OUTFOX

OPTIMISED UP-SCALED TECHNOLOGY FOR NEXT-GENERATION SOLID OXIDE ELECTROLYSIS

PUBLIC

D6.5 First Exploitation Plan

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Executive summary

This report is a preliminary exploitation plan and aims to provide the roadmap for preparing the final exploitation and business plans for OUTFOX, a project that has received funding through Horizon Europe's Clean Hydrogen Joint Undertaking (CHJU) programme. This document will provide the basis for discussions around exploitation in the earlier stages of the project in order to quickly identify exploitable project results and take necessary actions for IP protection or other means of future valorization.

The following are the key exploitable results (KER) identified by the OUTFOX consortium partners at the start of the project and are discussed in more detail within this report:

- Next-generation scaled-up fuel electrode supported cells
- Low-cost, large area solid-oxide cells (SOCs) produced with industrial manufacturing processes
- New stack designs for upscaled thin cells at industrial (≥ 300 cm^2) and next-generation (900 cm^2) scales.
- New module and full scale system designs for 100+ MW SOEL systems
- Information on adequate/profitable vs. unprofitable pathways for solid oxide electrolysis (SOEL) system deployment

This first exploitation plan focuses on the preliminary business case as well as the current IP status, as these are the main items that are known at this stage of the project. The investment and upscaling potential of the project outcomes are explored and the next steps towards commercialization are given.

The exploitation plan will be updated at M24 and at the project conclusion at M48.

Contents

1. Framing

This document outlines the initial exploitation plan, serving as a roadmap for developing the final exploitation and business plans for the OUTFOX project. This document will provide the basis for discussions around exploitation in the earlier stages of the project in order to quickly identify exploitable project results and take necessary actions for IP protection or other means of future valorization.

Linq Consulting & Management (LINQ) is the leader of Work Package 6 (WP6), overseeing communication, dissemination, and exploitation. LINQ will actively update and monitor impact and exploitation activities, ensuring that the consortium takes necessary actions to meet key impact targets and effectively protect and exploit the project's technologies in a timely manner.

1.1. Background and context

OUTFOX is a Clean Hydrogen Joint Undertaking (CHJU) project funded through Horizon Europe for 48 months. The project has officially started on the 1st of February 2023.

The project consortium, led by TNO, is comprised of partners with expertise along the entire solid oxide electrolysis (SOEL) green hydrogen value chain, from solid oxide cell research and development (TNO, VTT, Politecnico Di Milano) to industrial validation and implementation (Elcogen OY and AS, Convion, Shell Global Solutions International), along with end use and dissemination of the results (LINQ). The roles of each partner have been chosen to maximize their synergies and interdisciplinarity in order to realize the project objectives.

The main aim of OUTFOX is to remove scale as limiting factor in the deployment of SOEL technologies while proving their potential to become the preferred option for green hydrogen production. By combining experimental results up to 80 kW scales with identification of optimal cell and system designs, OUTFOX will prepare SOEL for industrial scale systems of 100+ MW with a Levelized Cost of Hydrogen (LCOH) as low as €2.7/kg H_2 and applicability to mass manufacturing lines.

1.2. High level objectives

The consortium acknowledges the complexity of the challenge and the range of individual obstacles that must be overcome to unlock cost-effective, large-scale, renewable hydrogen production. However, their expertise, experiences and diverse perspectives are leveraged to break down the problem into a set of measurable objectives. The following objectives were carefully chosen to be achievable and relevant to the technology, while also being ambitious such that they go beyond the requirements laid out in the call.

1. Manufacturing of scaled-up cells with geometric cell areas ranging from 300-900 cm^2, representing a 2-6 times boost in cell area when compared with the state-of-the-art.

