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ELECTROLIFE

Enhance knowledge on comprehensive electrolysers technologies degradation through modeling, testing and lifetime prevision, toward industrial implementation

Deliverable report

D1.9 – Annual progress report M12

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1 Introduction

This document is an overview of the progress the ELECTROLIFE project has made in the first 12 months since the start of the project on 1 January 2024 (M1-M12). The annual report is divided into five sections, of which section two and five contain the most important information.

Section two provides a detailed report of the activities done in the first twelve months of each work package and how these contributed to the progress of the targets and objectives. The fifth section summarizes the progress over the first year in a conclusion and provides recommendations for the second year of the project.

The document furthermore provides an overview of the deliverables and milestones achieved in the first year, an overview of the meetings, conferences and events in which the ELECTROLIFE partners have participated and three unforeseen risks which have been identified in the first year.

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2 WP technical update

WP1: Project Management and Coordination

T1.1 Technical and Scientific Coordination (lead: POLITO; participants: WP leaders) [M1-M60]

In M2 D1.1 Project Handbook was prepared and submitted, providing an overview of detailed explanation on project governance, meetings, the work plan, reporting, communication and dissemination rules, and confidentiality. This project handbook is meant as the guide for the project and will therefore be reviewed and updated if deemed required with updated information in an appendix. Furthermore, through the monthly Executive Board (EB) meetings and by joining dedicated (WP) technical progress meetings, the coordinator POLITO has supervised the progress of the activities. In this way, the coordinator was able to monitor any changes and act upon when needed (more information on any changes of activities in relation to the GA, see the different WP sections). Besides, POLITO has kept close alignment with the Clean Hydrogen Partnership and JRC regarding test activities and EU protocols.

UNR as project manager has set up monthly EB meetings, in which the WP leaders present the progress in their respective WPs, but also the close monitoring of any changes or possible risks are part of the EB agenda. For each meeting, WP leaders prepared a status update on ongoing activities, progress towards deliverables and milestones, and possible risks of their WP. Below an overview of the EB meetings in the first year.

EB#	Date
EB01	26 March 2024
EB02	23 April 2024
EB03	28 May 2024
EB04	25 Juni 2024
EB05	23 July 2024
EB06	27 August 2024
EB07	22 October 2024
EB08	26 November 2024
EB09	17 December 2024

Table 1 Overview of the Executive Board (EB) meetings held between M1-M12

Regarding the quality assurance, see D1.2 Initial Quality Assurance and Risk Management Plan., D1.2 describes how the quality of the work will be ensured and how risks will be identified and managed. In the first 12 months, POLITO and UNR have set up a review matrix, ensuring that two peer-reviewed experts assess each deliverable, in accordance with all the consortium members.

T1.2 Administrative and Financial Management (lead: UNR; participants: POLITO) [M1-M60]

As detailed in D1.1, the project management team (UNR, POLITO) has set up a framework of administrative and financial practices to constantly assess and monitor the project execution versus the project targets to achieve the project objectives. In addition to the kick-off meeting, one General Assembly Meeting as well as regular (once per month) Executive Board meetings were held to exchange information, update each other, discuss issues and highlights and make decisions and define next steps. Furthermore, the coordinator organised several meetings with the PO to know each other

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in person and to present the status and address several subjects for discussion and clarification. Most of these meetings were online, but he met the PO in person on 19-20 September 2023 at the headquarters of Clean Hydrogen Partnership in Brussels.

A Data Management Plan (D1.3) – in line with the Guidelines and FAIR Data Management in Horizon Europe – has been elaborated and prepared by POLITO with support of all partners in M6. The ELECTROLIFE data management plan (DMP) describes the data management lifecycle for all datasets being collected, processed, or generated through the project. It describes the policy for handling all the datasets generated within the project, how research data will be generated, collected, and handled during the project and after it is completed, describing what data will be collected/generated and what methodology and standards will be followed.

T1.3 Risk Management (lead: UNR; participants: WP Leaders) [M1-M60]
D1.2 Initial Quality Assurance and Risk Management Plan has been drafted and prepared by UNR describing and identifying risks and contingency plans and risk management protocols how to handle with (un)foreseen risks in the project. UNR has set up a risk monitoring file and during every EB meeting risks are identified and mitigation strategies are defined.

T1.4 Annual reporting for the Clean Hydrogen JU (lead: POLITO; participants: WP Leaders) [M1-M60]
UNR has set up a template and every WP leader, with input from the partners, will prepare an annual report of the activities done so far, including an overview of recommendation for the upcoming year and future steps in the project.

T1.5 KPIs reporting and monitoring
In the first periodic report an assessment of the progress towards achievement of the project KPIs will be provided in each of the reporting periods.

WP2: Degradation phenomena comprehension

WP2 focuses on comprehensively analysing degradation phenomena in electrolyser technologies to enhance their performance and durability. The goal is to identify and understand degradation mechanisms and develop strategies to mitigate them, particularly in systems coupled with renewable energy sources.

Key Activities:

Comprehensive Analysis:

- Gather and analyse existing studies, projects, and data related to degradation in electrolyser technologies (AEL, AEMEL, PEMEL, SOEL and PCCEL).
- Create a detailed overview of the degradation phenomena and their impact on different electrolyser technologies under various operational conditions.

Identification of Degradation Mechanisms:

- Investigate the causes and processes of degradation observed in electrolysers.
- Focus on the unique challenges posed by coupling these systems with renewable energy sources, such as variable input and environmental stressors.

