Ref. Ares(2024)2353765 - 29/03/2024

CLEAN HYPRO

Open Innovation Test Bed for Electrolysis Materials for Clean Hydrogen Production

D2.1 Preliminary Market Analysis

31/03/2024

Co-funded by the European Union

DOCUMENT CONTROL SHEET

PROJECT INFORMATION

Project Number	101091777		
Project Acronym	CLEANHYPRO		
Project Full title	Open Innovation Test Bed for Electrolysis Materials for Clean Hydrogen Production		
Project Start Date	01 October 2023		
Project Duration	48 months		
Funding Instrument	Horizon Europe	Type of action	HORIZON Innovation Actions
Call	HORIZON-CL4-2022-RESILIENCE-01		
Topic	HORIZON-CL4-2022-RESILIENCE-01-20		
Coordinator	Fundacion Tecnalia Research & Innovation		

DELIVERABLE INFORMATION

Deliverable No.	D2.1.		
Deliverable Title	Preliminary Market Analysis		
Work-Package No.	WP2		
Work-Package Title	Validation of the SEP: set up of open calls and Democases Development		
Lead Beneficiary	CIAOTECH, PNO Group		
Main Author	[Tiziana Fuoco, CIAOTECH, PNO Group]		
Other Authors			
Due date	M6		
Deliverable Type		Document, Report (R)	
Dissemination Level		Public (PU)	
	PU: Public, fully open SEN: Sensitive, limited under the conditions of the Grant Agreement Classified R-UE/EU-R – EU RESTRICTED under the Commission Decision No2015/444 Classified C-UE/EU-C – EU CONFIDENTIAL under the Commission Decision No2015/444 Classified S-UE/EU-S – EU SECRET under the Commission Decision No2015/444		

Document Revision History

Version	Date	Description of change	List of contributor(s)
1	11/03/2024	Included annexes for Stam and PNO	Tiziana Fuoco
2	14/03/2024	Small mistakes, typos	Tiziana Fuoco

PARTNERS

Participant number	Participant organisation name	Short name	Country
1	FUNDACION TECNALIA RESEARCH & INNOVATION	TEC	ES
2	STAM SRL	STAM	IT
3	KIC INNOENERGY SE	EGHAC	NL
4	COMMISSARIAT A L ENERGIE ATOMIQUE ET AUX ENERGIES ALTERNATIVES	CEA	FR
5	NEDERLANDSE ORGANISATIE VOOR TOEGEPAST NATUURWETENSCHAPPELIJK ONDERZOEK TNO	TNO	NL
6	TEKNOLOGIAN TUTKIMUSKESKUS VTT OY	VTT	FI
7	FUNDACIO INSTITUT DE RECERCA DE L'ENERGIA DE CATALUNYA	IREC	ES
8	FRAUNHOFER GESELLSCHAFT ZUR FORDERUNG DER ANGEWANDTEN FORSCHUNG EV	FHG	DE
9	BUREAU VERITAS SOLUTIONS IBERIA SLU	BV	ES
10	PNO INNOVATION UNIPESSOAL LDA	PNO	PT
10.1	CIAOTECH Srl	CIAOTECH	IT
11	CERAMIC POWDER TECHNOLOGY AS	CPT	NO
12	3DCERAM-SINTO	3DCS	FR
13	F6S NETWORK IRELAND LIMITED	F6S	IE
14	AGFA GEVAERT NV	AGFA	BE
15	SPARKNANO BV	SparkNano	NL
16	BRANDENBURGISCHE TECHNISCHE UNIVERSITAT COTTBUS-SENFTENBERG	BTU C-S	DE
17	ELCOGEN OY	ELC-1	FI
18	ENAPTER GMBH	ENAPTER	DE

19	AKTSIASELTS ELCOGEN	ELC -2	EE
20	MCPHY ENERGY	MCP	FR
21	MONDRAGON ASSEMBLY SOCIEDAD COOPERATIVA	MASS	ES
22	RHODIA OPERATIONS	SOLVAY	FR
22.1	Rhodia Laboratoire du Futur	SOLVLAB	FR
23	VSPARTICLE BV	VSP	NL
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EXECUTIVE SUMMARY

This deliverable reports the results of the preliminary market analysis performed within the scope of the CleanHyPro project, with the aim of materializing the offer of the OITB to the market. The specific objectives of the current analysis were to position the CleanHyPro offer within the landscape of similar OITB initiatives at the EU level and within the market sectors and the technologies it addresses: electrolyzer manufacturing for green hydrogen production; therefore, to identify a preliminary list of services to be offered to the market.

The methodologies involved both the gathering and analysis of secondary data and input from the partners in the project, which were collected through a survey.

The document thereby, reports as first the data from similar OITB initiatives, the sectors, and the products they target. The number of democases that each deployed is also analyzed as well as the approaches the consortia followed to ensure the sustainability of the SEP after the end of the projects. The analysis follows with the quantification of the market data trends related to the green hydrogen demand and production, the installed and manufacturing capacity of electrolyzers at global and European scale and a mapping of the key stakeholders in the sector.

Eventually, a list and classification of the CleanHyPro OITB technical and business-oriented services is provided. The technical services are organized into four clusters, each covering the manufacturing and testing of one of the four types of electrolyzers: AEL, PEM, AEM and SOEC. The technical services are integrated with business-oriented services covering both the regulatory and business development aspects that the OITB customers might deal with.

This preliminary market analysis will be followed by further steps with a focus on the demand to better define the value proposition of the CleanHyPro OITB for democases.

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ABBREVIATIONS

AEL	Alkaline Electrolyzer
AEM	Anion Exchange Membrane Electrolyzer
CAGR	Compound Annual Growth Rate
CAPEX	Capital Expenditure
CO_2	Carbon Dioxide
GW	Gigawatts
H_2	Hydrogen Gas
IA	Innovation Action
Mt	Million tons
MW	Megawatts
OIP	Open Innovation Platform
OITB	Open Innovation Test Bed
OPEX	Operating Expenditure
PEM	Proton Exchange Membrane Electrolyzer
R&D	Research and Development
RIA	Research and Innovation Action
SEP	Single Entry Point
SMEs	Small and medium-sized Enterprises
SOEC	Solid Oxide Electrolyzer Cell
TRL	Technology Readiness Level

1 PROJECT INTRODUCTION

CLEANHYPRO is an open innovation test bed (OITB) that gathers some of the most recognized, European experts in the electrolysis field for clean hydrogen production [1].