2. Development of an industrial scale, high-throughput manufacturing process to produce ≥300 cm^2 cells with a reduced thickness of 300 microns and minimal total thickness variation < 25 microns.
3. Demonstrate the potential for scaled-up manufacturing of the OUTFOX cells based on analysis of available production methods and associated supply chains.
4. Validate the performance of the scaled-up cells with geometric cell area of 300 – 900 cm^2 at the single repeating unit (SRU) and their downscaled version at short stack (15-cell) scales to show operation at high current density (> 0.85 A/ cm^2) and degradation rates of <1%/kh for steam electrolysis with 6000+ hours of total operating time.
5. Determine the optimal geometric cell area based on techno-economic analysis and compatibility with at-scale manufacturing techniques and stack architectures.
6. Design and validate, through modelling, a stack architecture capable of accommodating scaled-up cells with 300 cm^2 geometric cell area with reduced 300 micron thickness that is compatible with low-cost manufacturing techniques.
7. Develop a computational model to characterize and evaluate stack behaviour including thermal gradients, pressure drop characteristics, reactant distribution and gas tightness
8. Design a scaled-up solid oxide electolyser (SOE) module with enhanced power capacity per unit weight, 8 times higher per stack interface, and improved industrial usability.
9. Build and operate two 80 kW pilot modules for 4000+ total hours to show achievement of performance targets at larger scales and with operation under intermittent and other industrial operating regimes.
10. Demonstrate the impact of the SOEL technology scalability and potential to achieve an LCOH of €2.7/kg with an industrial scale plant model and techno-economic analysis.
11. Demonstrate the circularity, safety and sustainability of the stacks and stack components via a comprehensive life cycle analysis of relevant materials and processes.

1.3. Preliminary identification of Key Exploitable Results

The achievement of the above objectives will give both Key Exploitable Results (KERs) and other Expected Results (ERs). A KER is a main interesting result, selected and prioritized due to its high potential to be exploited to derive value chain benefits or as an important input to policy or further research. These are presented below for the OUTFOX project:

- Next-generation scaled-up fuel electrode supported cells
- Low-cost, large area solid-oxide cells (SOCs) produced with industrial manufacturing processes
- New stack designs for upscaled thin cells at industrial (≥ 300 cm^2) and next-generation (900 cm^2) scales.

- New module and full scale system designs for 100+ MW SOEL systems
- Information on adequate/profitable vs. unprofitable pathways for solid oxide electrolysis (SOEL) system deployment

An ER is an output generated by OUTFOX of any form or nature which is not directly protectable or exploitable. These have been identified as follows:

- Electrochemical performance and degradation behaviour of 300 micron thin cells at 144 cm2, 300 cm^2, and 900 cm^2 scales
- Identification of optimal cell sizes for 100+ MW systems
- Data and results from 2000+ hours of operation with reference scale thin cells in the 80 kW prototype system
- Data and results from 2000+ hours of operation with downscaled industrial scale cells in the 80 kW prototype system
- Post-test degradation analysis of cells from SRUs, short stacks, and 80 kW prototypes
- Detailed model for full 100+ MW SOEL system
- Techno-economic analysis of 100+ MW SOEL system
- Life cycle assessment of 100+ MW SOEL system
- Business models for various SOEL applications
- Roadmap towards 100+ MW systems and mass manufacturing

The KERs and ERs demonstrate how each project objective addresses the topic scope through Figure 1.

