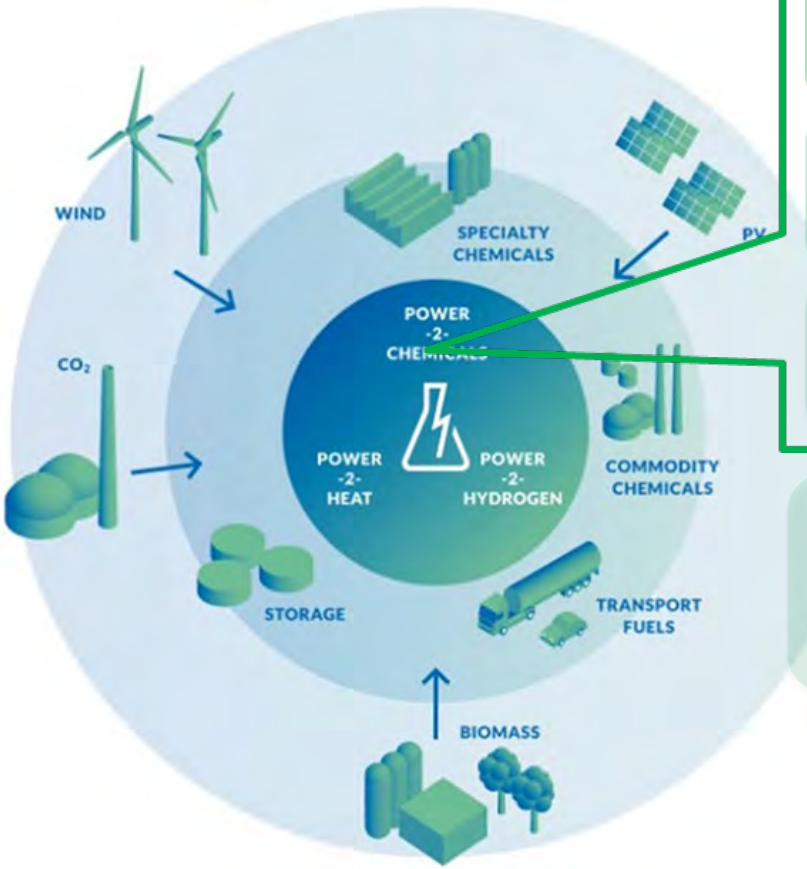
Holland High Tech

VOLTACHEM



- Public-Private ***Shared Innovation Program*** of ~4 M€ / year, initiated by TNO, ECN and Topsector Chemistry.
- Accelerate innovation and implementation of ***electrification & decarbonization*** in chemicals.
- Initiate and facilitate ***collaborative development*** *of technology and associated business models*.
- Addresses both the *indirect and direct use of electricity* within the chemical industry, involving stakeholders from ***chemicals***, ***energy & equipment supply***.

VOLTACHEM



Power to chemicals

Electro-organic synthesis

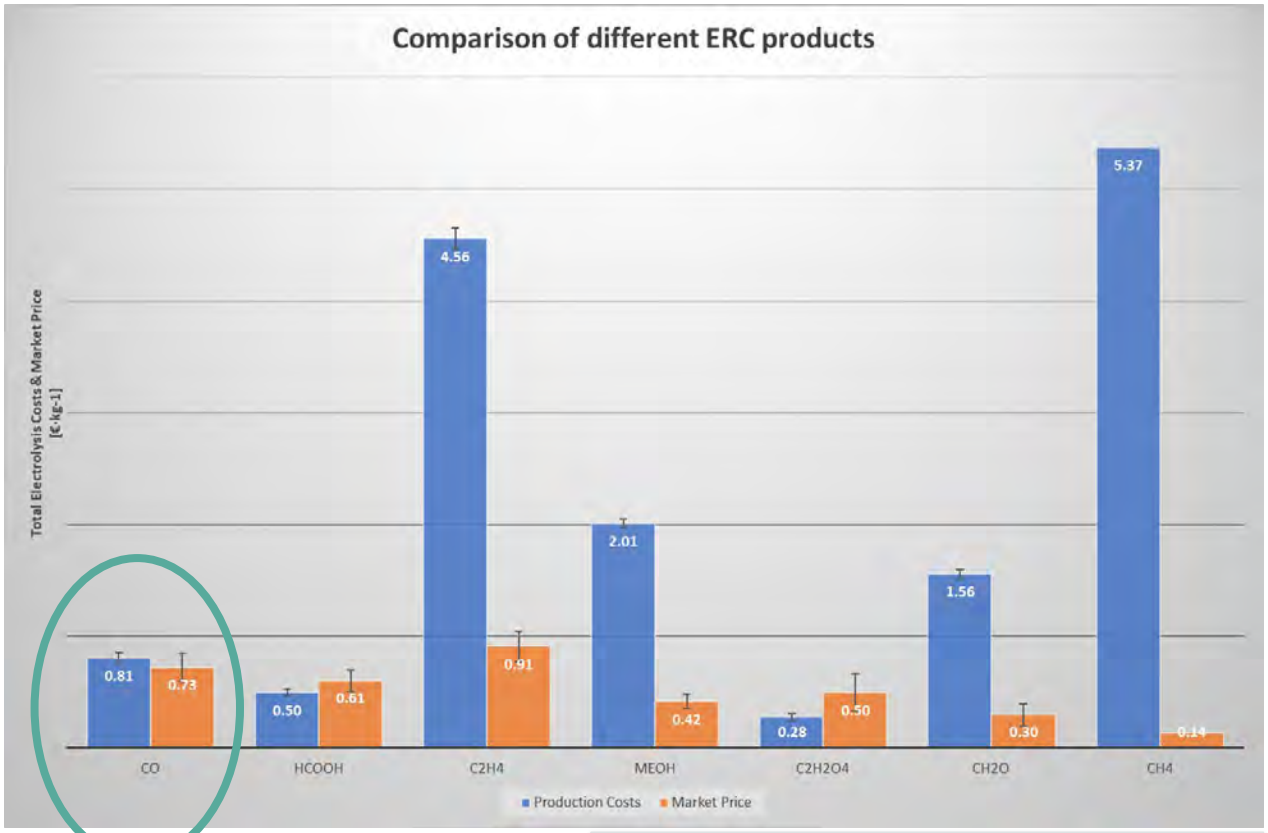
CO_2 electro-reduction

Electro-oxidation

Electro-reduction

- ✓ Oxidation of furfural
- ✓ Oxidation of hydroxymethylfuran
- ✓ Oxidation of alcohols
- ✓ Oxidation of glycerol
- ✓ Reduction of furfural
- ✓ Reduction of hydroxymethylfuran
- ✓ Reductive amination
- ✓ Reduction of oxygen
- ✓ Electrodimerization

Techno-economic analysis



0.81 € / kg

Profitable products from CO_2 reduction:

- CO
- HCOOH
- $C_2H_2O_4$

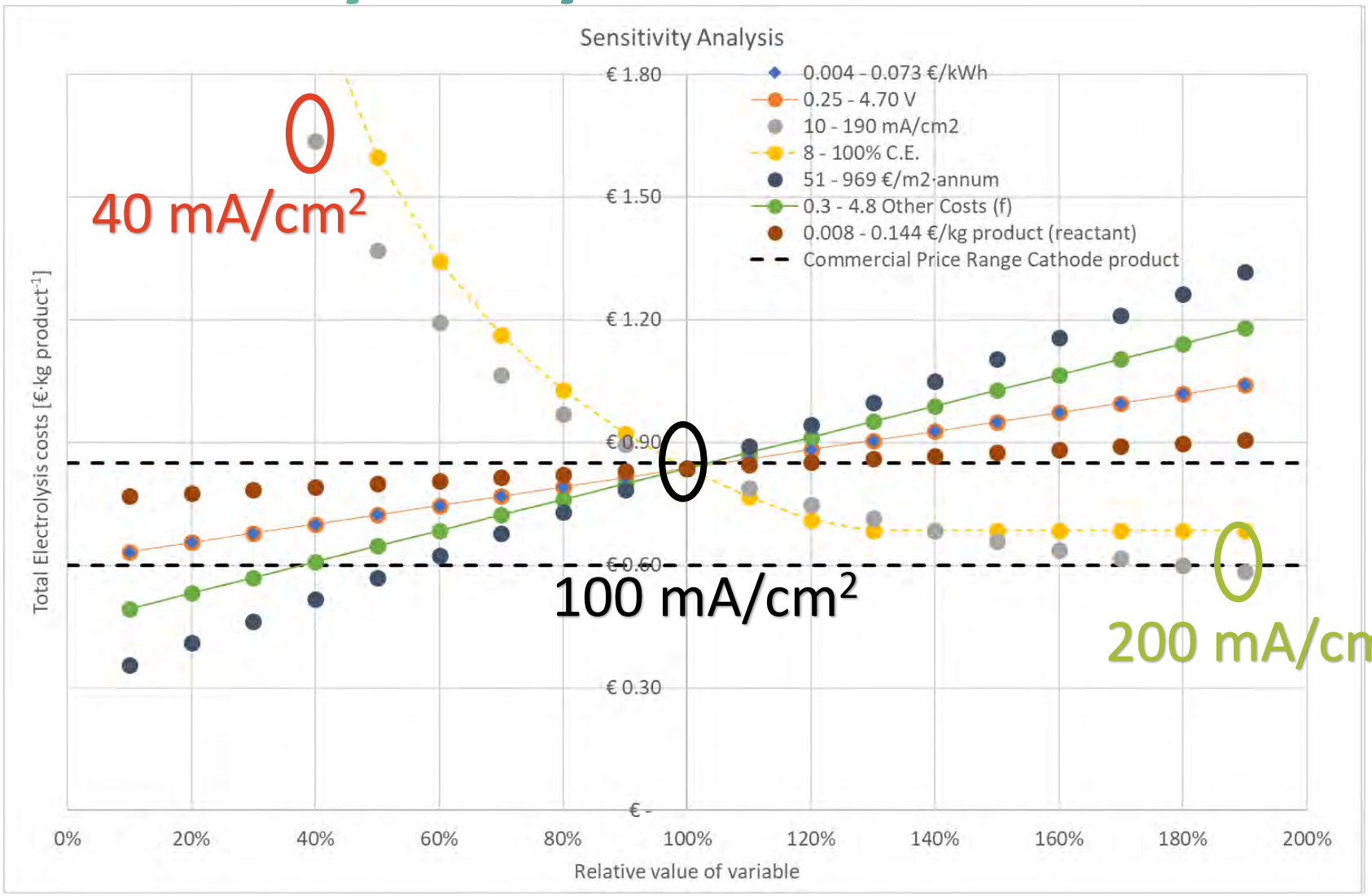
Due to :

- Low amount of electrons needed
- High atom efficiency

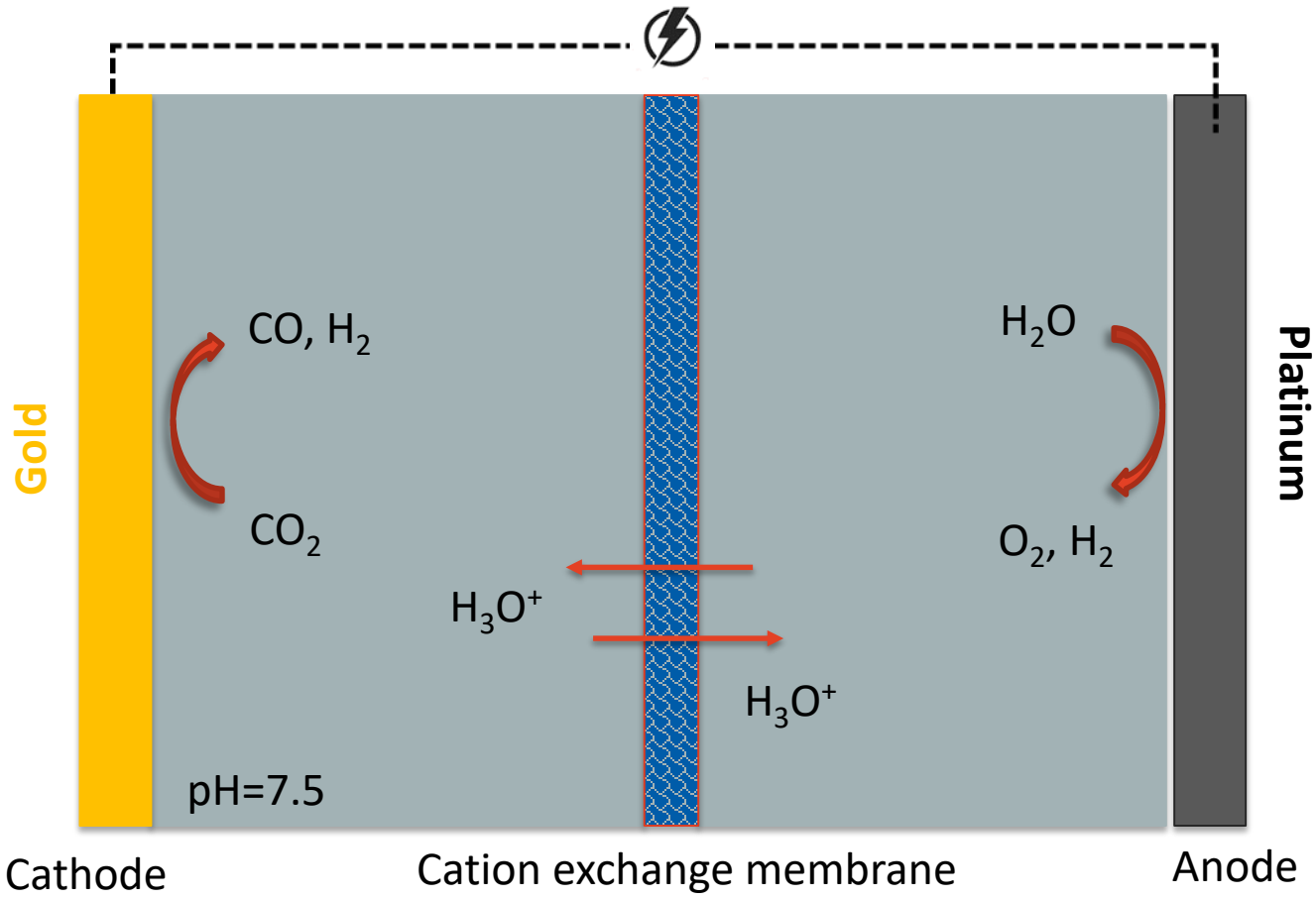
Base case:

Electricity Cost:	0.038 €/kWh
Cell Voltage:	2.47 V
Current Density:	100 mA/cm2
Current Efficiency:	80%
Electrolyser Costs:	510 €/m2·annum
Other Costs (f):	2.5
Reactant Costs:	0.076 €/kg product

Sensitivity analysis for CO formation



Reduction of CO_2 (Benchmark case)