Experimental Activities:

- Conduct experimental tests on electrolyser components and single cells using innovative materials and solutions.
- Collect and analyse data to build a comprehensive understanding of degradation causes and dynamics.

Development of Mitigation Strategies:

- Use insights from data analysis and experimentation to propose strategies that reduce degradation and extend the lifetime of electrolyser systems.

Significance:

- WP2 serves as a foundational work package, integrating expertise across partners to establish a thorough understanding of degradation phenomena. This knowledge will be used to influence subsequent work packages focused on diagnostics, testing, and technology optimization.

T2.1 Degradation phenomena compendium (lead: POLITO; participants: All partners) [M1-M12]

Overview

Politecnico di Torino (POLITO), with contributions from all project partners, leads Task 2.1, which is dedicated to building a comprehensive understanding of the degradation mechanisms that affect electrolyser technologies. This task spans the first year of the project (M1–M12) and serves as a cornerstone for subsequent work packages. The process starts with a comprehensive literature review, exploring a rich array of insights from peer-reviewed journal articles, technical reports, and outcomes of prior EU-supported projects. The focus extends across all major electrolyser technologies, including Alkaline Electrolysis (AEL), Proton Exchange Membrane Electrolysis (PEMEL), Anion Exchange Membrane Electrolysis (AEMEL), Solid Oxide Electrolysis (SOEL), and Proton Ceramic Electrolysis (PCCEL), also covering peculiarities of Project Partners technologies (Stargate, 1s1 Energy, Pietro

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Fiorentini/Hyter, SolydEra and Kerionics). This effort is designed to capture the current state of knowledge on degradation phenomena and identify key trends and gaps.
The findings will define targeted pathways for investigation, breaking down the complexities of degradation phenomena into manageable and focused areas of study. These pathways will then guide experimental and diagnostic activities in WPs 3 to 6, ensuring that efforts are aligned and impactful. The outcome of this task will be captured in Deliverable D2.1, a comprehensive report summarizing the findings and laying the groundwork for the project's next steps.

Comprehensive Documentation on Degradation Phenomena in Electrolysis Systems

We have developed a single comprehensive document that addresses the degradation phenomena in both low-temperature (LT) and high-temperature (HT) electrolysis systems. Each document provides a detailed exploration of the specific challenges, mechanisms, and strategies related to these technologies. These extensive documents form the foundation for the ELECTROLIFE project's understanding of degradation mechanisms and will be synthesized and compacted into Deliverable 2.1, which is scheduled for submission in Month 12 (M12). This deliverable will provide a concise and actionable summary of the findings, guiding future research and industrial implementation.

T2.2 Components and single cells degradation analysis (lead: POLITO; participants: FAU, FZJ, TUG, STARGATE, 1s1, PF/HYT, SE, KER) [M1-M24]

Overview

Task 2.2 of the ELECTROLIFE project, led by POLITO with contributions from FAU, FZJ, TUG, STARGATE, 1s1 Energy, PF/HYT, SE, and KER, focuses on investigating degradation mechanisms at both the component and single-cell levels. Running from Month 1 to Month 24, this task is generating essential experimental data to improve understanding and mitigation of degradation in low-temperature (LT) and high-temperature (HT) electrolysis systems.

Scope of Work

This work involves comprehensive data collection from experimental activities on components such as electrodes, gas diffusion electrodes, ionomers, membranes, sealing materials, cell designs, and bipolar plates. Single cells with active areas up to 25 cm^2 are tested to characterize performance and evaluate combined degradation phenomena. Advanced tools, including EIS for LT electrolysis and AST-EIS techniques for HT electrolysis, are employed to expose single cells to accelerated stress tests (ASTs). These tests help identify degradation in individual components, such as catalyst degradation and ionomer agglomeration in LT cells, or Ni coarsening, Ni migration, interface quality, and element interdiffusion in HT cells.

Advanced Analytical Techniques

Electrochemical Impedance Spectroscopy (EIS) is a key technique for both LT and HT electrolysis to monitor component behaviour during testing. This includes measuring internal resistance components like electron transfer, ionic resistance, and mass transport. Operational conditions, including variations in pressure, temperature, and water or electrolyte impurities, are being carefully evaluated. Additionally, different potentiostatic conditions, ranging from 0.1 V to 2.2 V per cell, are analysed to determine optimal operating conditions, focusing on current density dependencies. A Design of

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Experiments (DoE) approach has been developed to guide testing, ensuring that results are robust and relevant.

Progress to Date

Significant progress has been achieved despite challenges. POLITO initiated testing on commercial CCMs with non-PGM elements, utilizing components supplied by Pietro Fiorentini/Hyter for AEMEL systems. These tests focused on activation protocols and long-term durability under steady-state conditions, showing stable performance over 2000 hours. FAU began experimental studies on components provided by Stargate, including ultrasonic stress tests for mechanical stability and electrode activity evaluations in alkaline environments, demonstrating excellent robustness and electrochemical stability.

FZJ (Jülich) initiated testing on state-of-the-art MEAs for PEMEL with plans to compare results against industrial components upon arrival. Custom setups for short- and long-term performance evaluations were implemented. Similarly, TUG advanced work on SolydEra components, focusing on the performance and stability of commercial cells. Stargate and Pietro Fiorentini/Hyter prepared anodes, cathodes, and membranes to support benchmarking tests.

Challenges and Mitigation

While significant progress has been made, there have been delays in the delivery of PCCEL components. Despite this, commercial and SolydERA components for PCCEL are currently under evaluation, contributing to the broader effort of understanding degradation mechanisms and improving electrolyser performance. Mitigation strategies, including close coordination and contingency planning, were employed to address these delays. Other technical issues, such as water supply instability at FZJ, were swiftly resolved.