Hydrogen is a versatile energy carrier that has the potential of providing a clean alternative to fossil fuels. If produced using water electrolysis technology and electricity generated from renewable energy sources, such as solar or wind, it is defined as **green hydrogen**. Green hydrogen has an unprecedented momentum globally, since it is a key in accelerating the shift to clean energy [2].

The electrolysis process occurs in an electrolyzer, which uses direct electric current to drive a non-spontaneous reaction. There are four main types of water electrolysis technology: proton exchange membrane (**PEM**), anion exchange membrane (**AEM**), alkaline (**AEL**) and solid oxide (**SOEC**). Each electrolyzer functions slightly differently depending on the electrolyte material involved [3]. The further development, improvement, and commercialization of electrolyzers is crucial to make green hydrogen more readily available and enable energy transition from fossil to renewable sources. Driven by the ambition of reaching net-zero emission by 2025, Europe is indeed forecasted to be a leading market for the further development, commercialization, and installation of electrolyzer technologies [4]. In such a framework, **the CleanHyPro project aims at establishing a sustainable Open Innovation Test Bed (OITB) for electrolysis materials and components for different applications and at offering a network of facilities and services to companies operating in this sector through a single-entry point (SEP).**

CleanHyPro covers several circular innovative materials and key components related to the four main electrolysis technologies and geometries, providing for the first-time services in this technological sector to industrial partners, mainly SMEs, that aspire to meet their needs with minimum investment costs. CleanHyPro OITB opens opportunities for the demonstration of materials and components (up to TRL7) and thus, faster opening the market for these new products. Hence, the OITB acts as a technology transfer facilitator by proving:

(i) the most promising and breakthrough manufacturing pilots;
(ii) advanced characterization techniques and modeling;
(iii) non-technical services, related to business development.

The potential network of reachable stakeholders shall count thousands of businesses on an international scale: the project aims to reach out to more than 100 SMEs and enable more than 16 Democases; as well as to engage more than 300 investors.

2 OBJECTIVES OF THE DELIVERABLE

The scope of this deliverable is to **materialize the offer of the CleanHyPro OITB to the market.** This offer shall consolidate the capabilities of various partners into a cohesive document, which is expected to evolve and expand in the following market analysis and the catalogues of services. The final aim is to position the the OITB in the market, (i) find new potential clients and stakeholders to engage (ii) define the best value proposition to be provided and deployed already in the democases.

The development of the value proposition entails, in this deliverable, the current scenario assessment. Hence, the specific objectives of this deliverable are:

- The mapping of the past OITB initiatives within the EU landscape to identify the scientific outreach of the CleanHyPro projects and guidelines for stakeholders' engagement;
- An analysis of the technology trends and market trends, related to electrolysis and electrolyzer technologies to identify the principal market sectors and to map potential stakeholders that might be customers of the OITB;
- The evaluation the OITB's capabilities, which are attuned to the market needs, and not easily found in the market thus, facilitating the market integration of the CLEANHYPRO OITB. The objective encompasses:
    - The identification of the services provided by the OITB and their preliminary categorization under a regional scheme and clusters of services.

The overarching aim is to ensure that the offer of the OITB targets real needs and effectively identifies relevant communities, sectors and potential stakeholders and business partners. **The next step is a comprehensive stakeholder's analysis and mapping with a focus on the end-users and innovative SMEs.** This strategic approach should enhance the OITB positioning in the market, identify new potential clients and stakeholders, and **refine the value proposition for deployment in democases.**

FIGURE 1. OBJECTIVES OF THE DELIVERABLE.

3 METHODOLOGY

The general approach followed for the SEP service catalogue definition and preliminary market analysis is based on a combination of methods and tools used for secondary data collection through desk-based research. This analysis focuses on better-defining market sizes, spotting success stories emerging among market stage testbeds and OITBs, scouting innovative SMEs and end users in the electrolyzer manufacturing landscape. The latter play key roles in realizing commercially viable OITBs and/or providing services through innovative SEP business models.

The collected information is analyzed and screened to select the most relevant data, trends, and use-cases for CleanHyPro. The preliminary catalogue of services proposed aims at targeting the CleanHyPro partners, the service providers and users, and the external stakeholders.

Figure 2 provides an overview of the methodology followed for D2.1. While specific tools and sources are described in the following section.

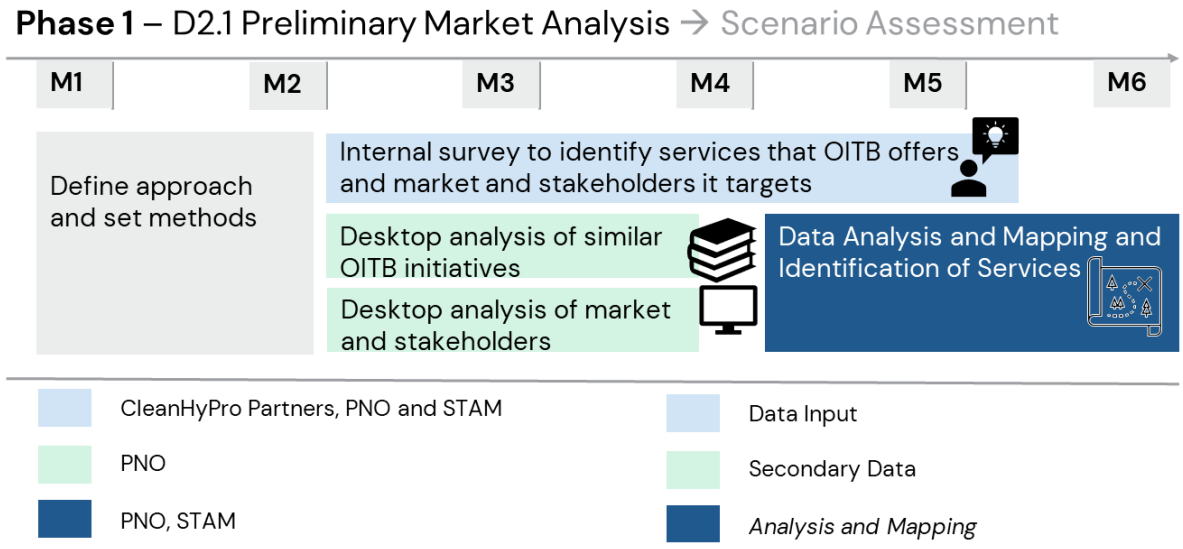


FIGURE 2. OVERVIEW OF THE METHODOLOGY.

