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Workshop: Advancing Water Electrolysis with Cutting-Edge Catalysts, Electrodes, and Sustainable Solutions

REDHy

Redox-Mediated economic, critical raw materials free, low capex and highly efficient green hydrogen production technology

Duration: 01.01.2024 – 31.12.2027

Clean Hydrogen Partnership

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1. Objectives and expected outcomes

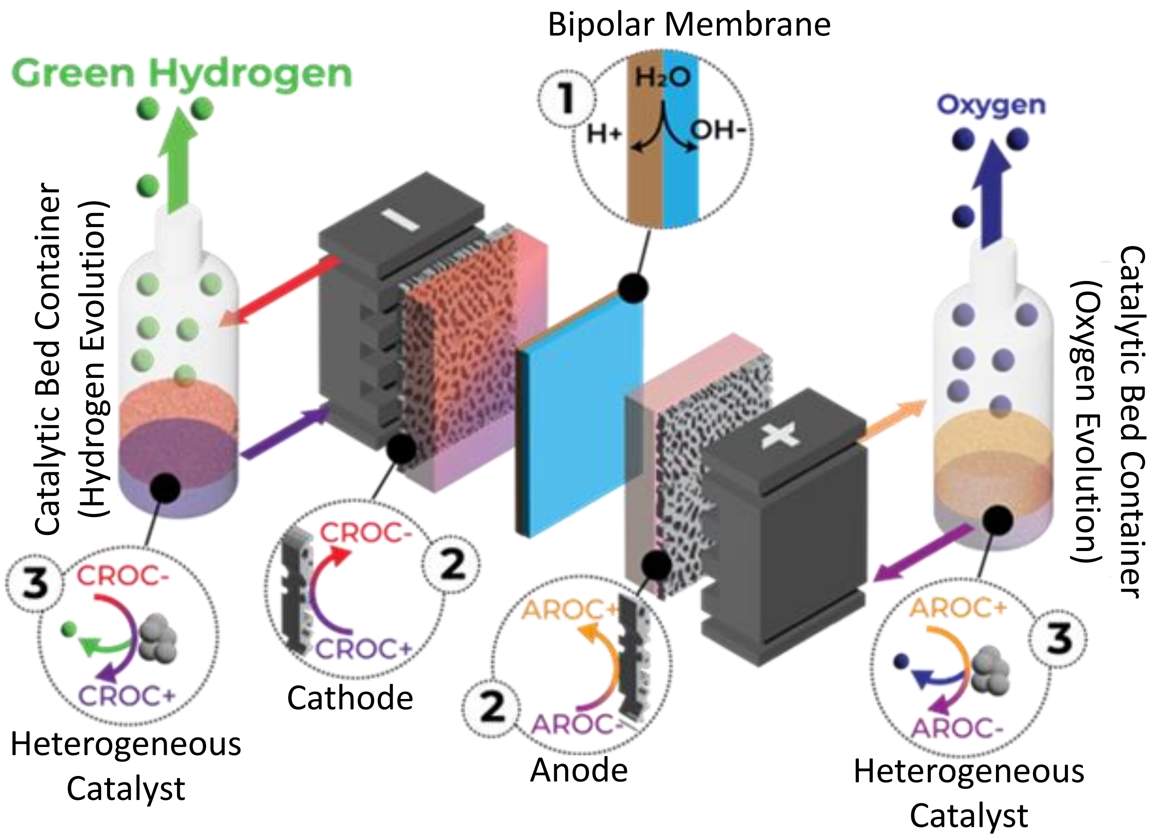
Objectives

1	Develop **highly efficient and durable materials free of critical raw and fluorine free materials**.
2	Validate the stack's efficiency and robustness to **address dynamic situations** frequently occurring when the electrical grid is fed by a large proportion of renewable energy sources or directly interfaced RES.
3	Eliminate the use of and the need for **critical raw materials and fluorinated membranes and ionomers at stack level**.
4	Demonstrate optimization strategies for the porous electrodes to enhance their **mass transport characteristic** and enhance energy efficiency.
5	Demonstrate a **reduced energy consumption** by implementing highly reversible, **stable redox mediators with enhanced kinetics**.
6	Demonstrate a **drastic reduction in interface resistance** across all cell components.
7	Demonstrate the **decoupling of oxygen and hydrogen production** and enabling the REDHy system to operate at min. 5 % partial load operation without exceeding 0.4 % of H_2 in O_2.
8	Demonstrate that the technology is capable to perform efficient and **direct seawater electrolysis**.
9	Integrate the short stack in a **prototype full system**.
10	Demonstrate the operation at **1.5 A/cm² over at least 1200 hours** of operation.