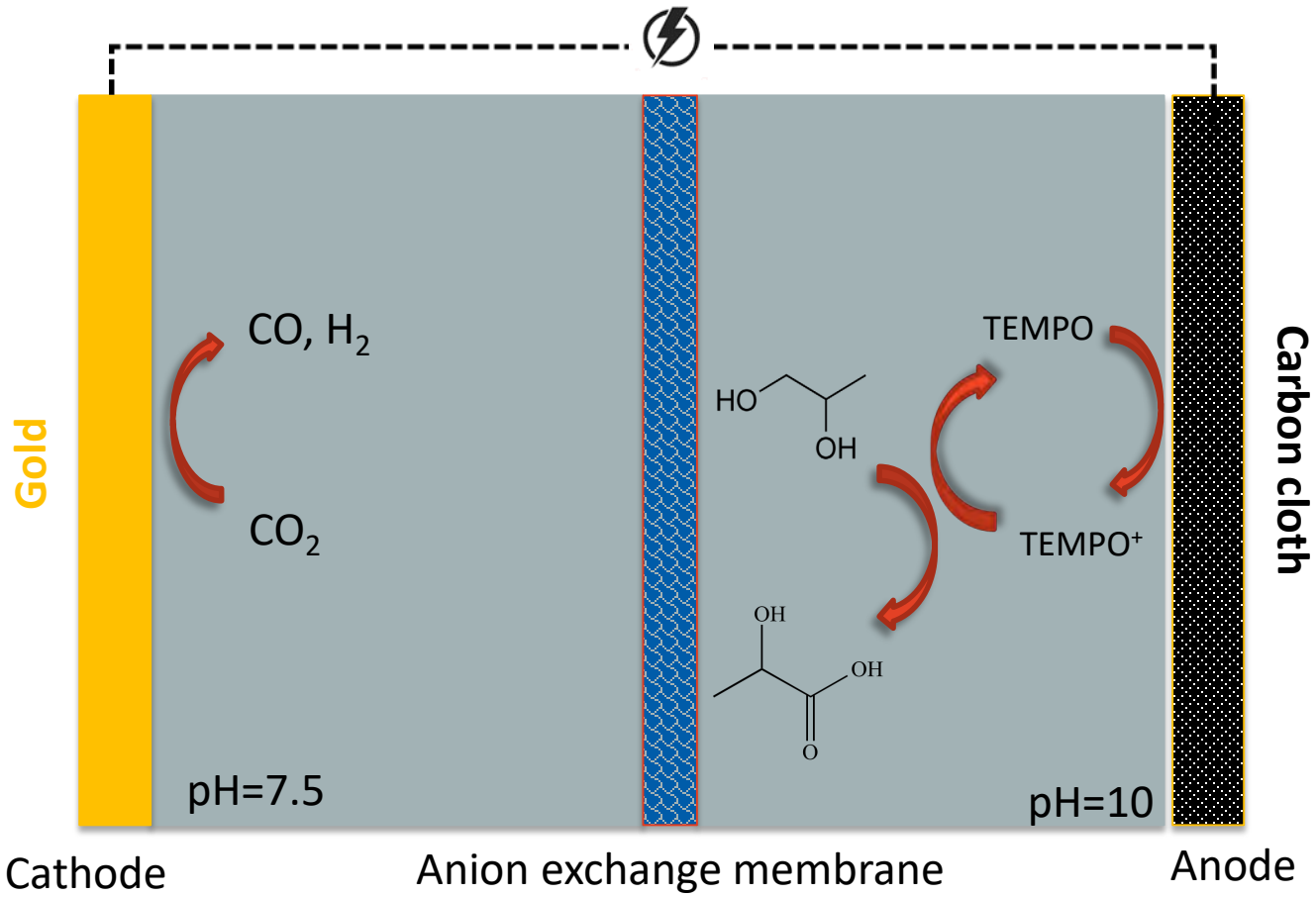


Most of the research has concentrated on the development of the cathode. Some studies exist also on the electrolytes, membranes, anode materials.

Our strategy

- How to improve the economically feasibility of CO_2 reduction?
  - ➢ Formation of 2 value-added products

Paired electrolysis concept



- Replace Pt anode with carbon anode
- Replace the O2 production by lactic acid production.

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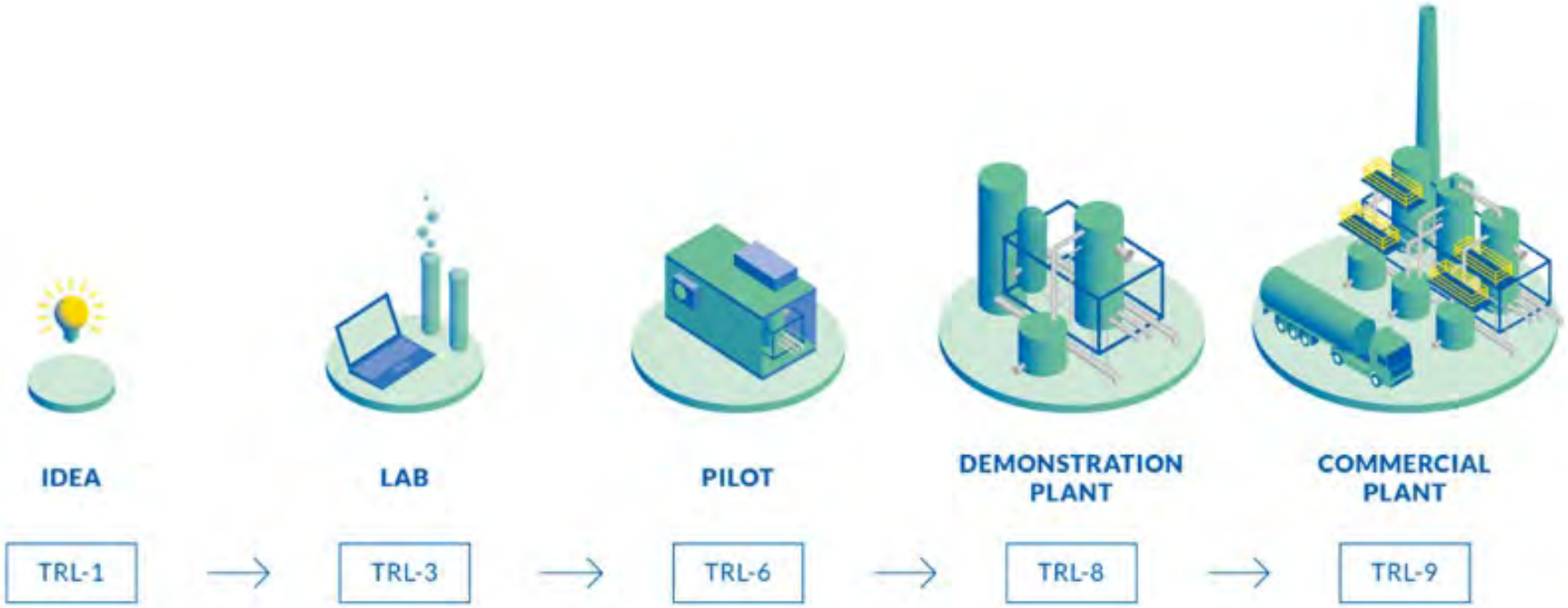
Why Lactic acid production?

- Feedstock is bio-based material
  - PDO can be easily produced via hydrogenolysis of glycerol which is the main side product of biodiesel production (cheap and abundant)
- Applications of lactic acid
  - Precursor of biodegradable polymers (Polylactic acid)
  - Food industry (for the production of yogurt)
  - In cosmetic industry (antimicrobial, moisturizing)
  - In pharmaceutical industry (synthesis of drugs and against osteoporosis)
- Demand of lactic acid : 150,000 metric tones per year
- Price of lactic acid: 1,38 €/kg
- Technical reasons:
  - Can be formed efficiently on cheap carbon electrodes
  - Lower oxidation potential than OER