Testing Protocols and Preliminary Results

Testing protocols have been meticulously developed to simulate steady-state and dynamic operational conditions, with ASTs evaluating stressors like current density, temperature, and pressure. These experiments provided preliminary insights into degradation mechanisms, laying the groundwork for further investigation.

Collaboration and Integration

Collaboration among partners has been critical, ensuring alignment on methodologies and facilitating the exchange of data and components. Results from Task 2.2 are being integrated into WP3 for degradation modelling and WP4 for testing protocol validation, fostering a unified approach across the project.

Next Steps

Looking ahead, the task will broaden its scope to include expanded testing as additional components become available, with a focus on durability and Accelerated Stress Testing (AST) under diverse operational conditions. Advanced electrochemical techniques, such as Electrochemical Impedance Spectroscopy (EIS), will remain critical. The final results will contribute to Deliverable D2.2, incorporating both Beginning of Life (BoL) and End of Life (EoL) characterizations. Task 2.2 continues to be a cornerstone of the ELECTROLIFE project, linking experimental data with modeling and practical applications to drive innovation, improve electrolyzer performance, and extend its operational lifespan.

WP3: Degradation modelling and lifetime prediction

T3.1 Degradation models development (lead: AAU; participants: TUG, ULille, POLITO, VDX) [M1-M51]

Task 3.1 is dedicated to the development of advanced degradation models for electrolysis cells, with AAU leading the effort in collaboration with TUG, ULille, POLITO, and VDX. The four universities—AAU, TUG, ULille, and POLITO—focus on the development of detailed mechanistic models, while VDX applies these models to create a "stressors map," which identifies key operational and environmental factors contributing to degradation. Additionally, EGP has been involved in the activities, with an interest in creating simplified models suitable for the economic evaluation of the identified electrolyser technologies.

In the initial phase of Task 3.1, a comprehensive review of existing models and techniques was conducted, drawing from both academic literature and previous experience of project partners.

The review process was carried out in close collaboration with WP2, where degradation mechanisms were systematically identified and documented for each electrolysis technology under study. This ensured that the modelling work is linked to degradation modes associated with different electrolyser systems. Additionally, the task benefits from testing activities from WP6, where experimental data is generated under controlled conditions to validate the degradation models. Collaboration with WP4 plays a key role, as degradation testing procedures developed there are directly used to guide and benchmark the modelling efforts. Finally, Task 3.1 is linked with WP5 and WP7, where partners such as EGP and VDX focus on simplifying the developed models for practical applications such as monitoring and diagnostic systems and techno-economic analysis.

At cell level, physical modelling approaches, from 0D to CFD, have been considered. All these approaches consider the key physical phenomena such as electrochemical reactions, mass transport, and heat transfer within the cell, with increasing levels of detail. For dynamic modelling, Matlab Simulink has been identified for modelling time-dependent systems, including electrochemical processes in electrolysis cells. ULille is using the bond graph method which provides a flexible platform to model all electrochemical and degradation modes dynamically.

Deliverable D3.1, focusing on cell degradation modelling, is scheduled for completion in December 2025. To ensure a collaborative and efficient process, a structured document outline has been agreed upon, with input contributions from partners for each electrolysis technology. The structure is here outlined:

- **Background**: Overview of the technology and degradation challenges.
- **Methods**: Modeling approaches and simulation of degradation processes.
- **Validation**: Experimental data from partners and validation methodology.
- **Results & Discussion**: Key findings, degradation analysis, and implications.

Each technology is assigned a responsible partner for modeling, with specific collaborators providing experimental data for validation to ensure robust and accurate model development.

At the current status, dynamic models have been developed by each WP partner to address specific electrolysis technologies, and to incorporate critical degradation mechanisms and operating conditions to optimize performance, durability, and efficiency.

T3.2 Lifetime models development (Lead: ULille, Part.: AAU, TUG, POLITO, VDX) [M12-M51]

Task has just started, no progress report ready.

T3.3 Degradation and Lifetime models validation (Lead: AAU, Part: POLITO, TUG, LILLE, VDX, EGP) [M24-M54]

Starts in M24.

WP4: Test procedures

T4.1 Low temperature electrolysis degradation protocols (lead: CNR; participants: FAU, FZJ, POLITO, STARGATE, 1s1, PF/HYT, EGP) [M1-M51]

The task *"Low-Temperature Electrolysis Degradation Protocols"* focuses on the development of standardized methodologies to evaluate the performance and degradation of low-temperature electrolyzers (LTWEs). These protocols, specifically tailored for PEMEL (Proton Exchange Membrane Electrolyzers), AEMEL (Anion Exchange Membrane Electrolyzers), and AEL (Alkaline Electrolyzers), are designed to ensure consistency and applicability across various operating conditions, aligning with JRC standards and insights from previous European projects.

Key Developments:

1. **Protocol Definition**:
    - Testing procedures have been outlined to study degradation mechanisms under steady-state and dynamic operating conditions.
    - The protocols incorporate methods such as polarization curves and Electrochemical Impedance Spectroscopy (EIS) to evaluate electrolyzer performance.
    - Accelerated Stress Testing (AST) has been proposed to simulate degradation processes in shorter timeframes, providing insight into the long-term stability of materials and components.
2. **Dynamic Profiles**:
    - Six dynamic stress profiles have been derived, three each for wind and solar energy scenarios, based on real-world renewable energy data.
    - These profiles replicate the variability of renewable power inputs, including load cycling and power fluctuations, to assess the impact on electrolyzer performance.
3. **Focus on Low-Temperature Electrolysis Challenges**:
    - The protocols address specific stressors such as thermal cycling, pressure variations, and transient loads that are critical for LTWEs.
    - Testing conditions are designed to reflect real-world scenarios while maintaining laboratory compatibility.
4. **Alignment and Harmonization**:
    - The protocols build upon existing JRC methodologies and previous European projects (e.g., ANIONE, HPEM2GAS) to ensure standardization and reliability.
    - A strong focus on validation and reproducibility aims to ensure the protocols can be widely adopted across different laboratories and applications.