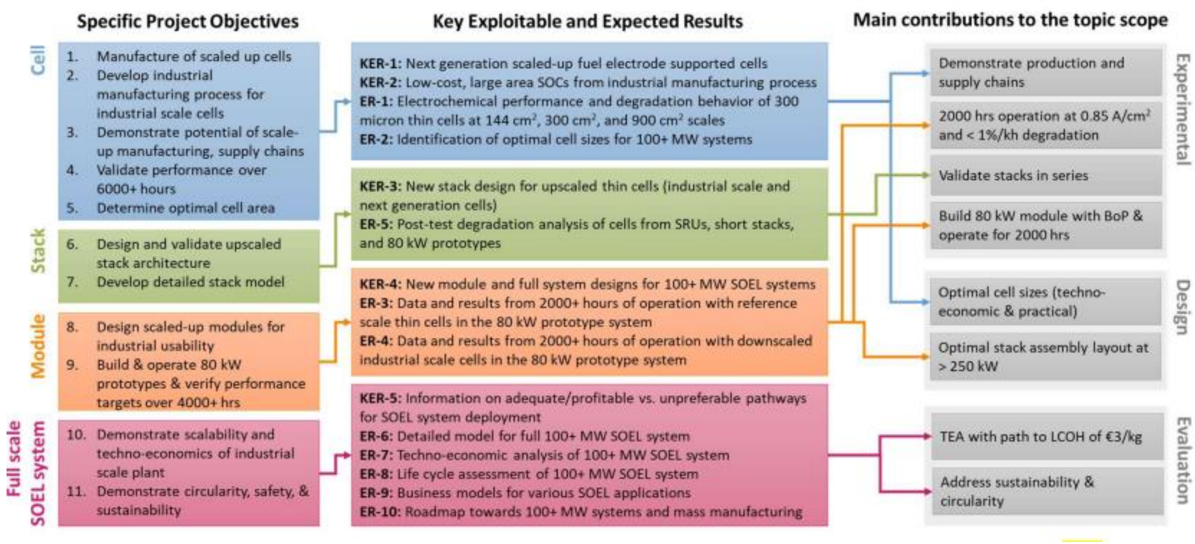

Figure 1: Diagram of the how the specific project objectives address the topic scope through the Key Exploitable Results (KERs) and other Expected Results (ERs).

2. Exploitation plan per KER

2.1. KER1: Next generation scaled-up fuel electrode supported cells

Description

Increasing solid oxide cell size and current density has been shown to reduce system CAPEX and OPEX by lowering the cost of production, decreasing the number of components per kW, and reducing the complexity of SOEL systems. The work to obtain the targeted OUTFOX next generation cells (NGCs) will consist of two parallel approaches. One will be the development of "industrial scaled-up cells" (ISCs) which will be based on the current manufacturing processes and will aim to reach cell areas of ≥300 cm^2, more than doubling that of the current state-of the art (100-150 cm^2). Simultaneously, the NGCs will be developed in line with TNO's laboratory-scale manufacturing process. This step aims to boost the size of the cells up to 6 times larger, targeting an active surface of 900 cm^2, 45% greater than the highest cell surface reported to date (550 cm^2) and 5-8 times higher than the typical state-of-the-art dimensions of 100-150 cm^2.

A key breakthrough aspect of the high geometric area cells will be their reduced thickness of 300 and 350 microns for the ISCs and NGCs, respectively. The reduction in thickness will represent a 25% drop from the current 400 micron thickness of the main commercially available solid oxide electrolyzer cells (SOECs) today. The thinner cells in combination with the enhanced geometric cell area will result in superior hydrogen production rates at a comparatively low material cost.

The development and validation of the 900 cm^2 NGC will create a new outlook towards near-future large-size cells and stacks. To achieve unprecedented production of cells of the targeted size (~900 cm^2), key manufacturing steps will be analyzed and tested for improvement to enable the production of a high geometric area cell with good mechanical integrity and superior performance.

To demonstrate the performance of NGCs in a laboratory environment, a novel ferritic steel housing test platform will be developed, enabling a new paradigm in high geometric area cell testing for industrial applications. Accommodating the scaled-up cells will require a 5-fold increase in the size of the housing when compared with average state-of-the-art ceramic-based cell housings commonly used for laboratory testing. When expanded to the envisioned size needed to house the NGCs, traditional ceramic cell housings are not applicable due to the mechanical failures often associated with high current levels and accompanying heat formation. The robust ferritic steel cell housing targeted by OUTFOX will be able to withstand the demanding conditions needed for high hydrogen production rates without compromising its mechanical integrity.

Intellectual Property Rights

TNO will develop expertise in manufacturing and testing 900 cm^2 cells, which will generate valuable know-how. However, there are currently no plans for patent applications.

Main aspects for the business case

The resulting next generation scaled-up cell will form the outlook towards the next step in enhancing the cell area for future follow-up (demonstration) projects.

The main aspects for the business case include:

- Increasing cell area, production volume, current density, and system scale while reducing fixed OPEX costs down to €2/kg will enable the envisaged reduction of LCOH from €5/kg to €2.7/kg.
- The thinner cells produced will reduce the materials required and will not disrupt supply chains of critical materials, improving sustainability and therefore making SOEL more attractive to end users.

2.2. KER2: Low-cost, large area SOCs produced with industrial manufacturing processes

Description

Every aspect of the cell development will be customized and optimized to achieve new levels of industrial usability and low-cost, reproducible manufacturing. The 95% theoretical yield targeted by OUTFOX would represent a breakthrough for large geometric area cell production. As varying cell thickness is a constant obstacle for the integration of cells into the stack, a ground-breaking outcome targeted by OUTFOX is the production of large geometric area cells with a low thickness variation (TTV) of < 25 microns. In order to complete the 80 kW system, approximately 1,500 cells will be manufactured, a production scale yet to be achieved for this class of cells.