Our approach: Scaling up



Our approach: Scaling up

Catalyst activity characterization

Optimization of flow, temperature, pH

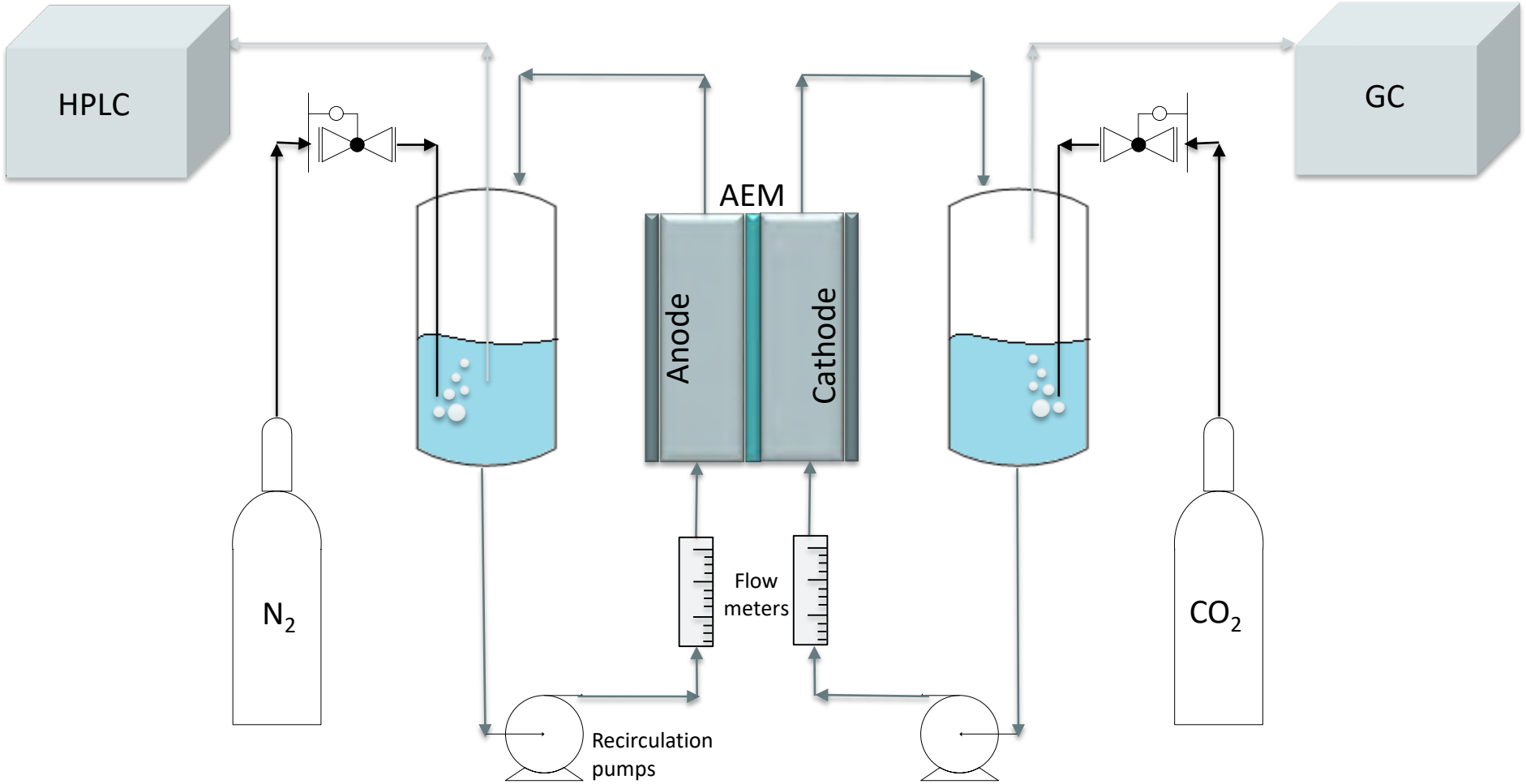
Continuous operation, higher productivity