3.1 SOURCES AND TOOLS FOR THE ANALYSIS

The analysis of existing similar initiatives, which correspond to other European-funded OITBs, has followed a mixed approach, which utilizes both PNO's proprietary innovation tool (such as. Wheesbee, Figure 3) and the scouting of key data through official documents related to OITB by the European Commission's analysis of existing OITBs, such as "Open Innovation Test Beds for Advanced Materials". European Commission, 2023 [5].

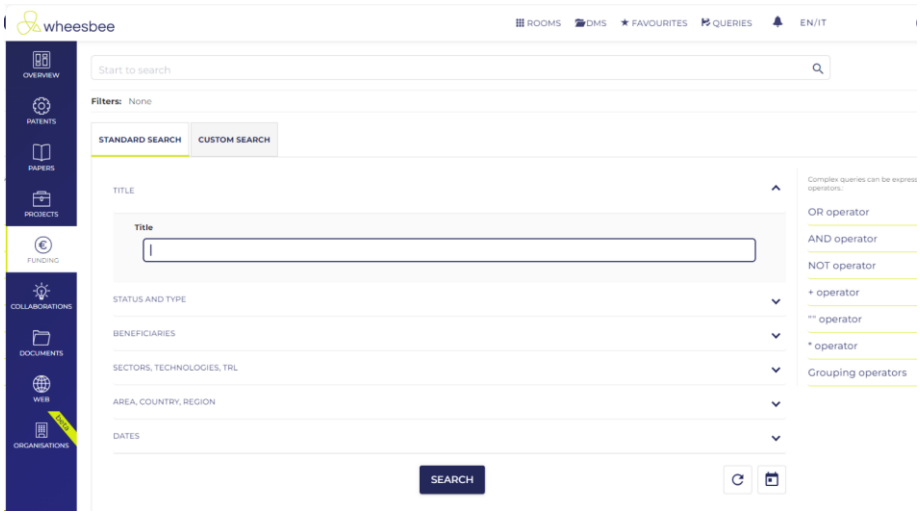


FIGURE 3. WHEESBEE INNOVATION TOOL, FUNDED PROJECT RESEARCH PAGE.

The analysis of markets and related trends has been approached through desktop research using a data-driven method utilizing publicly available secondary data sources such as market reports. The approach allowed the gathering of data on market sizes, technological trends, innovation trends (patenting and funding landscape), main market barriers and drivers, cost benchmarks, estimates on total capacity for electrolyzer production and installation, and downstream market analysis.

For the the identification of the services provided by the OITB and their preliminary categorization under a regional scheme and clusters of services. the project partners were engaged in a survey. The type of information provided, which were later validated, are outlined in Figure 4.

Survey with Internal Partners

Organisation name	
Organisation type	
Pilot Line(s)	
Technological expertise and capability	
IP/Technology	
Lab Infrastructure and Tech. Services	
Business-Oriented Services	
Addressed market sectos and potential end-users	

FIGURE 4. OUTLINE OF THE SURVEY WITH INTERNAL PARTNERS.

4 OPEN INNOVATION TEST BEDS IN THE EU

CleanHyPro is an Open Innovation Test Bed (OITB) project funded by the European Commission under the Horizon Europe Program, Innovation Actions and it is unique in the type of services, product, and sector of application it targets: **the development of electrolyzer technologies underpinning the hydrogen economy, specifically the production of green hydrogen.**

To meet the Europe's long-term economic, technological and environmental goals, the European Commission aims with the Open Test Bed projects to provide access to facilities and required services to small and medium-sized enterprises (SMEs) and industrial start-ups that often, cannot afford to invest in their own testing and validation infrastructures to bring their products to the market. The OITB access shall enable them to keep up with the increasing speed and complexity that innovation requires [6].

To position the CleanHyPro OITB in such a landscape, an analysis of the previous OITBs has been performed.

4.1 CLEANHYPRO IN THE OITB LANDSCAPE

Since 2019, both the Horizon 2020 and the Horizon Europe programmes have had dedicated Innovation Action (IA) and Research and innovation action (RIA) aiming at the support of OITB and Open Innovation Platform covering different technological and scientific fields for a total of 325.63 million euros (Table 1) [5, 7].

Programme	Field	Total Granted Budget (M€)	# Projects	Financed OITB
HORIZON 2020 (IA)	OITBs for lightweight, nano-enabled multifunctional composite materials and components	44.61	4	LIGHTME, LIGHTCOCE, OASIS, LEE-BED
	OITBs for safety testing of medical technologies for health	37.54	4	INNO4COV-19, TBMED, SAFE-N-MEDTECH, MDOT
	OITBs for Characterization	22.92	3	FORMPLANET, I-TRIBOMAT, TEESMAT
	OITBs for nano-enabled surfaces and membranes	58.64	4	INNOMEM, FLEXFUNCTION2SUSTAIN, NEWSKIN, NEXTGENMICROFLUIDICS
	OITBs for nano-enabled bio-based materials	55.64	4	INN-PRESSME, BIONANOPOLYS, BIOMAC, BIOMAT
	OITBs for materials for building envelopes	44.67	3	MEZEROE, ICLIMATBUILT, METABUILDING LABS
	OITBs for nano-pharmaceuticals production	11.1	1	PHOENIX
HORIZON 2020 (RIA)	Open Innovation Platform for materials modelling	15.71	3	OPENMODEL, VIPCOAT, MUSICODE
HORIZON EUROPE (IA)	OITBs on climate neutral and circular innovative materials technologies	34.8	3	**CLEANHYPRO,** CONVER2GREEN, EXPLOIT4INNOMAT
	TOTAL	**325.63**	**29**	

TABLE 1. OITB FINANCED FOR EACH EU PROGRAM AND ACTION SINCE 2019.

The Open Innovation Test Bed and the Open Innovation Platform (OIP) programmes have granted twenty-nine projects since 2019 (Table 2), their sector of applications range for instance, from construction to materials for healthcare, electronic to pharma, to renewable energy production. CleanHyPro is the first OITB that aims to provide technological services related to the manufacturing, testing, and regulatory approval of electrolyzers for hydrogen production.