OUTFOX will further enable its ambitious scale-up potential through the use of abundant low-cost materials and innovative measures to improve the sustainability of the associated manufacturing process. One such is the targeted 100% reincorporation of tape-casting waste back into the process. A comprehensive life-cycle analysis will be carried out to demonstrate the breakthrough circularity and safety of the cells, making OUTFOX's cells a true sustainable solution for hydrogen production.

Proceeding the cell development, testing and optimization of the manufacturing process, OUTFOX will carry out a novel study to determine the optimal cell size for large scale hydrogen production. The systematic evaluation will consider the performance of the cells as well as the limitation of the principal manufacturing steps to select a cell size which delivers a ground-breaking balance of performance and reproducibility. Building upon this evaluation, opportunities for adjustments to the in-house process will be identified and tested to increase the optimized geometric cell area and push the OUTFOX cells further beyond the current state-of-the-art

Intellectual Property Rights

Elcogen will develop valuable in-house expertise and trade secrets. While patenting is a possibility, there are currently no obligations to implement it.

Main aspects for the business case

The new stack designs will shape the future direction of enhancing cell area for follow-up demonstration projects, and technology development in industrialization.

The main aspects for the business case are:

- Creating high volume cells with 25% less thickness improving sustainability of manufacturing process through reducing total materials requirements as well as application of abundant low-cost materials.
- By focusing on low-cost manufacturing processes and materials and implementing scalable production methods, SOCs become more competitive, cost-effective, and attractive in the

energy market. These measures enhance market acceptance, enable large-scale production, and position SOCs as a reliable and efficient solution for clean energy generation and storage, driving their widespread adoption and industry growth. In turn, strengthening the partners position if the SOEC market.

2.3. KER3: New stack design for upscaled thin cells at industrial (≥ 300 cm^2) and next-generation (900 cm^2) scale

Description

Design and modelling activities to be conducted during the OUTFOX project working towards the integration of the upscaled cells into stacks as well as the design of a new specialized stack architecture for large geometric area cells. The stack design work will consist of two parallel workflows. In one, downscaled versions of the high geometric area cells (≥300 cm^2 → 144 cm^2) will be integrated in current state-of-the-art stacks and undergo a series of tests aiming to validate their performance with regards to current density, degradation, and specific energy consumption. In another, design and modelling work will be performed towards the conceptualization of a high geometric cell area stack architecture.

The downscaled cells are to be inserted into the current state of the art stacks and will be identical to the high geometric area cells with respect to microstructure, associated manufacturing steps and thickness. This is intended to solidify the results of the tests as applicable to the high geometric area cells and corresponding stacks. The fulfilment of all project KPIs and OUTFOX objectives will be sought during the tests of the downscaled cells. Along with the validation of the stack performance, work is to be carried out to ensure the reproducible, economic manufacturing of the stacks and their compatibility with the envisioned system modules. Validation of the full-scale stack performance, employing 119 downscaled cells will be carried out in a laboratory environment prior to their deployment for integration in the system prototype.

Simultaneously, a new stack architecture is to be designed to accommodate the NGCs. The work will revolve around a redefinition of a large geometric cell area and thinner single repeating units (SRUs) based on the ISC cell dimensions and properties. A model will be developed to characterize the behavior of the novel SRU, especially regarding how to minimize thermal gradients and maximize the exploitation of the cell active area. Further work based on Design for Manufacturing (DFM) principles and FEM analysis will be undertaken to ensure that the stacks are compatible with economic manufacturing processes and are structurally robust in industrial environments, respectively. An additional model simulating the operation of the upscaled stack design will be developed to evaluate the effect of the new design parameters.

Intellectual Property Rights

The knowledge base for Elcogen and VTT will be enhanced regarding the challenges associated to increasing the stack size. Additionally, there is potential for new intellectual property (IP) features to be protected under a new patent, building upon the existing patent-protected stack geometry.

Main aspects for the business case

- The new stack design allows for the production of significantly larger stacks, with electrical power capacity nearly 10 times greater than those currently available. This advancement facilitates the development of modular SOEC systems at the megawatt (MW) scale, which can be conveniently accommodated within a standard sea container.
- Elcogen Oy aims at bringing to market a new product family based on the outcome of this project, which would step up from the current product family which power range in electrolysis mode is in the order of 10 kW. Key aspects to be considered while reaching this goal is to ensure that the new, larger stack fulfils the requirements of manufacturability and robustness. While doing this, manufacturing processes, material selection and overall design concept will be selected accordingly.
- Activities in the project will help identifying the most suitable stack geometry and how that could be affected by the specific use case. Drivers from the market will contribute to tailor the development activities.