Glass H-cell

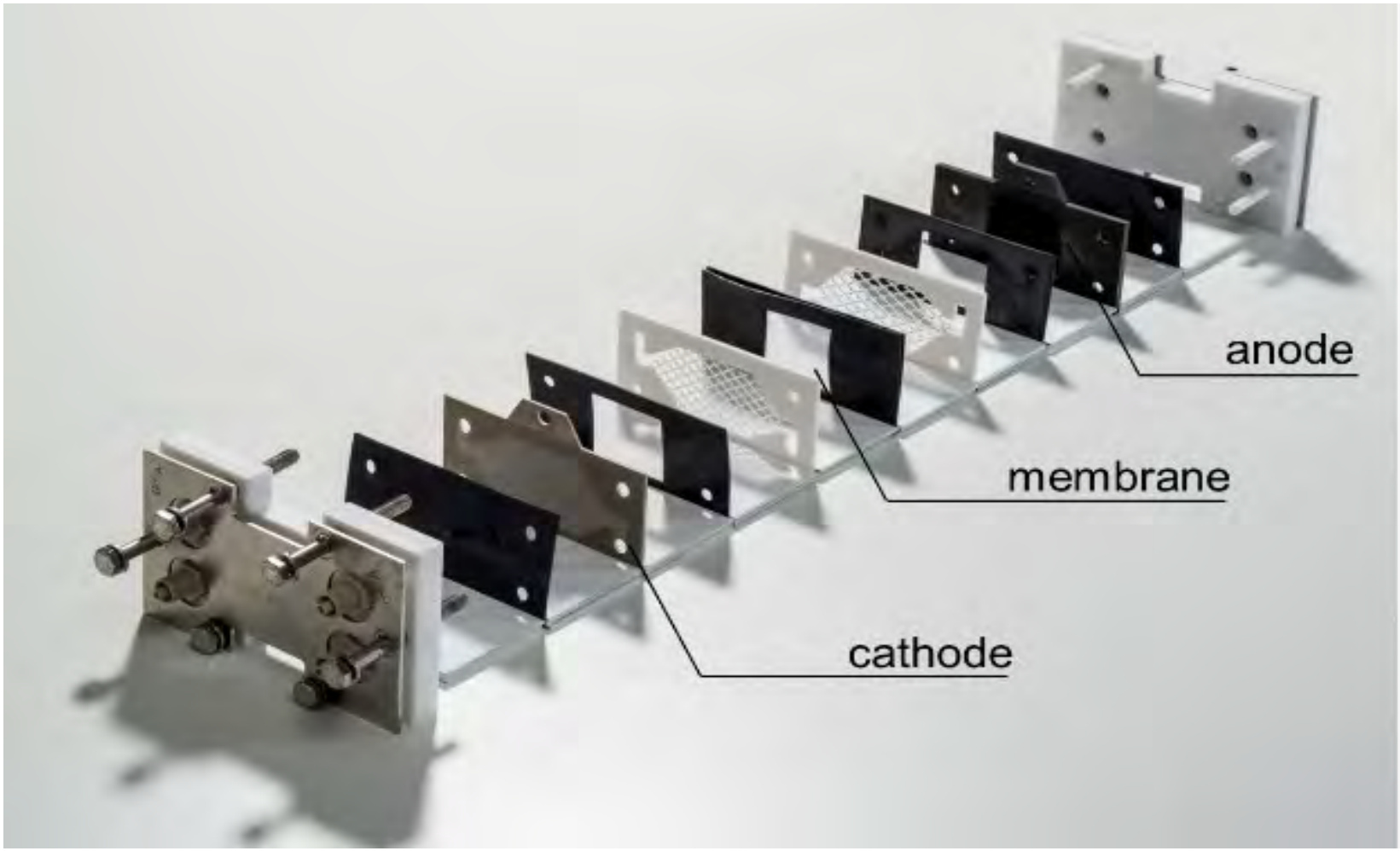
Flow cell ambient pressure

Flow cell high pressure

Experimental set -up

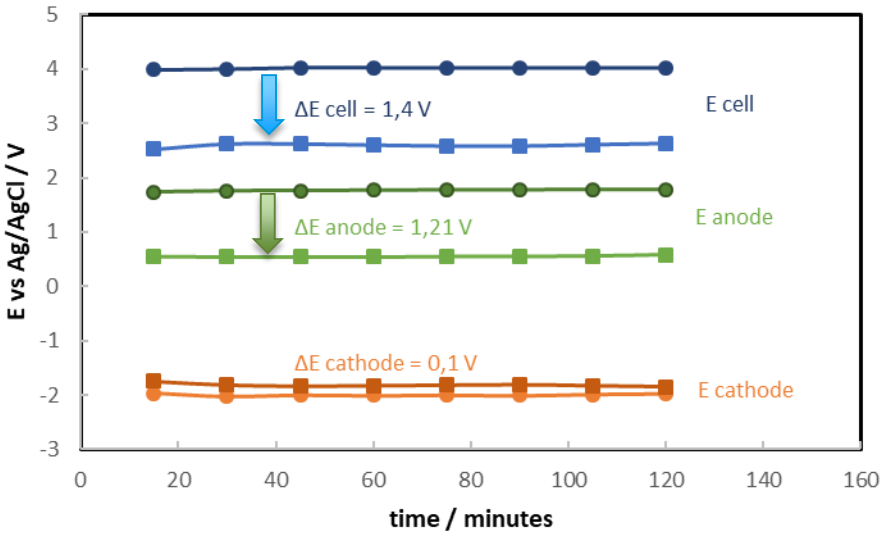


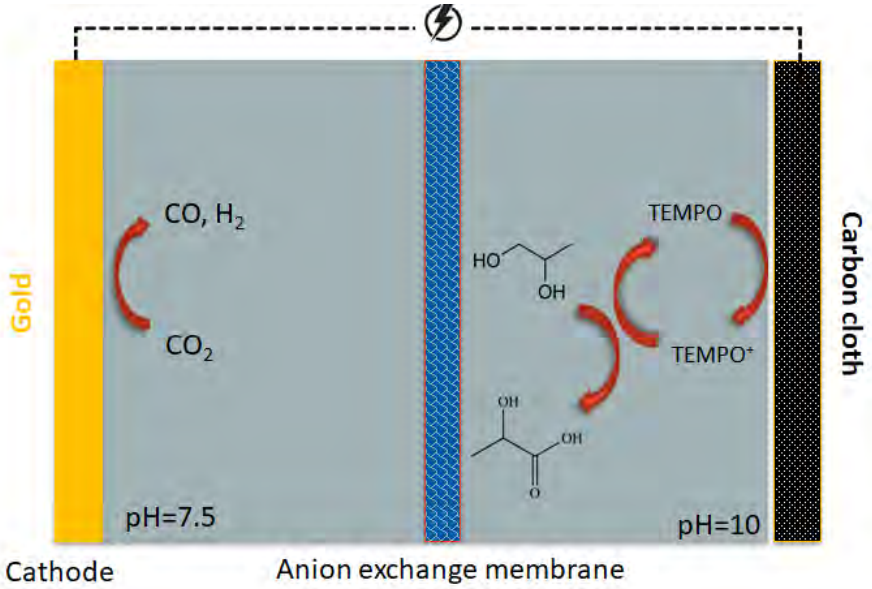
Flow filter press cell



Paired electrolysis results

- Potentials measured during chronopotentiometry at -15 mA/cm^2





- Decrease in cell voltage → Decrease in energy demand

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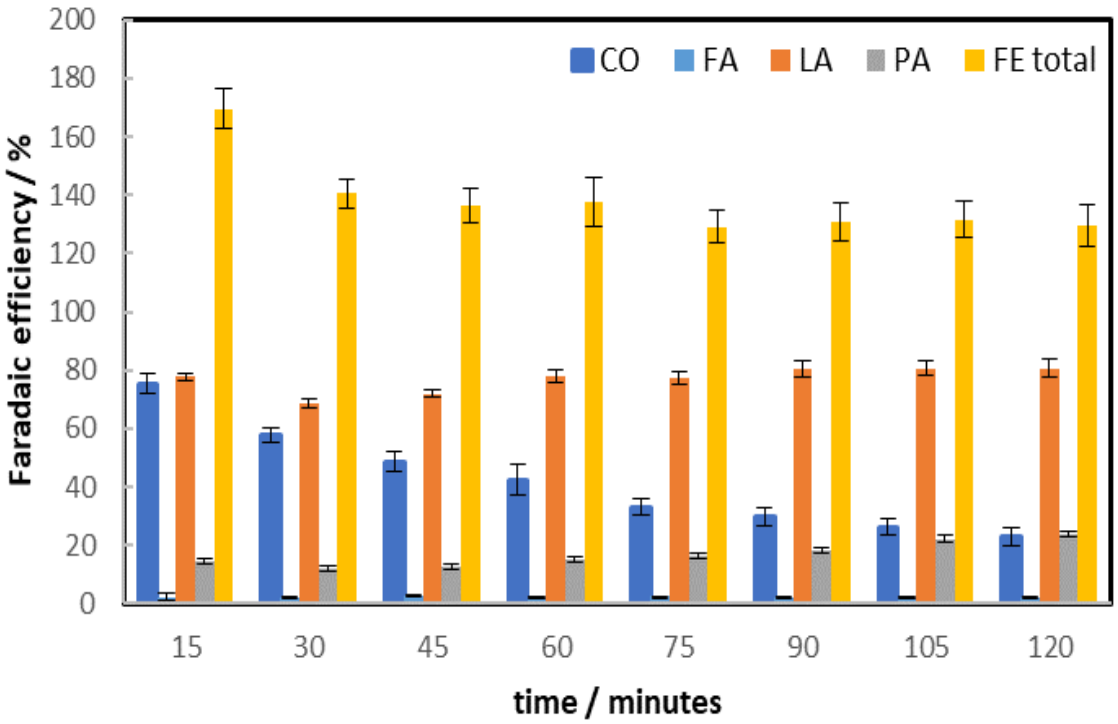
Paired electrolysis results



- The current is used to form 2 valuable products
- Total combined faradaic efficiency ~150 %

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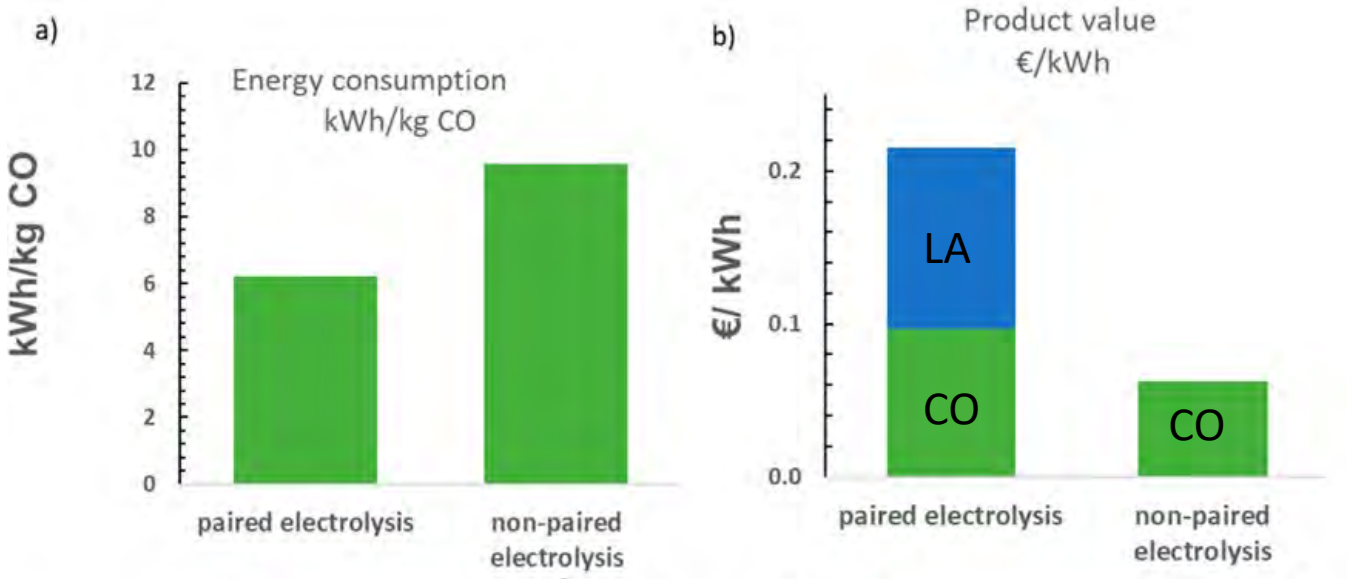
Techno-economical comparison of paired and non-paired electrolysis

OPEX



Benefits of Paired Electrolysis

- 35 % decrease of energy consumption per kg of CO
- 4-fold increase in product value per kWh

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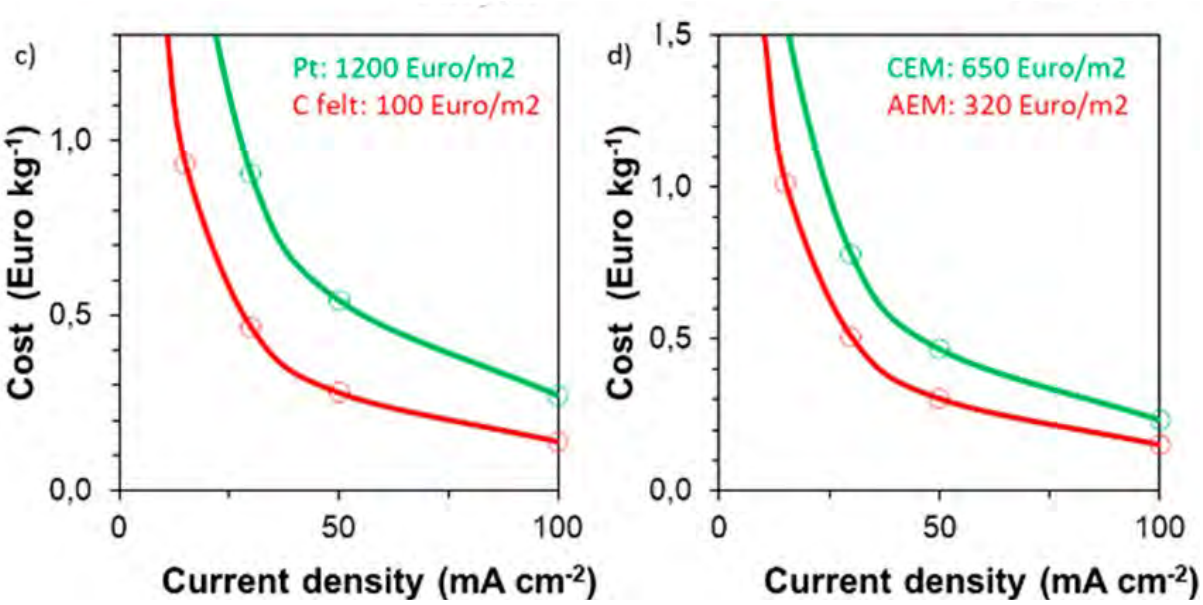
Technoeconomical comparison of paired and non-paired electrolysis