Project	Year	Sector of Application	Product/Technology
CleanHyPro	**2023**	**Hydrogen Production**	**Electrolysis**
Convert2Green	2023	Transport, Healthcare, Electronics, Renewable Energy	Ecofriendly and Advanced Materials
Exploit4InnoMat	2023	Construction	Nanomaterials
Phoenix	2021	Pharma	Nanotechnologies
BIOMAC	2021	Food Packaging, Construction, Transport, Agriculture and Printed Electronics	Biomaterials, Nanotechnologies
METABUILDING LABS	2021	Construction	Systems
BIOMAT	2021	Construction, Transport, Furniture	Biomaterials, Nanotechnologies
BIONANOPOLYS	2021	Packaging, Textile, Agriculture, Cosmetics, Pharma, Food	Biomaterials, Nanotechnologies
INN-PRESSME	2021	Food packaging, Renewable energy, Transport, Electronics	Biomaterials, Nanotechnologies
OpenModel[a]	2021	Transport	Advanced Materials
Mezeroe	2021	Construction	Bio-based envelop products
iclimabuilt	2021	Construction	Advanced Biomaterials and Technical Systems
Vipcoat[a]	2021	Transport	Advanced and Sustainable Coatings
Musicode[a]	2021	Food Packaging, Electronics	Advanced Materials
Innomem	2020	Water Treatment, Gas Separation	Membrane
NewSkin	2020	Construction, Water treatment, Transport, Packaging, Healthcare, Renewable energy, Electronics	Nanotechnologies, Membrane
INNO4COV-19	2020	Healthcare&Medical	Covid Related Technologies
NextGenMicrofluidics	2020	Pharma, Electronics, Food Packaging	Nanotechnologies, Membranes for Microfluidics
FlexFunction2Sustain	2020	Food Packaging, Electronics, Furniture, Transport	Nanotechnologies, Membrane
TBMED	2019	Healthcare	Devices
SAFE-N-MEDTECH	2019	Healthcare	Biomaterials, Nanotechnologies
TEESMAT	2019	Electrochemical Energy Storage Systems	Advanced Materials
LEE-BED	2019	Electronics	Nanomaterials
FormPlanet	2019	Metalworking	Metal Forming
i-TRIBOMAT	2019	Transport, Renewable energy, Manufacturing	Tribological Materials
MDOT	2019	Healthcare	Inhalation Technology, 3D-Printed Active Neural Implants, Coatings for Orthopaedic Prostheses
OASIS	2019	Transport, Construction, Metalworking	Multifunctional Lightweight Composites

Lightme	2019	Transport, Manufacturing	Lightweight Alloys and Composites
Lightcoce	2019	Construction	Multifunctional Lightweight Composites

[a] Open Innovation Platform

TABLE 2. OITB AND OIP FINANCED BY EUROPEAN COMMISSION SINCE 2019.

Specifically, the first generation of OITBs projects kicked off in 2019 with a total of 10 projects funded in different fields. The second generation consisted of 5 projects starting in early 2020, followed by a third generation of 8 projects at the beginning of 2021. Under Horizon 2020 program, in addition to the third generation of OITBs, 3 projects on Open Innovation Platforms for materials modelling were launched, focusing on the modelling aspects of material development (Figure 5).

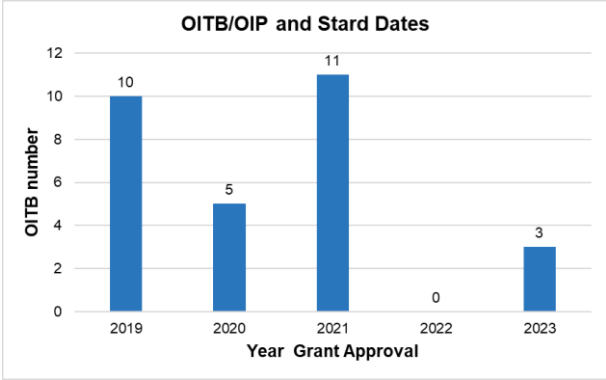


FIGURE 5. CHART OF APPROVED OITBS BY NUMBER SINCE 2019.

Horizon Europe opened the door to a fourth generation of OITBs. The Horizon Europe Work Programme 2021- 2022 included one topic on Open Innovation Test Beds on climate neutral and circular innovative materials technologies. These projects shall provide services to industry for the design, development, testing, regulatory and environmental assessment, and upscaling of climate neutral and circular innovative materials technologies. The relevant call closed in March 2022, and three projects were funded in January 2023, being CleanHyPro one of them together with Convert2Green and Exploit4InnoMat projects, which target as product Ecofriendly, Advanced Materials, and Nanomaterials, respectively (Table 2).

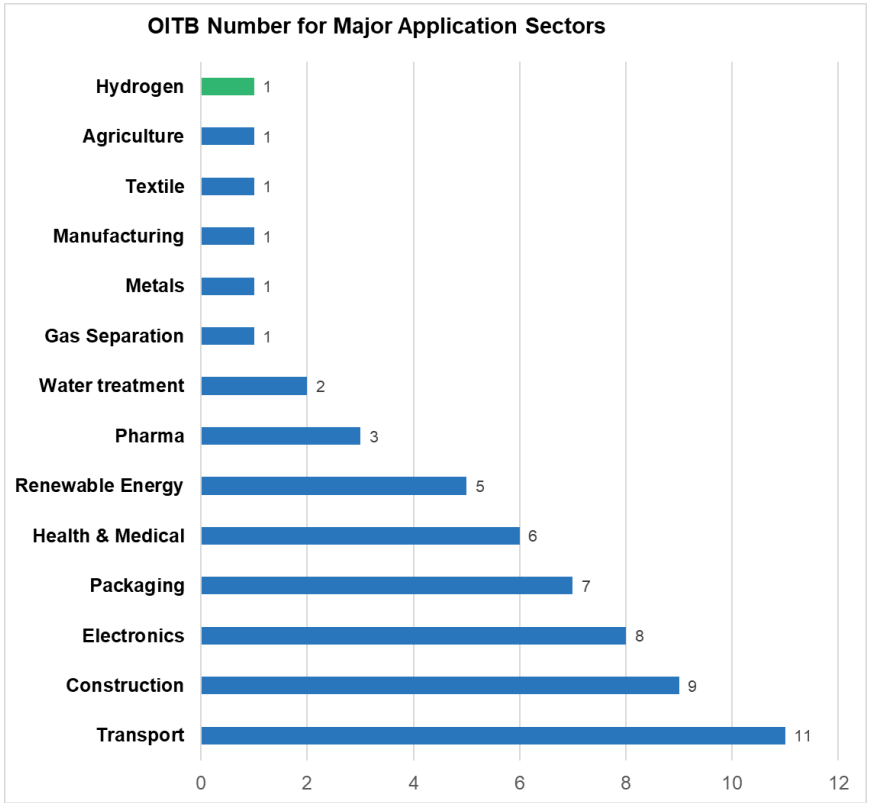


FIGURE 6. CHART OF OITB NUMBER AGAINST THE SECTOR OF APPLICATION.