Expected Outcomes

1	Transforming electrolyser into next generation devices with a higher level of competitiveness in comparison to classic alkaline and PEM electrolysers.
2	Develop CRM free, highly efficient and stable materials with the ability to mass-production and a circular-economy character that an be adapted to water electrolysers.
3	Open new ways for disruptive concepts towards performance levels close to the theoretical Higher Heating Value of these electrolysers, i.e. higher to what is typically observed in cells and stacks for conventional alkaline and PEM electrolyser.

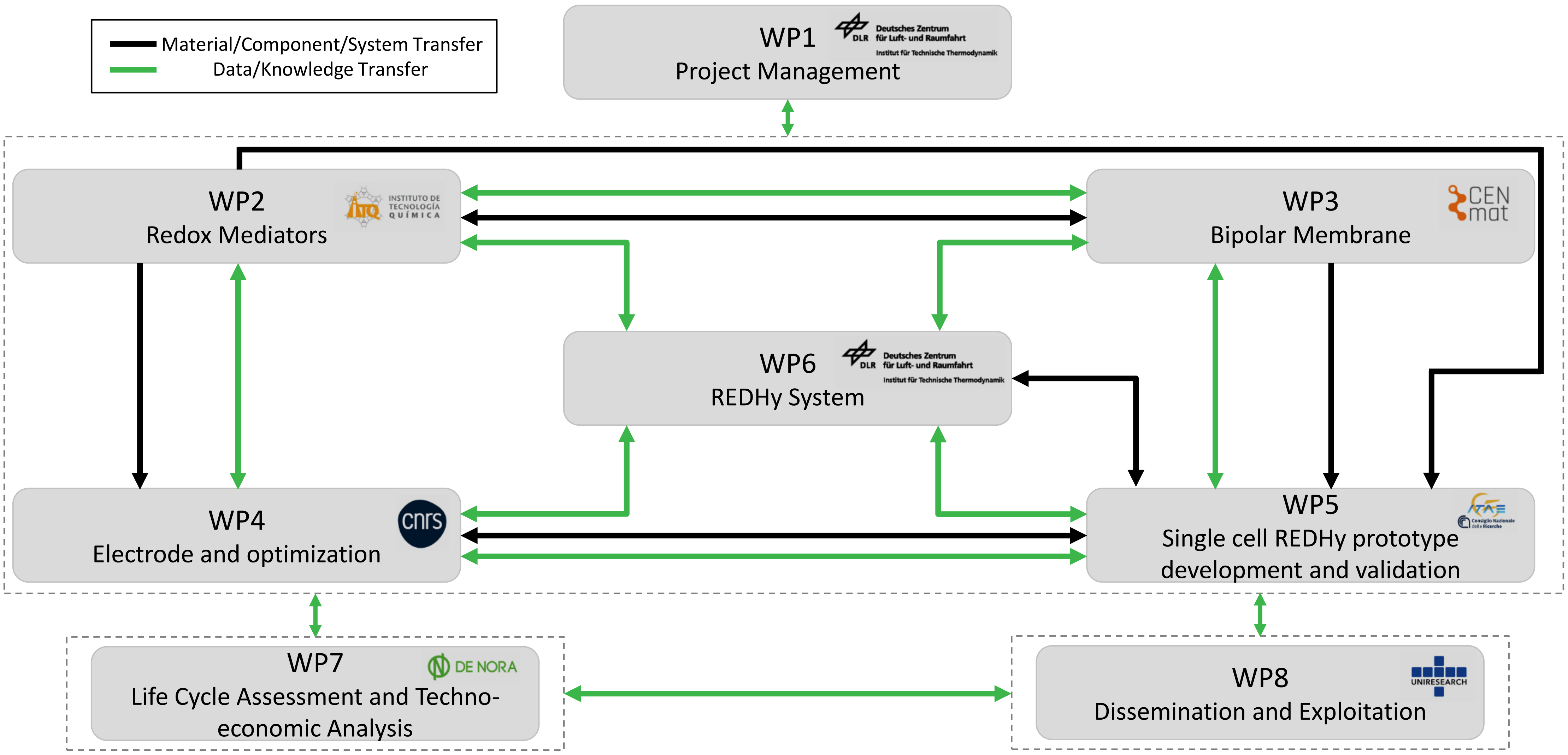
2. Concept of REDHy



Three-step process:

1. Applied potential initiates water dissociation into protons and hydroxide ions traveling to the opposite charged electrodes
2. At the electrodes cathodic redox couples (CROC) and the anodic redox couple (AROC) are fed and changed by the applied potential
3. Charged CROC and AROC are transferred to the catalytic bed container reducing the protons to hydrogen and oxidizing the hydroxide to oxygen in contact with the heterogenous catalysts in the catalytic bed

3. Project consortium



4. Project methodology

Development (1)

Redox Mediators:
- CRM free, stable and economic
- Synthesis of AROC and CROC
- Characterization: impurities, physical and spectroscopic properties, modelling