CAPEX



Benefits of Paired Electrolysis

- Decrease of CAPEX due to cheaper materials

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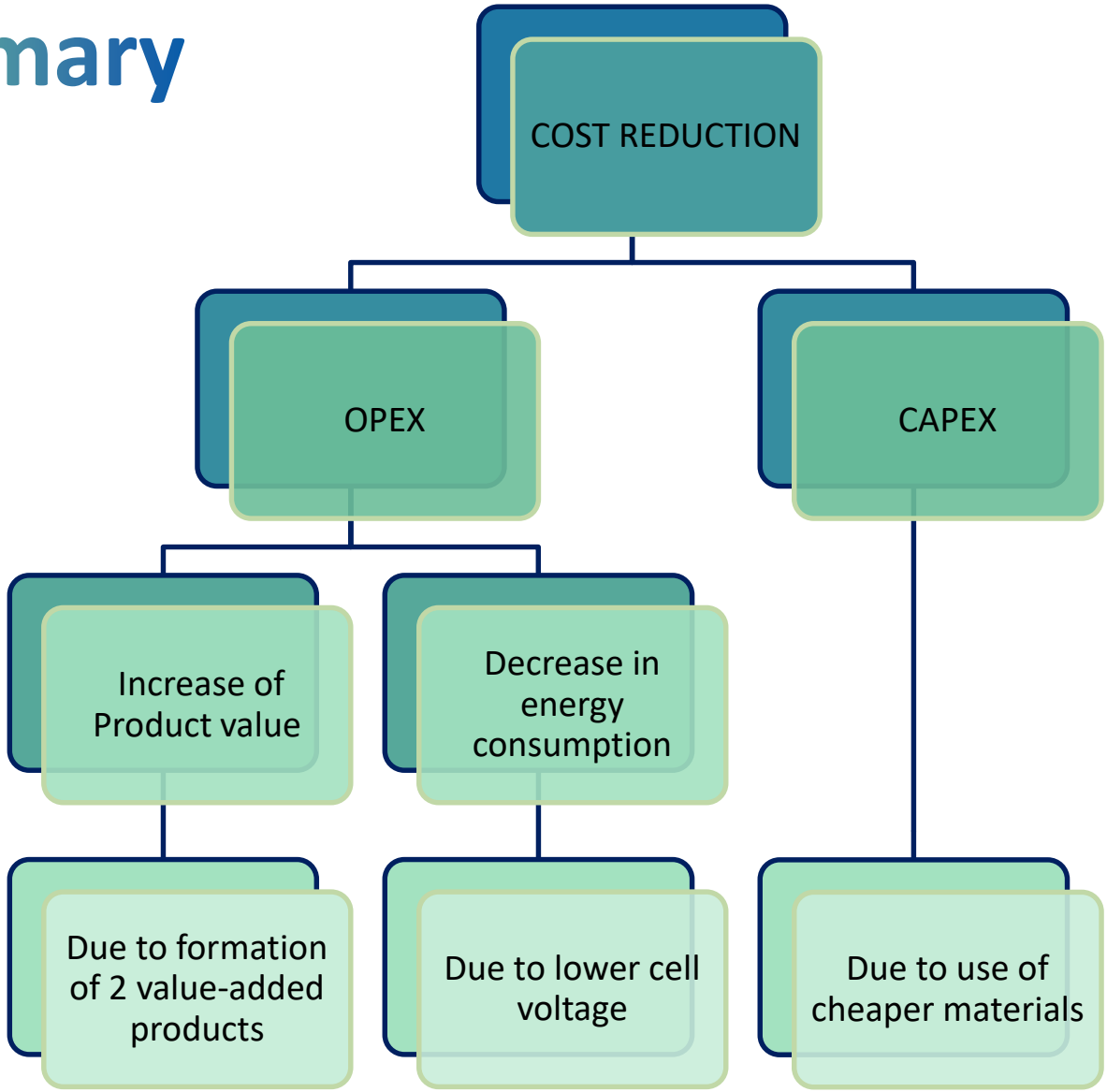
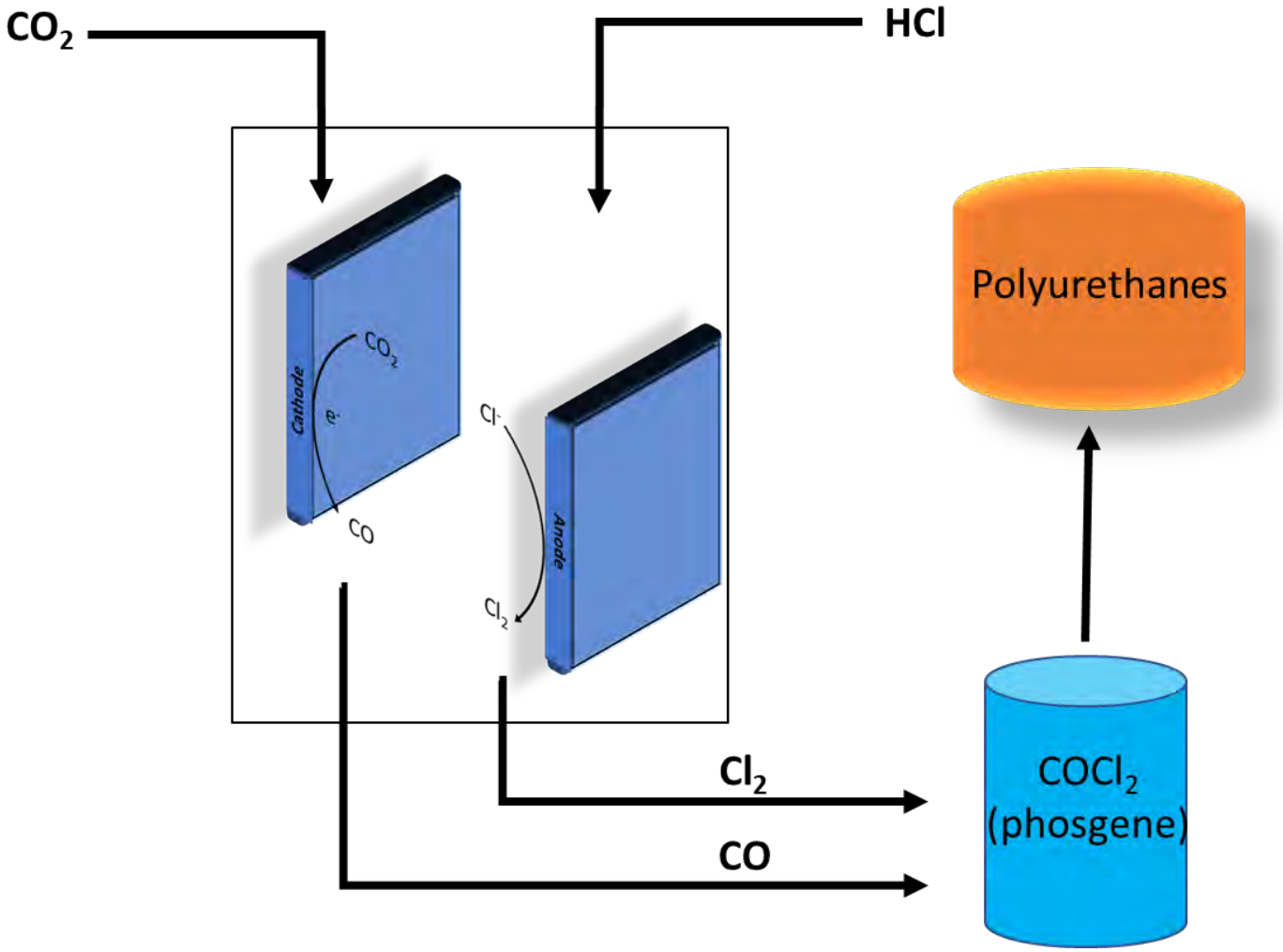
Summary