The type of services provided by each of the OITB are mainly related to the design, manufacturing and testing of the specific products that the OIBT aims to provide, and they target to support in the technological and business development start-ups, SMEs as well as large enterprises. The granted OITB aims at advancing technology and innovation in different sectors as shown in Figure 6 and reported in the Table 2.

If the OITB are classified under the major technologies clusters, it results that 18 OITB have fostered the development of advanced and bio-based materials related technologies, 11 of them belong instead to the field of the nanotechnologies and the nanomaterials, 3 are devoted to other types of technologies and 1 of them to the electrolyzer related technologies, i.e. CleanHyPro (Figure 7).

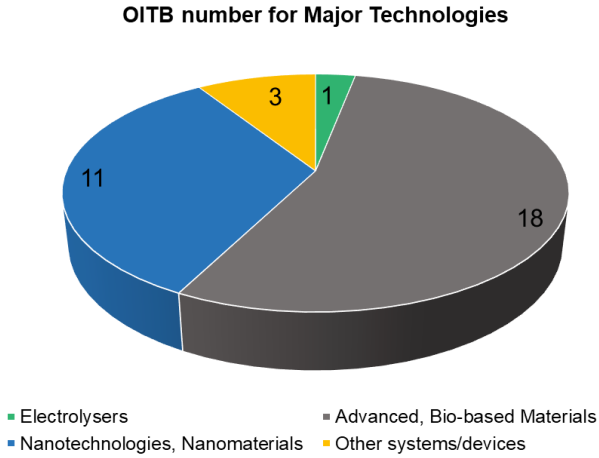


FIGURE 7. CHART OF THE OITB NUMBER AGAINST THE TECHNOLOGY.

Looking ahead, the Horizon Europe Work Programme of 2023-24 includes this further topic for an OITB: the support and development of the hydrogen economy in the EU, with a dedicated, estimated budget of €10 Million. The underpinning aim is to contribute to the goals of the European Hydrogen Strategy.

4.2 OITB SUCCESS AND STAKEHOLDERS' ENGAGEMENT

The analysis of the previous OITBs in the European landscape has also taken into consideration the type of services they provide, the customers and therefore, the number of democases, and how the strategies and/or the requirements have been changed over the last years to ensure the engagement of the customers and the success of the OITB throughout and beyond the scope of the EU project [5]. Such analysis, together with the preliminary market and stakeholders' analysis of the specific technological sector that follows, shall provide a framework for the positioning of the CleanHyPro OITB in the current market and hence, later materialize the offer of the SEP [8].

- The **type of services** that the granted OITB have so far offered are quite similar, they involve the development, manufacturing, testing, and characterization services related to a specific technology and/or product, as well as non-technical services that complete the SEP package and aim to foster the business development of the R&D activities of the OITB partners and its customers. The OITBs approach customers SMEs and larger industries, 50 % of the evaluated OITBs offer services also to R&D entities like RTOs and Universities.
- The **number of customers** and/or provided services is represented by the number of **democases** for each OITB, Figure 8. There is a wide diversity among the OITBs, going

from OITB which accounts for less than 10 democases to OITB where the number overpass the 20 democases.

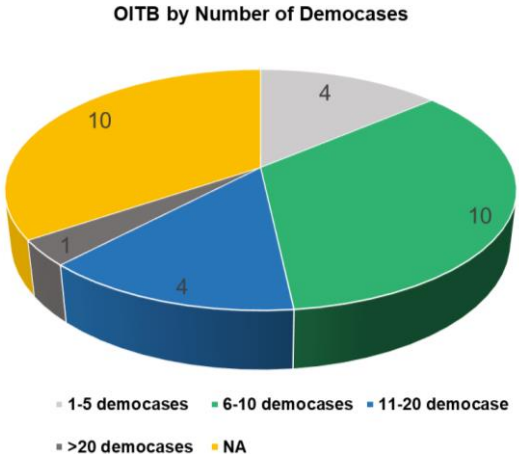


FIGURE 8. CHART OF THE OITB NUMBER AGAINST THE NUMBER OF SUPPORTED DEMOCASES.

The first and second generation of OITBs launched in fact Open Calls for the participation to the Democases. When developing new products, companies search for possibilities to test innovative technologies and the OITBs usually provide access to pilot lines. Besides the technical knowledge, OITB have also provided support on how to address non-technological barriers such as regulation and financing: services for instance include the development of business plans, access to investors and leading companies, and early access to guidance on regulation for compliance with European norms.

OITB visibility is the most important aspect to make SMEs and other customers aware of the advantages the OITBs offer: a well-structured communication and dissemination strategy had to be incorporated by the early stage to reach out to clients throughout and beyond the project to ensure the sustainability of the SEP. The Open Calls for the democases have required an active outreach, as in many cases the OITBs received a limited number of applications when they launched the Open Calls.
The analysis of the customers engagement has specifically shown that:

- 84% of the OITBs have organized Open calls. From the Open Calls, 60% resulted in 1 to 10 demos, 30% resulted in 11 to 50, and 10% resulted in more than 50;
- 55% of the OITBs had 1 to 10 SMEs applications to the Open Calls, 36% had 11 to 50, and 9% had more than 50 applications. Depending on the OITB, more than 50% of the total demo cases were performed for SMEs. The total of demo cases is higher than the number of demos in the Open Calls, showing that the OITBs are delivering services beyond the Open Calls;
- 30% of the OITBs have generated more than 10 innovative products or processes, 50% have generated 6 to 10 and 20% have generated 1 to 5. 10% of the OITBs have at least 5 innovations that have reached the market. For 60% it is too early to say, as this is an ongoing process;
- The TRLs of the services range from: 3 to 5 (69%), 4 to 6 (69%), 5 to 7 (38%), and 6 to 8 (8%). 77% of the innovations are related to advanced materials, 31% to other applications, 23% to critical raw materials, and 15% to secondary raw materials;

- The main hurdles customers face are financial (85%), investment (62%), regulatory (46%) and technical (46%);
- The markets fields of the OITBs include: 38% health care; 23% construction, renewable energy and hydrogen, transport, and packaging; 8% textiles and electronics; and 15% other markets.

Overall, the main customers of the OITB are SMEs. The participation of SMEs in the calls ranged from 40 to 80%, with some project calls being restricted to SMEs. **Until September 2022, more than 80 SMEs applied to these Open Calls with a success rate of more than 50%.**

The strong participation of SMEs as customers of the OITBs ensures the continuity of operation and services well beyond the end of the project.

From the 26 OITBs of H2020, 10 SEPs are or will be established as for-profit organizations, 8 as non-profit organizations, and 1 is a collaboration agreement.