2.4. KER4: New module and full scale system designs for 100+ MW SOEL systems

Description

The multi-MW systems and large-scale green hydrogen production to be enabled by the OUTFOX project will require SOE modules capable of economically accommodating larger stacks and operating in demanding and dynamic conditions. Via a ground-breaking computational model, OUTFOX will explore the maximum level of scale-up which can be achieved through the module design stage. The module will be further equipped for high current density operation, further enhancing potential power capacity per unit weight and volume of the system to ten times that of the current state of the art for commercial applications. As with each aspect of OUTFOX, the module will be specially designed to deliver unparalleled industrial usability. Novel features and solutions will be explored to maximize the thermal self-containment and flexibility to consistently operate in 100% renewable use-cases. A comprehensive study will provide new knowledge on the optimal module size with regards to CAPEX.

To progress towards the integration of large area cells into an SOE system, the activities will consist of the design and characterization of a scaled-up SOE module. Initially, a study will be conducted to determine the maximum viable module size when considering cost and manufacturability. Following this, design pathways will be evaluated towards maximizing the power level of the system while minimizing cost. The critical factor in this step is minimizing the quantity of costly stack interfaces.

In the subsequent step, a conceptual design and computational model will be developed. Key inputs into the module design include accommodating the high geometric area cells as well as ensuring industrial usability. The latter will be achieved through maximizing thermal containment, evaluating module design features for high current density operation and by enabling operational flexibility to be compatible with high renewable energy use. Close collaboration with the stack architecture design team will be key here, as the respective models will mutually support each other to improve the stack geometries.

Certain aspects of the conceptual model will be translated to the module that is eventually integrated into the 80 kW system. This includes its ability to operate under high current density, its flexibility and some of the scaled-up design parameters.

Intellectual Property Rights

Convion will develop valuable know-how regarding new module and full system designs for 100+ MW SOEL systems. However, at this time in the project, there are no plans for patent applications.

Main aspects for the business case

Main aspects for the business case are:

- The design aims to significantly increase the efficiency and power output of each stack interface. These improvements result in reduced costs for stack interfacing and balance, increased system power density, and enhanced value for customers who can achieve higher power densities and potentially require fewer stack interfaces for their applications.
- The thermal self-containment is maximized and operational flexibility is enabled to be compatible with high renewable energy use. This will optimize energy conversion and minimize energy losses and by utilizing renewable energy sources this allows the technology to tap into the growing market for renewable energy solutions, attracting a broader customer base and market opportunity.
- Market demand for green hydrogen is increasing rapidly and particularly in integrated industrial hydrogen production, often in hard-to-abate sector, high efficiency and a possibility of utilisation of waste heat for steam generation are key attributes why solid oxide technology is preferred, once proven.

2.5. KER5: Information on adequate/profitable vs. unprofitable pathways for SOEL system deployment

Description

With the envisioned breakthrough performance of the OUTFOX next-generation cells and stacks, novel opportunities for commerce and industrial eco-systems will emerge. New market segments are to be identified based on low-cost SOEL hydrogen production with an analysis undertaken to demonstrate how to bring the solution to market. A business model based on the performance of the full-scale demonstrators will be developed and validated. This will include a novel, structured outline of the obstacles hindering the market placement of the innovation. Additional breakthrough industrial models enabled by the OUTFOX technology will be systematically outlined and described, such as those related to chemical co-generation, energy storage and transport.

To further elaborate on the applications and impact of large-scale SOEL, a new simulation tool will be developed to underpin the targeted techno-economic assessment. Using the tool, environmental aspects will be analysed, guiding the creation of an exploitation roadmap. The roadmap will provide an illustration of a new viable and sustainable path towards the implementation of multi-MW scale SOEL systems.

All plant components, including the electrolyzer unit, will be defined within an ASPEN Plus ® simulation. Additionally, in-house developed codes will be used to model certain physical and electrochemical phenomena. Results from the cell, stack and module development activities will be integrated into the model to ensure its applicability to the OUTFOX project. The simulation will be run for various use scenarios and eventually extended to encompass defined case studies based on real-world electricity availability curves. A yearly simulation will be developed allowing for LCOH and CAPEX calculations for the different scenarios. The various contributions of the OUTFOX developments – cell, stack, and module improvements from WPs 1, 2, and 3, respectively – to the economic results will be evaluated to advise the roadmap activities and future development work.