COST REDUCTION
OPEX
CAPEX
Increase of Product value
Decrease in energy consumption
Due to formation of 2 value-added products
Due to lower cell voltage
Due to use of cheaper materials

Other paired electrolysis



Voltachem team

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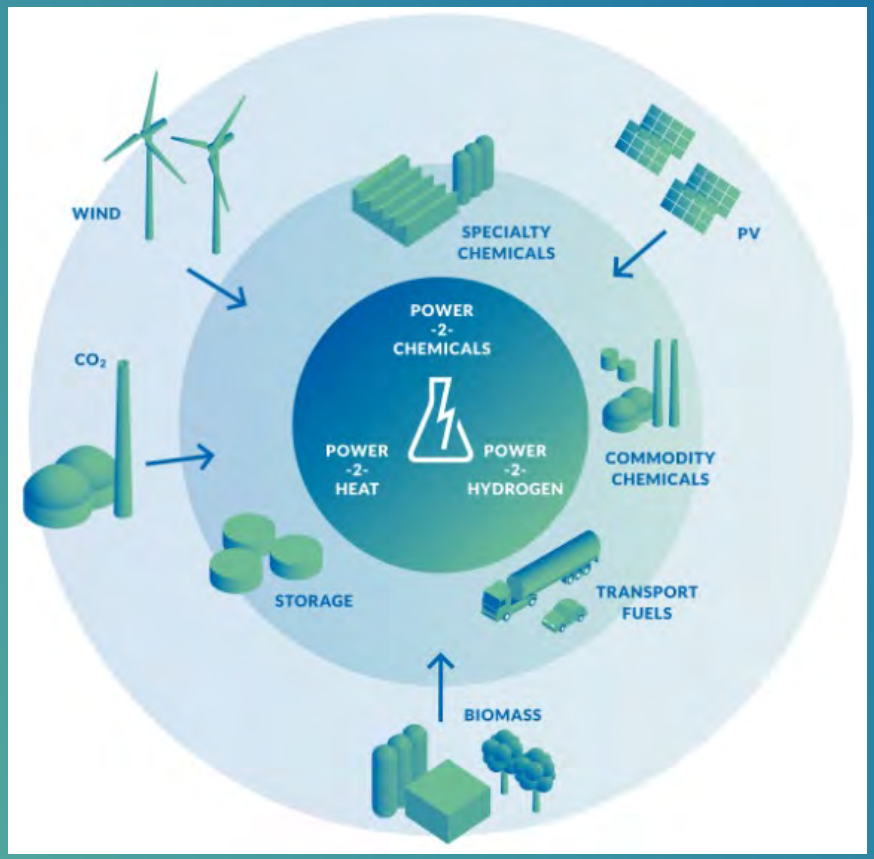
Let’s energize innovation together!



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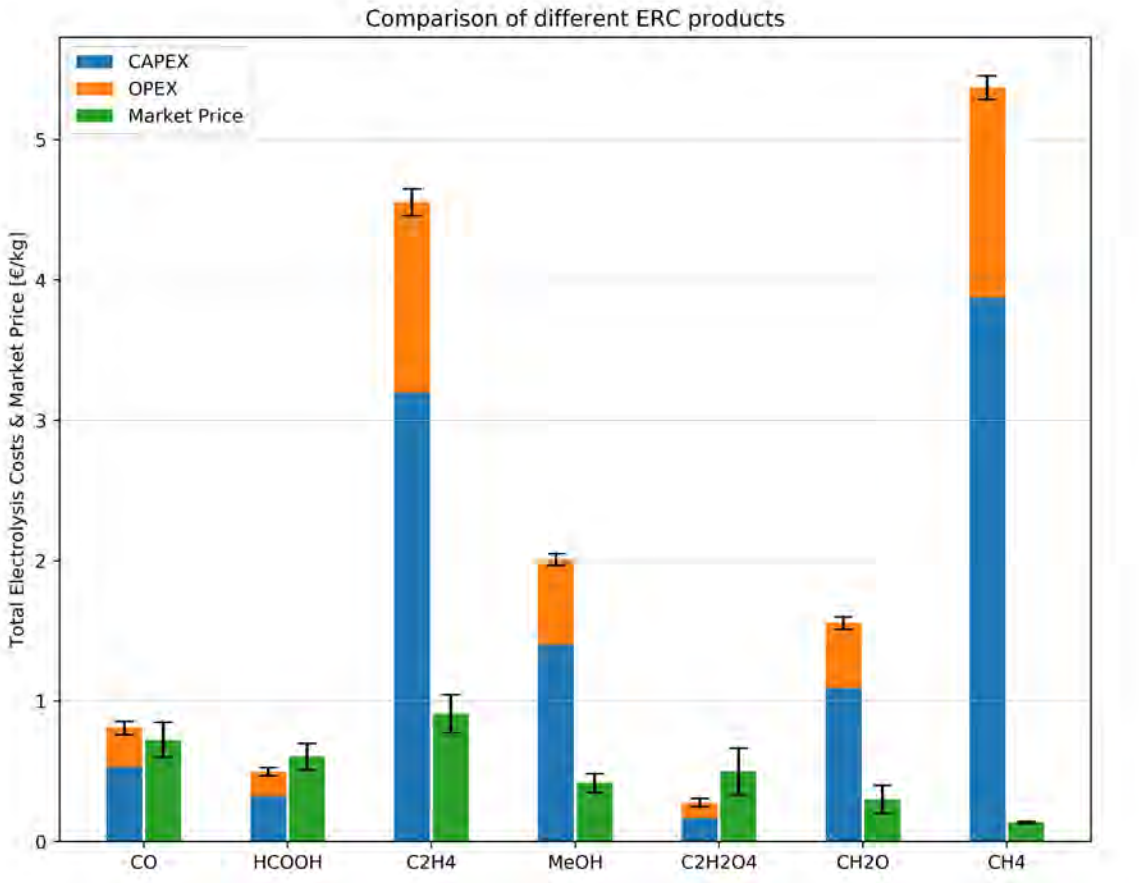
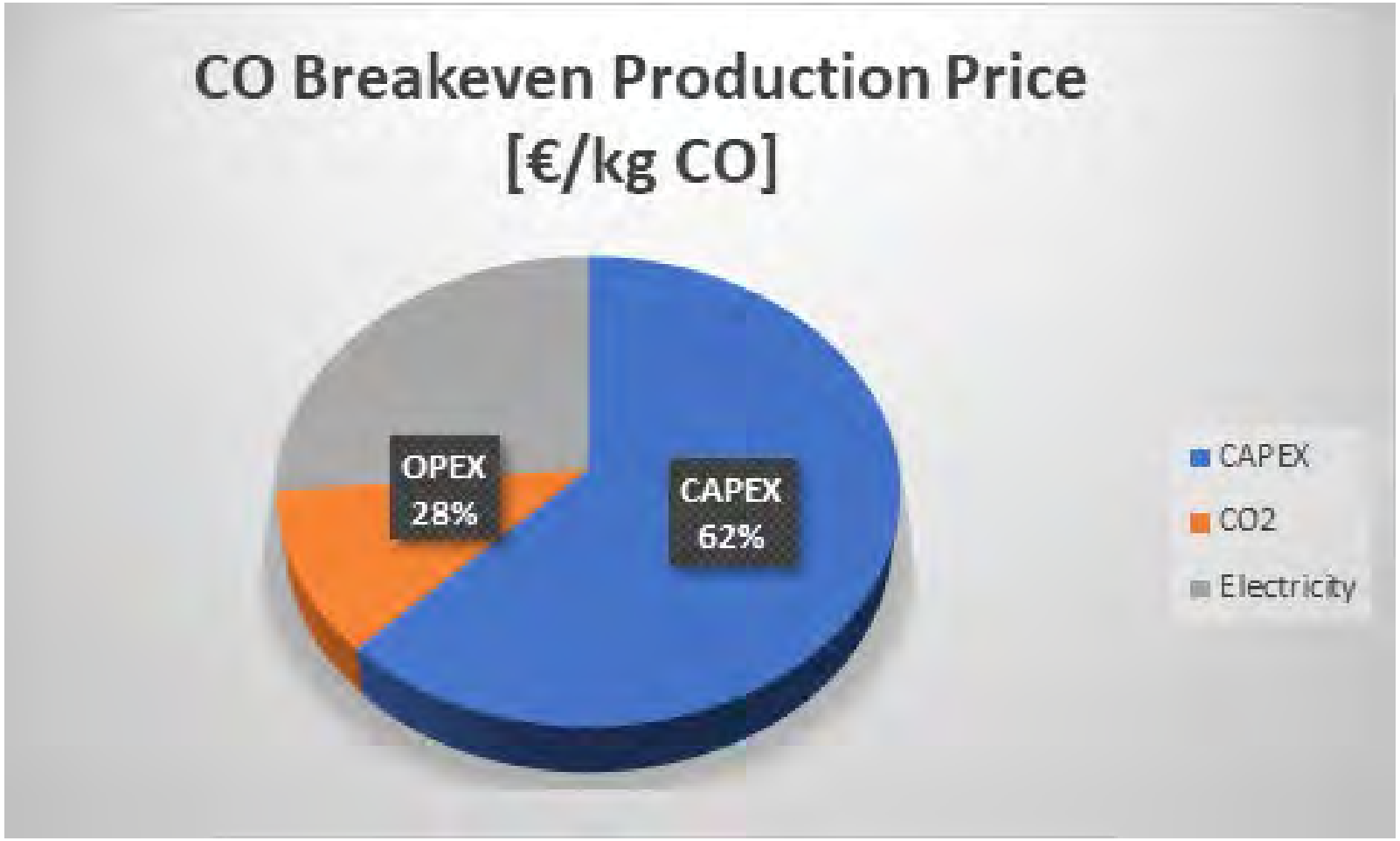
Total electrolysis cost