To support the implementation of the protocols, several tables provide detailed descriptions of the procedures for performance and durability testing. These tables outline the steps for steady-state evaluations, dynamic load tests, and accelerated stress testing, offering a structured guide for reproducibility.

Figures accompany the tables to illustrate key aspects of the methodologies. For example, they include representations of renewable energy profiles used for simulating wind and solar variability, visual guides for applying dynamic stressor profiles, and diagrams of temperature cycling protocols for thermal stress evaluation.

Aligned with project objectives, protocols for accelerated stress tests (AST) have been designed based on key stressors identified in JRC guidelines, recent literature and partners experience. These protocols aim to simulate real-world degradation phenomena, such as on/off cycling, pressure and temperature

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variations, and dynamic loading, while also investigating the effects of low and high current density load cycling on electrolyzer performance.

The development of these procedures requires setting specific stressor values and ranges, tailored to the specifications provided by MEA manufacturers and the capabilities of the test stations. The process follows a structured approach similar to durability tests under dynamic loads, consisting of:

Dynamic profiles, including renewable energy source (RES) profiles, are integrated into Accelerated Stress Testing (AST).

The main testing procedures developed so far are:

- Polarization curve test procedure;
- Durability test under steady state condition;
- Durability test under dynamic load;
- Wind and PV derived profiles for the Assessment of Degradation Phenomena under Dynamic Conditions;
- Accelerated Testing protocols and procedures
    - Dynamic Load profiles
    - High current and High voltage fluctuating profiles
    - On/off cycling test profiles
    - Pressure Cycling test profiles

These profiles are still under evaluation among the partners to ensure their relevance, reliability, and alignment with the project's objectives. Feedback from this collaborative review will be crucial for refining and finalising the procedures.

Further and detailed information on the procedures developed will be included in Deliverable 4.1 (due by 31/12/2024).

T4.2 High temperature electrolysis degradation protocols (lead: CNR; participants: TUG, FZJ, POLITO, SE, KER, EGP) [M1-M51]

This task involves the creation of a comprehensive framework for testing SOEC and PCCEL, leveraging existing international standards and methodologies. During this period, an extensive literature analysis is being carried out in collaboration with the partners involved in the task. The objective is to define procedures that are shared among the partners and tailored to the specific devices to be tested.

A close collaboration is also underway with the partners responsible for building the test bench for device testing. The protocols will be based on JRC guidelines for HTEL, literature data, and insights from previous EU projects.

The development of testing protocols will involve clearly defining the conditions under which tests will be conducted, as well as identifying key performance indicators and parameters to assess durability. Additionally, standardised duty cycles will be created to replicate real-world operating scenarios, including profiles that reflect the integration of renewable energy sources.

T4.3 Ex situ procedures characterization of LTEL and HTEL stacks components (lead: CNR; participants: FZJ, POLITO, FAU, TUG) [M6-M54]

The initial phase of Task 4.3 has focused on laying the groundwork for the development of ex-situ testing protocols to characterise key components of Low-Temperature Electrolysis (LTEL) and High-Temperature Electrolysis (HTEL) stacks. These components include catalyst-coated membranes

(CCMs), catalysts, bipolar plates, porous transport layers (PTLs), membranes, ceramic electrolytes, and end plates.

An extensive review of the existing literature and protocols is currently underway to gather insights into state-of-the-art methodologies for ex-situ characterisation. The ongoing analysis aims to identify best practices, gaps, and challenges in evaluating the physical, physico-chemical, electrical, and thermal properties of stack/cell components. This review is also focused on understanding degradation mechanisms and will provide a foundation for defining key performance metrics once completed.

Multiple meetings with project partners, including CNR, FZJ, POLITO, FAU, and TUG, have been organised to align objectives and discuss the development of testing procedures. These sessions facilitated the exchange of expertise and knowledge, ensuring that the protocols being developed are both comprehensive and relevant to LTEL and HTEL technologies.

Efforts have been made to ensure alignment with the activities of WP2 and WP6, where the protocols will support experimental investigations. This coordination ensures consistency and relevance across the project's broader objectives.

WP5: Testing and diagnostic tools

Work package 5 (WP5) is dedicated to the development of testing and diagnostic tools that support the assessment of the electrolyzers technologies involved in the ELECTROLIFE project. The main objectives of the WP5 are:

- Development of ad-hoc test benches and tools, able to: implement the testing protocols defined in WP4 for stacks (developed in WP6); perform detailed measurements, in order to detect and analyze degradation mechanisms.
- Establishing a consistent and standardized approach and format for collection of data (coming from experimental activities). For the large datasets expected, this will allow efficient exportation, storage, sharing and analysis in the post-processing phase.
- Creating tools and methods of analysis of experimental data, aimed at diagnostic, assessing the state of health of stacks and components, understanding mechanisms of degradation, predict and increase the lifetime and (as further development) supporting operation and maintenance of electrolyser.

In the following figure, a visual representation of the main activities of the project that are linked with the tools developed in WP5 is reported below, highlighting the interaction between the partners involved.