Previous analyses and questionnaires performed in 2023 concluded that [5, 8]:

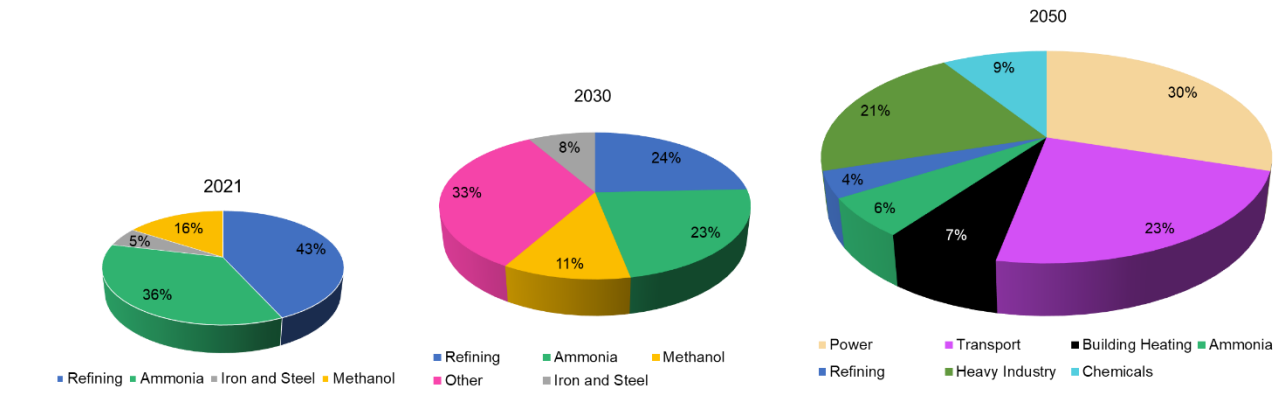
- 85% of these OITBs rely on membership fees to achieve financial sustainability, 46% on public funding, and 31% on specialized services, 23% of the OITB plan to achieve sustainability immediately after the grant ends, 31% within one year and 15% within two years.
- 38% of the OITBs expected to have an additional turnover of 4 times the EU funding within 5 years, and a further 31% in 5 to 10 years. 54% of the OITBs had less than 1 M€ of gross revenue and 8% between 1 and 5 million. 38% preferred not to answer.
- 85% of the OITBs do not have particular prices for SMEs, since their services are considered to have a fair price and depend on the activity rather than the customer. The average price charged varies considerably, from 30,000 to 100,000 €, depending on the service and the provider.

5 MARKET AND STAKEHOLDERS LANDSCAPE

5.1 HYDROGEN MARKET

Hydrogen (H_2) is one of the key elements for energy transition that could help tackle climate change. It is a versatile energy carrier that can be produced using renewable energy sources and has potential applications in fuel cells for transportation and industrial processes, providing a clean alternative to fossil fuels. Hydrogen production today is primarily based on unabated fossil fuel technologies. Yet – it is expected that in the Net Zero Emissions by 2050 scenario, low-emissions hydrogen will play a key role in sectors that are hard to decarbonize, such as heavy industry and long-distance transport, with electrolysis powered by renewable electricity being the main route of production [9].

Global demand and hence, global production of H_2 are indeed, forecasted to significantly grow in the next three decades. While in 2021, the demand for H_2 was about 92.3 Mt, the amount is expected to reach 793 Mt in 2050 (Figure 9). As a consequence of its key role in energy transitions the high quest for H_2 in new application sectors is also forecasted: if today H_2 is mainly utilized for refining and the production of ammonia (ca. 80% of the total demand), in 2025 transport and power generation will be the application sectors demanding more than 50% of the total H_2, whit the traditional application sectors such as ammonia production, chemicals, refining and heavy industry accounting for the remaining percentage (Figure 9) [10].



Total demand (Mt)	92.3	152.3	793

FIGURE 9. GLOBAL DEMAND OF H_2 (MT) AND BY SECTOR (%) AS IN 2021 AND AS FORECASTED IN 2030 AND 2050.

To cover such an increasing demand, H_2 production is also expected to grow at the global scale as well as its production route to move from fossil sources to electrolysis. In 2021, 120 Mt of H_2 have been produced and only 4% of this amount has been obtained through electrolysis. This route leads indeed to the production of the so-called **green hydrogen**, which differs from the **grey** and **blue** types since no CO_2 is formed during its production (Table 3) [11, 12].

Color	GREY H_2	BLUE H_2	GREEN H_2
Process	Steam Reforming	Steam Reforming with **CCUS**	Electrolysis
Source	Fossil	Fossil	Renewable Electricity
GHG Emissions	Very High	Moderate to Low	Zero

TABLE 3. DIFFERENCES BETWEEN HYDROGEN TYPES.

Grey hydrogen is obtained from fossil resources mainly through the reforming of natural gas (40% of the total production in 2021) a process that leads to the generation of CO_2: the hydrogen as-produced is defined as blue when technologies for carbon capture utilization and storage (CCUS) capture the CO_2 created during the reforming process before it is released into the atmosphere. By 2050, the total, global H_2 production is expected to reach 528 Mt, against the 120 Mt of today being electrolysis the process that will cover 50% of the production against the 4% of today. The relative percentage of production routes is expected to change over the next years, with electrolysis reaching 29% in 2030: Electrolysis processes are going to be intensely developed and implemented in the current decade (Figure 10) [10].

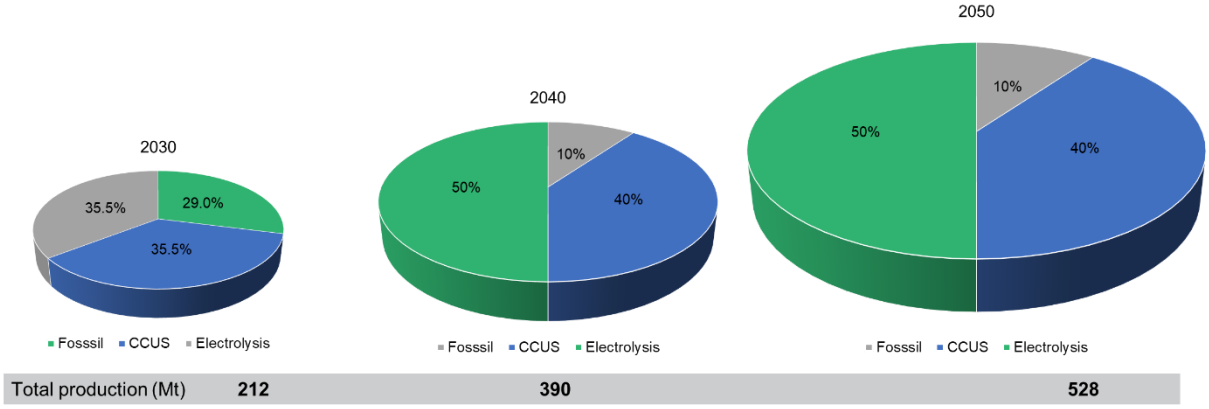


FIGURE 10. FORECASTED GLOBAL H_2 PRODUCTION (MT) AND BY RESOURCE (%) IN 2030, 2040 AND 2050; WHERE H_2 FROM FOSSIL RESOURCES IS DEFINED AS GREY HYDROGEN, PRODUCED WITH CCUS AS BLUE HYDROGEN AND FROM ELECTROLYSIS AS GREEN HYDROGEN.