CO breakeven production price



OPEX calculation

- (Specific energy usage · Electricity cost) + CO_2 cost

$$SPE\left[\frac{kWh}{kg\ product}\right] = \frac{n_{e^-} \cdot F\left[\frac{C}{mol}\right] \cdot \Delta V_{Cell}[V]}{C.E. \cdot M_{product}\left[\frac{kg}{mol}\right]} \cdot \frac{1\ kJ}{10^3\ J} \cdot \frac{1\ kWh}{3600\ J}$$

Electricity cost: 0,038 €/kWh

CO_2 cost: 50 €/ton

CAPEX calculation

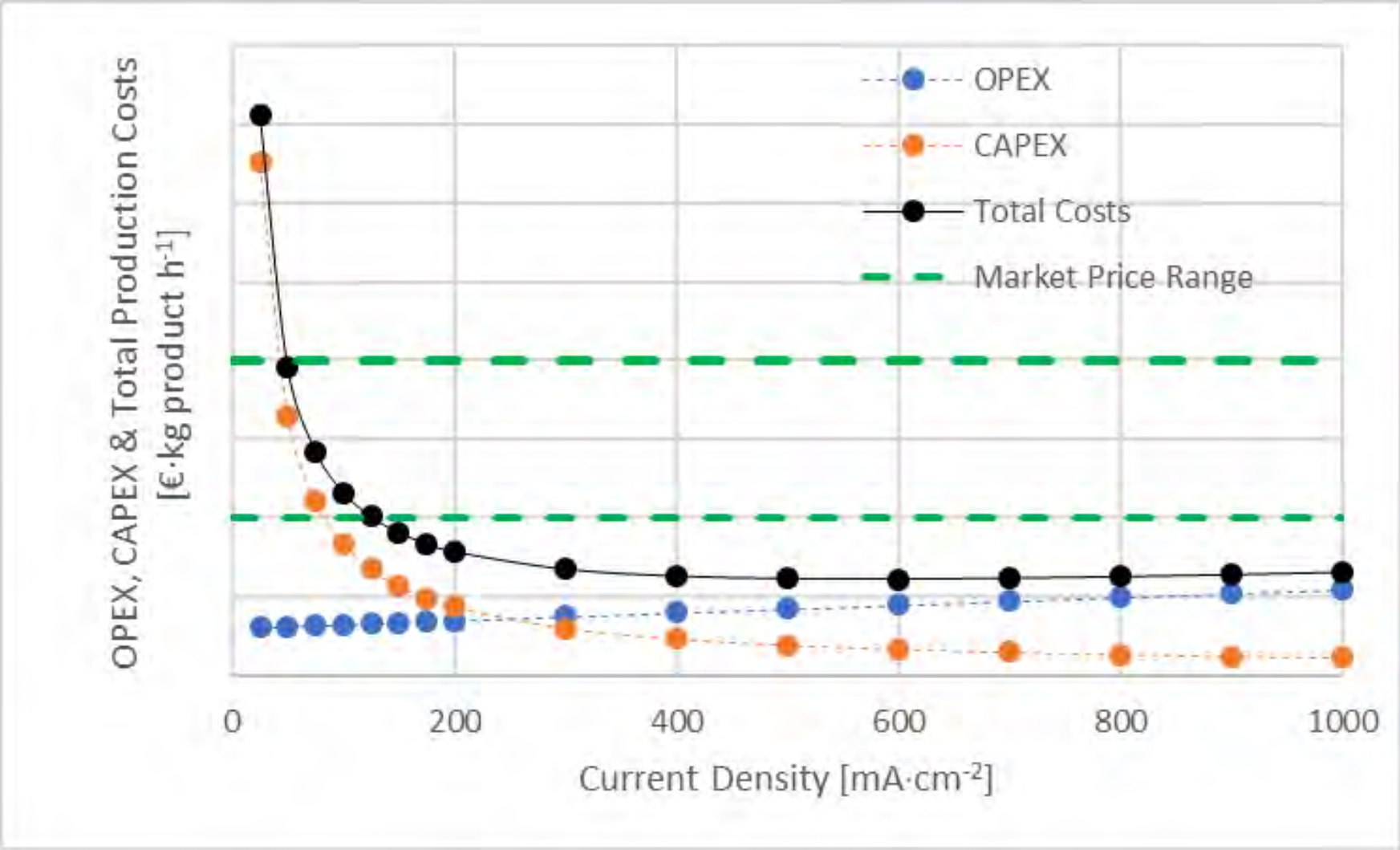
$$CAPEX\left[\frac{€}{kg\ product}\right] = (1+f)\cdot {}^{Electrolyser}Cost_{Total}\left[\frac{€}{kg\ product}\right]$$

$${}^{Electrolyser}Cost_{Total}\left[\frac{€}{kg\ product}\right] = \frac{{}^{Annualised\ Electrolyser}Cost_{Total}\left[\frac{€}{m^2\cdot annum}\right]}{Productivity\left[\frac{kg\ product}{m^2\cdot annum}\right]}$$

$${}^{Annualised\ Electrolyser}Cost_{Total}\left[\frac{€}{m^2\cdot annum}\right] = \sum_i \frac{Costs\left[\frac{€}{m^2}\right]}{Exp.\ t_{life}[anni]}$$

$$Productivity\left[\frac{kg\ product}{m^2\cdot annum}\right] = \frac{j\left[\frac{A}{m^2}\right]\cdot C.E.}{n_{e^-}\cdot F\left[\frac{C}{mol}\right]}\cdot M_{product}\left[\frac{kg}{mol}\right]\cdot Op.Time\left[\frac{h}{annum}\right]\cdot\frac{3600s}{1h}$$

Optimum


OPEX
CAPEX
Total Costs
Market Price Range
OPEX, CAPEX & Total Production Costs [€·kg product h-1]
0
200
400
600
800
1000
Current Density [mA·cm-2]