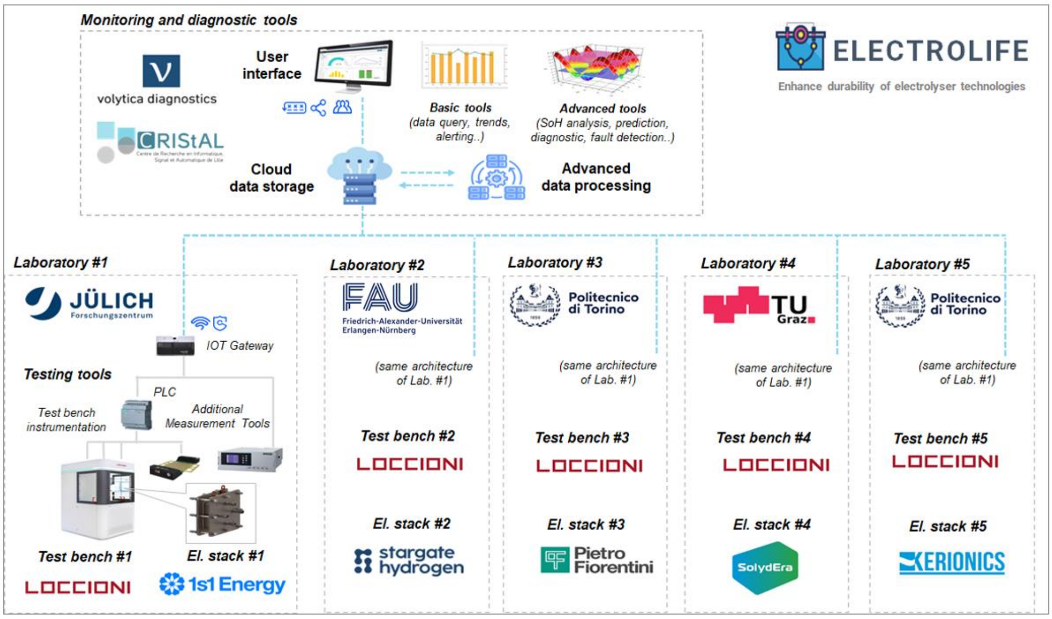

Figure 1 Scheme of the main activities of ELECTROLIFE project

A simplified summary of the activities and timeline is provided below.

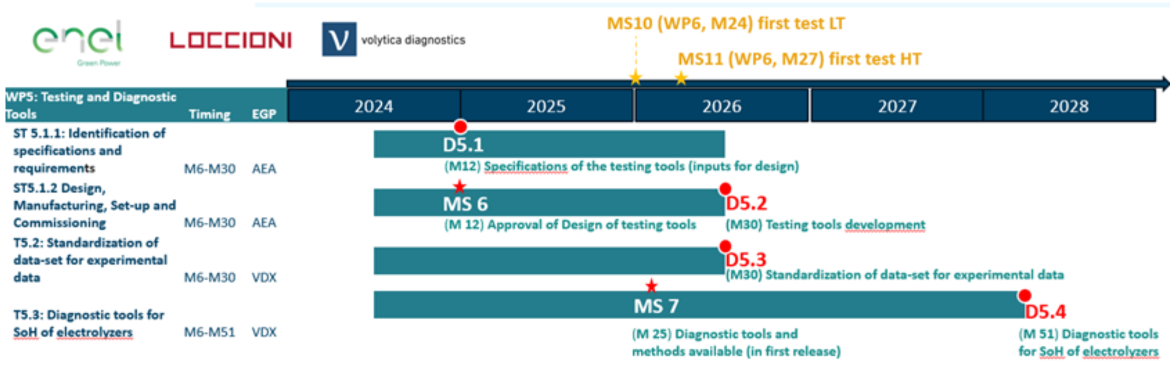

Figure 2 Simplified WP5 Gantt

For the management of WP5 activities, starting from month 1 (M1), EGP (WP5 leader) jointly with the WP5 partners (VDX and AEA) has defined and updated a detailed gantt, listing all the activities foreseen in the WP, the owner of the activity, the period foreseen for its development and the possible connections with other activities foreseen in other WPs or developed by other consortium partners. This Gantt is used for continuously monitoring the progress of the work package activities.

Moreover, a monthly meeting with the partners involved in this WP (AEA and Volytica) has been set in order to monitor the advancement of different tasks, share the main activities carried out and criticalities/divergences from the original plan and for work together on specific common topics.

T5.1 Development of Testing tools (lead: AEA; participants: All)

The objective of this task is to develop ad-hoc “testing tools” for the 5 technologies object of the project, allowing wide and accurate experimental activities on electrolyser stacks, aimed at accelerating, detecting and analyzing degradation mechanism. Testing tools include “test benches” (able to control and measure main electrical and process electrolysis parameters) and “additional measurement tools” (that will allow to perform specific measurements and tests, enhancing detailed analysis of performance and degradation phenomena or related variables, like EIS, Cyclic voltammetry (CV), cell voltage monitoring).

The development of testing tools is led by AEA with oversight of the activities by EGP, and with support from all Partners for the definition of specifications and requirements of the testing tools.
The development of testing tools officially started in June 2024, nevertheless several preliminary actions for setting the activities and the preliminary requirement and specification of the Tools had been carried out by EGP and AEA between M1 and M6 (in order to allow quicker advancement of the activity with all Partners involved and to mitigate any risk of delay).
The activities developed in T5.1 have been divided into two subtasks; the activities performed in these two tasks during the reporting period M1-12 are reported in the following.