Indeed, today of the production of low carbon hydrogen, (total amount of blue, and green hydrogen) 1.5 Mt is blue hydrogen (produced with CCUS) and only 0.5 Mt is green hydrogen produced through electrolysis. In 2030, 75 Mt is expected to be green hydrogen and 17 Mt is blue hydrogen [13].

5.1.1 Hydrogen Market in EU

In recent years, the hydrogen market in Europe has undergone significant transformations, reflecting the global trends: along with the traditional applications, its key role is emerging in clean energy transitions. Currently, a substantial portion, accounting for 50.50%, is utilized as a chemical feedstock for oil refining, signifying its importance in industrial processes.

Additionally, hydrogen finds extensive use in ammonia production (29.50%), methanol synthesis (4.30%), and various other chemical syntheses (7.30%). Moreover, it is employed in niche sectors such as the food industry, glass manufacturing, and power generation cooling, constituting 4.70% of the demand. Despite its versatility, hydrogen's role in energy production remains relatively modest, comprising only 3.70% of its overall usage, primarily in industrial settings where it is combusted for its energy content. Transport applications, while promising, currently represent a minuscule fraction, standing at just 0.001% of the total demand [10].

As of 2020, hydrogen production sites across Europe numbered 504, underscoring the region's substantial infrastructure for hydrogen generation. With **a total production of 11.5 Mt**, the seven key players, Germany, the Netherlands, Poland, Italy, France, Spain and UK collectively held 69% of the market share. The demand for H_2 reflects the production capacity in these countries, 72% of the total EU demand (Table 4). Water electrolysis accounted for about 0.25% of this total (11.5 Mt/year) hydrogen production capacity in Europe [10].

Top EU Countries in H_2 Production and Demand	Germany	Netherlands	Poland	Italy	France	Spain	UK
H_2 Produced (Mt)	2.09	1.55	1.03	0.85	0.82	0.79	0.78
Market Share (%)	18	13	9	7	7	7	7
H_2 Production by Top 7 (%)	69						
H_2 Demand (Mt)	20	15	9	7	7	7	7
H_2 Demand by Top 7 (%)	72						

TABLE 4. TOP EU COUNTRIES BY H_2 PRODUCTION AND DEMAND IN 2020.

Looking towards the future, the planned industrial consumption of renewable hydrogen is projected to witness substantial growth, reaching 5.4 MtH2/y by 2030 and expanding further to 6.1 MtH2/y when factoring in projects with undisclosed operational dates. Notably, Germany emerges as a pivotal player, expected to drive 38% of the total clean hydrogen consumption, underscoring its commitment to sustainable energy solutions. These developments underscore a paradigm shift towards renewable green hydrogen, indicating a strategic move towards decarbonization and sustainable energy practices in Europe. As the continent continues to navigate the complexities of energy transitions, the hydrogen market stands poised for further expansion and innovation in the years to come.

In 2023, the landscape saw the beginning of this transition, marked by the production of 1 Mt of blue hydrogen with CCUS technology, alongside and 0.2 Mt generated through electrolysis. This initial step underscored the continent's commitment to exploring diverse pathways towards hydrogen production. Indeed, fast forward to 2030, and the European hydrogen sector experiences a remarkable expansion: Blue hydrogen production, augmented by CCUS, scales up significantly to 8 Mt and with electrolysis emerging as a pivotal player, contributing a substantial 24 Mt of green hydrogen to the market (Figure 11) [13].

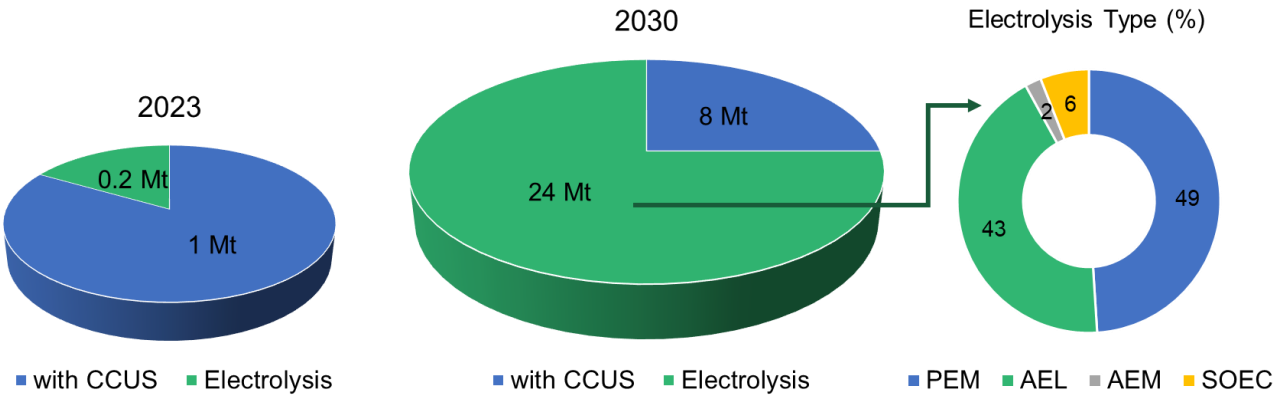


FIGURE 11. GREEN AND BLUE EUROPEAN H_2 PRODUCTION (MT) IN 2023 AND AS FORECASTED BY 2030. PERCENTAGE OF EACH ELECTROLYSIS TYPE IN 2030.