Electrodes: advanced porous CRM free with enhanced kinetics and mass transfer
- Design of 3D structured electrodes by modelling
- Fabrication: 3D printing
- Characterization: nano-electrical properties and reaction kinetic of redox mediator

Bipolar membrane: high performant, non per-fluorinated
- Base material: CENmat's proton exchange polymer ProFLX
- Combined with microphase separated copolymers
- Characterization: proton conductivity, ion exchange capacity, mechanical properties and water uptake
- Result: Optimal architecture and preparation method

Heterogeneous Catalyst: CRM free
- Material synthetized for specific environmental conditions
- Examined ex-situ to determine their redox potential
- Validation ex-situ in heterogeneous reaction for water splitting in presence of specific redox mediator

REDHy System (2)

Single cell prototype:
- Developed parts will be assessed in prototype consisting of a single cell and external catalyst reactor
- Screening of components under practical operating conditions (TLR3)
- System evaluated at different temperatures (identify optimal range and potential degradations mechanisms

Short-stack prototype:
- Scale-up of single cell
- Base materials: graphite and stainless steel
- Injection moulded components

REDHy System:
- Stack and heterogeneous reactors
- Better understanding of transport phenomena at pressure and electrochemical reaction rates as a function of operating conditions
- Accelerated stress test
- Measurements: electrochemical, LC-MS, ICP-MS, ex-situ (AEM, SEM, …)
- Gas production at different distances to prove security improvements
- Aim: enhance functional materials and components for optimal operation
- Operating under labor conditions for 1500 h (TLR4)

Environmental and economic impact assessment (3)

Life cycle assessment (LCA):
- Identifying opportunities to improve environmental behavior during development process, by providing ex-ante ecodesign measures

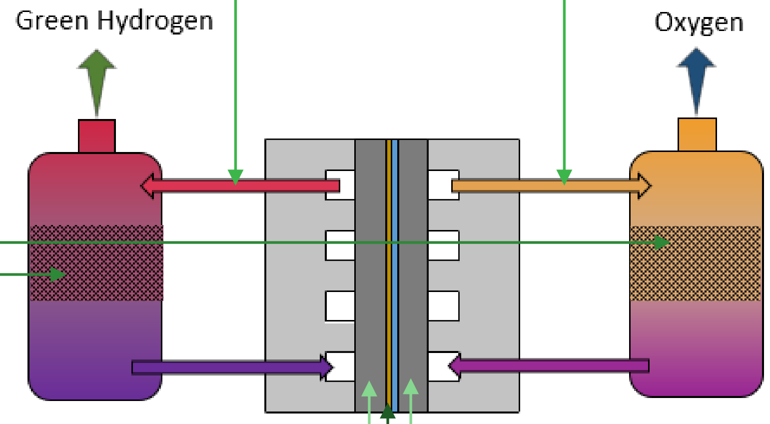
Life Cycle Inventory (LCI)+Life Cycle Impact Assessment (LCIA) :
- All stages in the value chain including upstream and downstream processes related to the use of end-of-life phases of the system
- Quantification of incoming/outgoing material flows and energy flows
- Combining input data collected by partners with reliable and available literature sources, industry-average life-cycle data from life-cycle-inventory databases

Techno-Economic Assessment (TEA):
- Carried out in second part of project, once data quality of operational phase of REDHy will increased

Circularity assessment:
- Quantify absolute consumption of materials
- Potential recyclability over entire life-cycle

5. How the project addresses material development for water electrolysis

- **Redox Mediator Couple:**
  - Adaptation to the system and heterogeneous catalyst
  - Observe and calculate the solubility and potential in water and sea water
  - Stable at temperature ≥ 60 °C
  - Stable at current density of 1.5 A/cm²
- **Heterogeneous Catalyst:**
  - CRM free, XRD, TEM, XPS
  - Optimal and efficient hydrogen/oxygen evolution
  - Stable in electrolyte
- **Bipolar Membrane:**
  - Interfacial catalysts, anion and proton exchange parts
  - Stable at temperature ≥ 60 °C
  - Stable at current density of 1.5 A/cm²
- **Electrode:**
  - CRM free, 3D printed
  - Stable at current density of 1.5 A/cm²
  - Voltage < 1.8 V
  - Printable



6. How the project addresses sustainability and circularity

Sustainability

- Reduced resources depletion:
  - Eliminating the use of CRM, depletion of scarce natural resources will be reduced potentially reducing the environmental impact of mining and extraction processes
- Lower energy consumption:
  - Highly efficient system will reduce the overall energy consumption for green hydrogen production and lower carbon footprint of green hydrogen even further
- Reduced ozone depletion potential (ODP):
  - Independency for CRM could lead to a significant reduction of ODP of electrolysis in comparison to today's SoA electrolysis, contributing to a more sustainable green hydrogen production process

Circularity

- Focus on recyclable materials
- LCA, TEA

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