ST 5.1.1: Identification of specifications and requirements:

In order to identify main requirements and specifications of testing tools able to assess electrolyser stacks (developed in WP6), in coherence with procedures and key parameters (identified in WP4), EGP and AEA defined and preliminary filled a dedicated excel form (one for each of the 5 technologies involved) in which relevant characteristics of test bench and relative electrolyser stack have been listed.

These forms have been shared with the project partners involved: the 5 electrolyser manufacturers (1s1, PF, STARGATE, KER, SE), the respective testing Labs (POLITO, FZJ, TUG, FAU) and CNR (leader of WP4 project leader) in order to have their contribution in the definition of the Tools specifications and requirements. Several meetings among EGP, AEA and partners for each technology have been held, as well as documents revision through common file shared in the project folder on Microsoft Teams. The final version, agreed among the Partners, has been established and served as the basis for the definition of the Test benches specifications and the related deliverable expected: D5.1 "Specifications of the testing tools".

Specific requirements have been set for each test bench, considering the peculiarities of the stack technology and of the testing labs. Some key common features have been set (related to layout, measurements devices, Control and Monitoring system, control philosophy, safety equipment,...), in order to enhance the comparability and the mutual sharing of results across different technologies, groups and institutions in the project.

Some specifications have been also provided for the stacks to be tested and for the laboratories, in order to assure compatibility with the test bench. Battery limits and general requirements for installation and operation in the laboratories have been also identified (safety, power and water feed, gas connections, venting, etc.). In particular, general requirements of laboratories for operation and safety have been preliminary identified as well as requirements for data acquisition and transmission (in coherence with standardized format/dataset defined in activity T5.2).

ST 5.1.1: Identification of specifications and requirements:

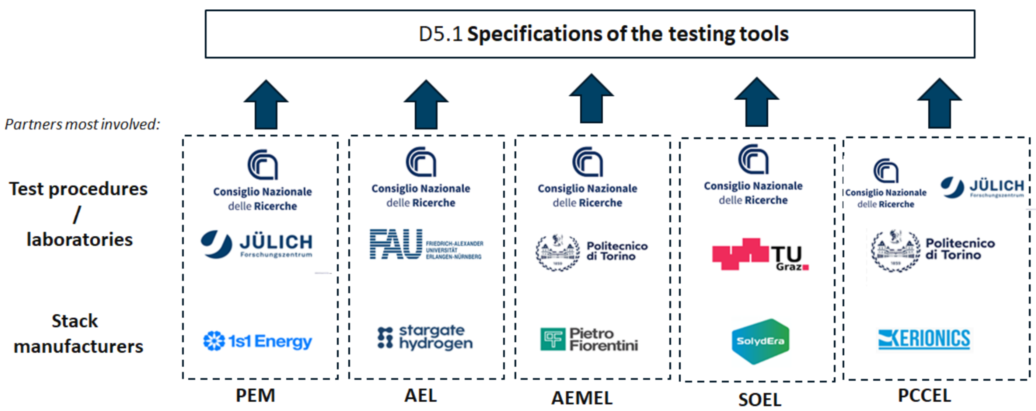

Figure 3 Specification of the testing tools

During the period M6-12, starting from the first draft of specifications developed, AEA has been carrying out the design of test benches, that is currently on going for what concerns the detailed design

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phase. Each one of the 5 test benches have been designed by AEA ad-hoc, in coherence with specifications identified in T5.1.1. The design and architecture of each test bench has been deepened with each Lab and technology provider involved in the specific bench, through several meetings and exchange of information (emails/documents).
The completion of basic design of test benches has been taken as reference for WP5 milestone MS6: Approval of Design of testing tools.

T5.2 Standardization of data-set for experimental data (lead: VDX, participants: EGP, CNR, AEA, POLITO) [M6-M30]

The objective of this task is to develop a reference dataset and related format in order to assess performance and degradation of electrolysers, enhancing the reproducibility of experimental results and enabling comparison of results across the different electrolysis technologies, research groups and institutions in the project.
Moreover, this Task is a fundamental pillar for the implementation of Task T5.3, representing a starting point for the development of the diagnostic tool to monitor and analyse electrolysers operation.

The development of the standard data-set is led by VDX with oversight of the activities by EGP, and with support from all Partners for the definition of the data-set.
The development of the standard data-set officially started in June 2024, but preliminary activities had been carried out by VDX between M1 and M6.
The approach is based on the concept of Canonical Data Models (CDMs). This is a standardized, consistent representation of data to facilitate integration, communication, and interoperability between diverse systems, applications, or databases. It acts as a common language for data exchange, reducing complexity and data translation effort. As can be seen from the figure below, the CDM simplifies integration compared to point-to-point mappings by providing a single, standardized format for all systems. This reduces complexity, ensures consistency, and requires fewer mappings, as each system connects only to the CDM. Unlike point-to-point setups, which increase exponentially as more systems are added, a CDM streamlines maintenance, simplifies troubleshooting, and enhances scalability and interoperability, making it a more efficient and future-proof approach. As we are dealing with data from electrolysers in this case, the associated data model is called ‘Canonical Electrolyser Data Model’ (CEDM).
Next steps include the development of transformation rules to map source data to CEDM, resolving conflicts and ensuring data integrity. The system will be rigorously tested to validate mappings and transformations. Based on feedback, the CEDM will be iterated and optimized to meet evolving requirements. Comprehensive documentation will be created, and teams are trained on using the CEDM. Ongoing monitoring and maintenance ensure the CEDM will remains reliable and adapts to changes in connected systems.
In order to identify the most important signals, parameters and KPIs to be included in the CEDM, VDX conducted a survey with all the experts in the ELECTROLIFE consortium, sharing a spreadsheet in which to identify the main measurement/variables most relevant to them.
The final version of CEDM, agreed among the Partners, will be established in the next reporting period (M12-24) and will serve as the basis for deliverable D5.3 “Definition of data format for future standard approach” expected by M24.