To validate the sustainability of the OUTFOX technologies, a Life-Cycle Assessment (LCA) analysis will be carried out for both the manufacturing and use phases of the SOE systems. Using a combination of OUTFOX specific performance results and databases, the GHG emissions and environmental footprint associated with SOEL large-scale hydrogen production will be obtained.

Complementing the techno-economic assessment (TEA) will be a market exploitation roadmap. To create the roadmap, all partners will first contribute to developing and validating business models around multi-MW SOEL systems. Building on the identified business models, the roadmap will be developed towards the implementation of two pilot plants by 2030. Market potential, scale-up needs, and technological requirements will be evaluated for various scenarios when deciding on the optimal pathway to implementation.

Intellectual Property Rights

POLIMI will generate valuable know-how on adequate/profitable vs. unpreferable pathways for SOEL system deployment through completion of LCA analysis, TEA assessment and a market exploitation roadmap towards scaled-up systems.

Main aspects for the business case

The main aspects for a business case are:

- New market segments to be identified based on low-cost SOEL hydrogen production with an analysis undertaken to demonstrate how to bring the solution to market.
- A new simulation tool will be developed to underpin the targeted techno-economic assessment. Using the tool, environmental aspects will be analysed, guiding the creation of an exploitation roadmap. This roadmap will be developed towards the implementation of two pilot plants by 2030. Market potential, scale-up needs, and technological requirements will be evaluated for various scenarios when deciding on the optimal pathway to implementation.

3. Investment & upscaling to industrial level

OUTFOX is a highly industrially driven project involving key partners along the value chain. The industrial partners Elcogen AS, Elcogen OY and Convion are already involved in the development and commercialization of solid oxide fuel cells (SOFCs) and see a strong opportunity for their companies to expand into the future SOEL industry while leveraging their current development and manufacturing capabilities. The growth of green hydrogen technologies is only expected to increase and develop into a mature industry with a variety of technologies to be commercialized to address the various market applications, giving ample drive for developing new SOEL technology. At the same time, the partners recognize that the electrolyzer industry as a whole is developing very quickly and requires quick action to exploit the market opportunities. By involving the industrial partners directly in the development work, the manufacturability of the new cell and stack designs will be a key criterion guiding the R&D activities.

The key exploitable results have been thus identified as being exploitable in the short term (< 5 years after the project end), first through a multi-MW follow-up project, and then through commercialization, making use of existing manufacturing lines and supply chains. The involvement of Shell Global Solutions International will be key in guiding the project developments and evaluating the various applications for SOEL systems. Shell will provide insights on business models and application requirements, such as desired system sizes, electricity supply characteristics, and required lifetimes. Shell and Convion have signed a collaboration agreement for a development of up 1 MW reversible SOEC system to be deployed in the Energy Transition Campus (ETCA) in Amsterdam where for the Phase 1 of the project, Convion will purchase stacks from Elcogen. Additionally, Shell is also building a 1 MW SOEL unit with Ceres in Bangalore, India. Both these projects highlight Shell's commitment to mature next generation electrolyser technologies and make Shell an ideal partner for exploiting the results of OUTFOX and continuing collaborations between the partners.

The realization of OUTFOX's scaled-up SOEL system, in collaboration with the aforementioned value chain, ensures broad market adoption. The project aims to engage other energy producers to reach an increasing number of consumers and expand its overall impact.

4. Preliminary business case

Table 1:Preliminary business case

Business Case	
Value Proposition	SOELs have the potential to capture a majority share of the market and be the preferred option for green hydrogen production because of their superior efficiency, rapidly declining costs, and scalability. OUTFOX will prepare SOEL for industrial scale systems of 100+ MW with an LCOH as low as €2.7/kg H_2 and applicability to mass manufacturing lines.