T5.3 Diagnostic tools for SoH of electrolysers (lead: VDX; participants: AAU, TUG, ULille, EGP, POLITO) [M6-M51]

The objective of this task is to create advanced tools and methods for analysis of electrolysers operation data, aimed at assessing the state of health (SoH) of stacks and components, understanding mechanisms of degradation, predict and increase the lifetime of electrolysers.

The development of the diagnostic tool is led by VDX with oversight of the activities by EGP, and with support from partners involved in electrolyser modelling and plant operation optimization.

The development of the diagnostic tool officially started in June 2024, but preliminary activities had been carried out by VDX between M1 and M6.

In the reporting period M1-M12 the following activities have been carried out:

- IOT gateway concept definition for data transmission;
- Set up cloud environment;
- Preliminary algorithm development;
- Preliminary Anomaly detection and alerting definition;
- Preliminary Predictive modeling definition;

WP6 Technologies development and assessment

Starts in M15.

WP7 Improved durability solutions

Starts in M42.

WP8: Dissemination, exploitation and communication

T8.1 Communication strategy, project visual identity (lead: UNR; participants: All) [M1-M60]

The project's visual identity included designing the project logo, creating a flyer, developing templates for documents and presentations, and setting up the ELECTROLIFE website and LinkedIn page. The communication actions were outlined in the Communication and Dissemination Plan. The primary objectives of these efforts are to build project awareness, keep stakeholders and end-users informed about ELECTROLIFE developments, and support market adoption. In the first year, communication activities concentrated on raising awareness via social media (LinkedIn), website updates, and a newsletter. Below is an overview of the main communication channels and tools used for ELECTROLIFE.

Website: The ELECTROLIFE website (https://electrolife-project.eu/) was launched in March 2024 (M3). It provides comprehensive information about the project, including results, news, events, and partner interviews. As of December 2024, the website hosts 15 updates, comprising 7 event announcements, 7 interviews, and 1 newsletter update.

LinkedIn: The ELECTROLIFE LinkedIn page was created in March 2024 (M3) to raise project awareness and build a strong community. Since its launch, it has gained 304 followers. Posts primarily share updates from the project website and information about events attended by project partners. New content is posted regularly, with at least two updates/month.

Newsletter: The ELECTROLIFE newsletter is released every 6–8 months to report on project results and ongoing activities. The first issue was published in M7, with the second planned for February 2025 (M14). Each newsletter is available on the project website and shared on LinkedIn once published.

Templates: The ELECTROLIFE templates have been designed for presentations, posters, deliverables, and milestones, all consistent with the project's visual identity of ELECTROLIFE. Designed templates include the project logo, grant number, EU and Clean Hydrogen Partnership acknowledgment, and a disclaimer.

T8.2 Dissemination activities (lead: UNR; participants: All) [M1-M60]

The project results will be presented at various events (conferences, workshops, exhibitions, fairs) and summarized in open-access publications. UNR tracks dissemination activities and collects updates every six months. Event updates are posted on the website and shared on the project's LinkedIn page. Information about upcoming partner activities is also regularly featured in the project newsletter.

T8.3 Exploitation plans for project results and knowledge protection (lead: EGP; participants: All) [M1-M60]

The plans for exploiting project results, knowledge management, and the intellectual property rights (IPR) strategy will be compiled in document D8.3 by M24 and finalized in document D8.4 by M45. A preliminary list of exploitable results has already been gathered.

3 Deliverables and Milestones

Below an overview of the deliverables and milestones in M1-M12 and their status.

Del. No	Deliverable title	Lead Beneficiary	Comments
D1.1	Project Handbook	2 - UNR	Submitted
D8.1	Project identity (including project website)	2 - UNR	Submitted
D1.2	Initial Quality Assurance and Risk Management Plan	2 - UNR	Submitted
D1.3	Data Management Plan	1 - POLITO	Submitted
D8.2	Communication & Dissemination Plan including preliminary Exploitation strategy	2 - UNR	Submitted
D1.9	Annual progress report M12	1 - POLITO	In preparation
D1.10	Annual progress report extended M12	1 - POLITO	In preparation
D2.1	Degradation phenomena compendium	1 - POLITO	In preparation
D4.1	Specification, terminology and Harmonised protocols for LTEL	12 - CNR	In preparation
D5.1	Specifications of the testing tools	3 - EGP	In preparation

MS. No	Milestone title	Related WP	Lead	Due date	Means of verification	Status
1	First polarization curves for Single cells	WP2	1 – POLITO	M6	Polarisation curves presented, analysed and reported in D1.5	Achieved
6	Approval of Design of testing tools	WP5	14 - AEA	M12	Test benches design developed, checked by coordinator and partners involved	Achieved

4 Participation at meetings/conferences/events

In the period M1-M12, all partners have participated in the following meetings:

- 1st GA – project kick-of (M1), January 2024, Torino (Italy), host: POLITO
- 2nd GA – September 2024, Ancona (Italy), host: AEA

WPLs actively participate in monthly EB meetings (online).