	Cells: • The ISCs, featuring a geometric cell area of ≥300 cm^2, and NGCs, with geometric cell areas up to 900 cm^2, will surpass the highest reported cell surface area to date (550 cm^2) by 45%. Moreover, these dimensions are 5-8 times larger than the typical state-of-the-art cell sizes of 100-150 cm^2. • The reduction in thickness (300 and 350 microns for the ISC and NGC respectively) will represent a 25% drop from the current 400 micron thickness being the main commercially available SOECs today. • The ISC will be developed to be compatible with the current industrial high throughput cell manufacturing line of Elcogen AS. **Stack Design:** • Enhanced performance and stability of the cells by optimizing reactant distribution over the active cell area and minimizing thermal gradients respectively • Minimizing diffusion losses, while maintaining competition with state-of-the-art product performance **SOE Modules:** • The design aims to significantly increase the efficiency and power output of each stack interface. • The module will be equipped for high current density operation, enhancing potential power capacity per unit weight and volume of the system to 10 times that of the current state of the art for commercial applications.
Existing alternatives and competitors	Electrolyte-supported and metal-supported SOECs are the existing alternatives to the fuel electrode-supported SOECs, which is the type of the cell used in OUTFOX. The main competitors in the field of SOE market are Sunfire, Ceres Power, Haldor Topsoe and Bloom Energy.
Market size	The global electrolyzer market in 2020 was valued at €250 million, with SOEL making up 13.8% of the total market.
Growth rate	The global electrolyzer market is expected to grow at a CAGR of over 30% between 2022 and 2030. Maintaining this market share would result in a total market value of €6.9 billion.
Market trends	The EU has been placing a strong emphasis on decarbonization and renewable energy. As a result, there is increasing interest in green hydrogen, which is produced using electrolysis powered by renewable energy sources. To support the development and deployment of hydrogen technologies, the EU has been implementing policies and initiatives. Consequently, the Europe Electrolyzer Market is projected to experience

	significant growth which is driven by the rising demand for hydrogen as a raw material in the chemical industry.
Barriers and risks	It is essential to strengthen the value chain surrounding SOEL technology; otherwise, efficient scalability of the developed solutions may not be possible. Mitigating this barrier requires the involvement of industrial partners throughout the supply chain. End users' reluctance to adopt new technologies is a concern if costs don't meet expectations. Inflation and recent events in Eastern Europe may hinder the reduction of CAPEX and OPEX to the necessary levels for widespread adoption of SOEL technology.
Business approach	The business model is based on business-to-business (B2B); however, it is expected that further subsidized collaborative research projects will be needed to continue to scale up and demonstrate the SOEL technologies before commercialization can be realized. Once this is accomplished, a similar approach as to the SOFC market is expected, involving many of the same supply chain actors and stakeholders (cell manufacturers, stack manufacturers, module manufacturers, end users, etc.)

5. Key activities & next steps

The detailed exploitation strategy to be developed during the project lifetime will cover all potential uses of the results for various purposes. The main exploitation route in the short term immediately following the project end will be the realization of a multi-MW demonstration of the cell technologies and system designs developed in OUTFOX. In parallel, other types of potential exploitation have been identified which include financial/commercial, societal, scientific and political and legislative exploitation, which will also be pursued to maximize the reach and impact of the project results. These are presented below in Table 2.

Table 2: Strategy per type of exploitation

Type of Exploitation	OUTFOX strategy
Financial/Commercial	OUTFOX will generate multiple results that can and will provide opportunities for financial/commercial exploitation through establishing new products, processes and services for the industrial partners, majority of which are SMEs. Specific relevant KERs: KER-2, KER-3, KER-4
Societal	Outputs from OUTFOX will provide routes to validating the value of research and innovation in addressing societal challenges. Improving the sustainability of energy and chemicals production and reducing the environmental effects of electrolysis. Specific relevant KERs: KER-4, KER-5.

Scientific	OUTFOX will generate outputs that will influence further research and development through new SOEL component designs and validation of the developments at TRL6. Specific KERs: KER-1, KER-2, KER-3.
Political	OUTFOX will seek to provide information on development pathways that will serve to advise policy and legislation in order to accelerate the advancement and scale up of SOEL technology. Specific KER: KER-5.

WP4 will perform a full system assessment by developing a simulation tool for techno-economic assessment of the envisioned full-scale SOE plant and by realizing a medium-term analysis on environmental aspects regarding both manufacturing and operational aspects. The analysis of the full system assessment will guide the definition of a roadmap for exploitation of such SOEL systems up to the multi-MW scale, in view of the objective for two demonstration plant projects starting 2027. However, at this stage, M6, it is too early within the project for this to be carried out.

The consortium is fully committed to OUTFOX and the outputs and the immediate next steps will be to ensure the technologies are developed and validated in order to take the SOEL technology towards commercialization.