TUG – European Hydrogen Week (18-22 November 2024; Brussels, Belgium)
KER – The business booster (16-17 October 2024, Barcelona, Spain)
ULille – Second International Conference on Green Hydrogen - ICGH 2024 (4-6 December 2024, Rabat, Morocco)
STARGATE – World Hydrogen Week 2024 (30 September - 4 October 2024, Copenhagen); Polish Hydrogen technology and conference (7-8 Oct 2024, Poland); Hydrogen Technology Europe Expo (23-24 October 2024 Hamburg, Germany); European Hydrogen Week (18-22 November 2024 , Brussels, Belgium)
PF – Hydrogen Fair in Verona (16-17 October, Verona, Italy); Enlit Europe (22-24 October 2024 Milan, Italy);
1s1 – Berlin Electrolyzer Conference (6-7 December 2024 Berlin, Germany)

5 Conclusion and Recommendation

Conclusion M1-M12

The first year of the ELECTROLIFE project has been a good year. The six active work packages (WP1, WP2, WP3, WP4, WP5 & WP8) have started accordingly to the GA and have progressed accordingly.

In WP1 project management and coordination, the main activities involved the set up of a daily management monitoring system (as described in D1.1 Project handbook) and a series of meetings (bi-weekly management meetings, Executive Board meetings and General Assemblies) to monitor the progress of the activities and were necessary intervene or provide support to keep track with the progress with the project objectives. Furthermore, a quality and risk management plan has been set up to monitor the risks and quality of the results.

In WP2 POLITO, with support of all the partners has started to build a comprehensive understanding of the degradation mechanisms that affect electrolyser technologies. These extensive documents form the foundation for the ELECTROLIFE project's understanding of degradation mechanisms and will be synthesized and compacted into D2.1 (*Degradation phenomena compendium*), which is scheduled for submission in M12(Dec 2024). Furthermore, POLITO has led T2.2 on components and single cells degradation mechanism analysis and despite challenges in the delay of the several components, significant progress has been made.

In WP3 the main results have been made in preparing a comprehensive review of existing models and techniques was conducted, drawing from both academic literature and previous experience of project partners. In addition, physical modelling approaches, from 0D to CFD, have been considered.

In WP4 during the first year of activities, significant progress has been achieved across Tasks T4.1, T4.2, and T4.3, providing a robust basis for the development of testing protocols and methodologies for both low-temperature electrolysis (LTEL) and high-temperature electrolysis (HTEL) technologies.

In WP5, the main results were the design and development of the testing tools for the five technologies allowing wide and accurate experimental activities on electrolyser stacks, aimed at accelerating, detecting and analyzing degradation mechanism. The result will be published in D5.1 (*Specifications of the testing tools*) in M12 (Dec 2024). Other results were the start of the developments of the standard data-set and diagnostics tools.

In WP8, the main activities and results concerned the set up of a project identify through the building of a website and LinkedIn page. Furthermore, through a dozen of LinkedIn posts and website items, the project has received much exposure and gained 270 followers.

Recommendations for the second year (M13-M24)

The second year of the ELECTROLIFE project will see activities which will be consolidated or finalized, which have been started during the first year, and new activities which will start. In this section an short overview of upcoming activities will be presented as recommendations to be followed or look forward to.

One of the main activities which will be finalized in the second year concerns the components and single cells degradation analysis in T2.2. Together with the technology providers and test institutes, Polito will characterize the collected data in different tests and using different advanced tools. The results will be presented in M24 in D2.2 *Components and single cells degradation analysis*.

Another important activity which will be finalized concerns the physical modelling for single cells (0D and 1D) in T3.1. These models are especially important for understanding of fundamental degradation mechanism and impact of different operating parameters. The results will be presented in D3.1 *Modeling at single cell level*.

In WP4, a key priority will be consolidating feedback from initial testing activities to refine and optimise the protocols, ensuring they effectively address performance and degradation challenges. The results will be presented in D4.2 *Specification, terminology and Harmonised protocols for HTEL.* This phase will help identify areas for further improvement and build confidence in the protocols' applicability across different devices. Additional renewable energy profiles will be developed, representing diverse geographic regions and operational scenarios. These new profiles will ensure the protocols capture a wide range of real-world conditions, enhancing their applicability to various renewable energy integration scenarios. Results of this work will be presented in D4.3 *Ex-situ testing protocols for assessing LTEL and HTEL*.

New activities which will start in the second year concern will be the post mortem analysis in T6.3 conducted on the prototypes of electrolysers that have been tested under different conditions.

In WP8 major steps will be taken in the further set up and definition of the exploitation plan. One of these steps will be the organisation of a dedicated workshop to align on the project exploitation results and (individual) exploitation plans. The results will be presented in D8.3 *Exploitable results and exploitation routes.*

6 Acknowledgement

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Project partners:

#	Partner short name	Partner Full Name
1	POLITO	Politecnico di Torino
2	UNR	Uniresearch B.V.
3	EGP	Enel Green Power SpA
4	FAU	Friedrich-Alexander-Universitaet Erlangen-Nuernberg
5	TUG	Graz University of Technology
6	KER	Kerionics s.l.
7	AAU	Aalborg University
8	FZJ	Forschungszentrum Jülich gmbh
9	ULille	University of Lille
10	STARGATE	Stargate Hydrogen Solutions OU
11	PF	Pietro Fiorentini s.p.a.
11.1	HYT	Hyter s.r.l. (Affiliated)
12	CNR	Consiglio Nazionale delle Ricerche
13	1s1	1s1 Energy Portugal Unipessoal Lda
14	AEA	AEA s.r.l.
15	VDX	Volytica diagnostics GmbH
16	SE	SolydEra SpA

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