A closer look at the electrolysis landscape forecasted for 2030 reveals that Proton Exchange Membrane (PEM) electrolysis takes the lead, constituting 49% of the total electrolysis capacity. Alkaline Electrolysis (AEL) accounts for 43% of the capacity, while Anion Exchange Membrane (AEM) and Solid Oxide Electrolysis Cell (SOEC) technologies collectively contribute to the remaining capacity. The specific details and trends of the four technologies are highlighted in the following paragraphs. CleanHyPro OITB aims to serve as a key platform to provide services and *know-how* to stakeholders operating in such a market sector and hence, foster the energy transition by supporting the development, and implementation of all four types of electrolyzer technologies and hence, the expansion of water electrolysis technologies. In the long vision of reaching net-zero by 2025 Europe is forecasted to be the largest market for electrolysers [14].

Indeed, the additional capacity of water electrolysis will be covered both by the existing plans as well as by under-construction plants across the entire Europe (Figure 12). Currently, Germany has a leading role contributing 38% of the total water electrolysis installed capacity, equivalent to 64.12 MW within Europe, closely followed by France, with 15% of the total water electrolysis installed capacity, or 15 MW. However, the landscape is set to change with the plants currently under construction, which are poised to place Sweden, France, and the Netherlands at the forefront. These new developments are expected to contribute a substantial increase in their water electrolysis production capacity, with Sweden adding 520 MW, France contributing 252.3 MW (or 41,700.91 t/year), and the Netherlands adding 205 MW (or 33,883.02 t/year) to their respective total production capacities by 2025 [15, 16].

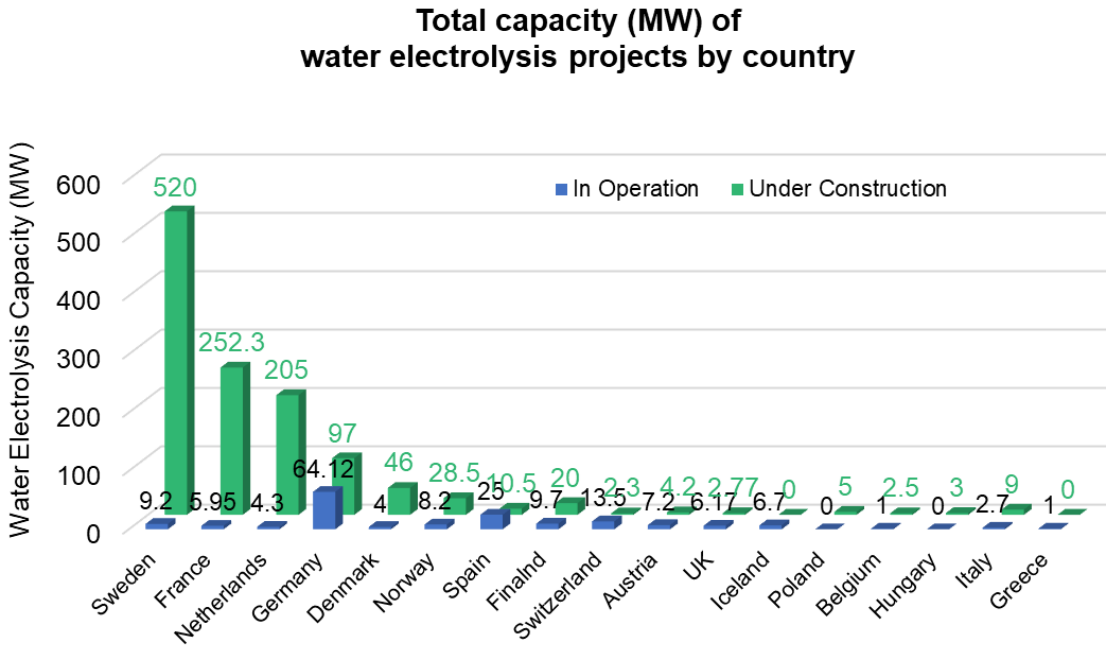


FIGURE 12. TOTAL (MW) OF WATER ELECTROLYSIS POWER-TO-HYDROGEN PROJECTS BY EUROPEAN COUNTRIES.

5.2 ELECTROLYZERS MARKET

The global and European transition from grey and blue to green hydrogen production, its scale-up to meet the energy transition goals by 2050, and the increasing demand for hydrogen all, rely on the development, implementation, and increased capacity of electrolysis technologies. Electrolysers, which use electricity to generate hydrogen and oxygen from water, are the critical technological platforms to produce green hydrogen. The market trends and forecasts for the future related to electrolyzer technology reflect the fast advancement toward the energy transition goals (Figure 13) [17, 18].

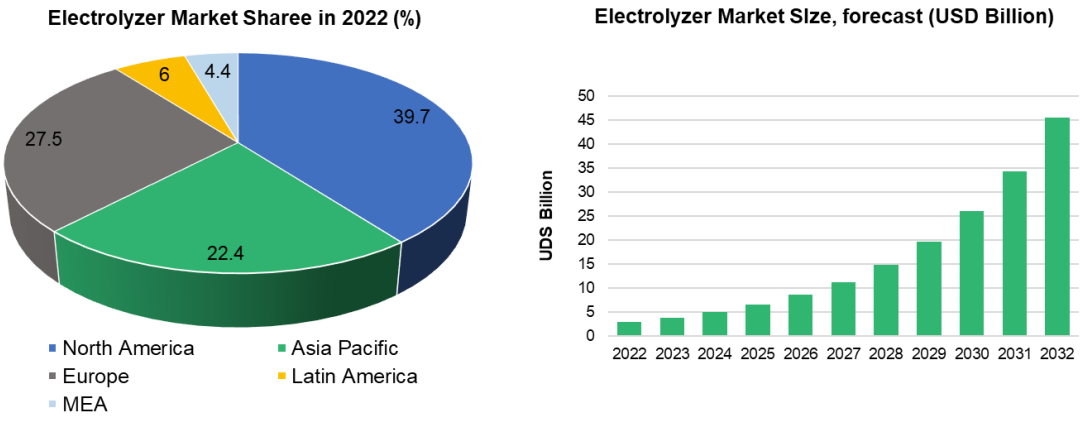


FIGURE 13. ELECTROLYZER MARKET SHARE (I.E. REVENUE SHARE) PER REGION AND FORECAST.

As of 2022, Europe has 27.5% of the electrolyzer market share, with North America having the larger share of market, 39.7%, and Asia accounting for 22.4%; the other economic regions

account for just 10% of the market. Such a market is expected to grow at a CAGR rate of 32.20% from 2022 to 2032 reaching a value of USD 45.48 billion against the 2.8 billion of 2022 [19].

The electrolyzer manufacturing capacity increased by more than 25% from 2021 to 2022, reaching nearly 11 GW of yearly capacity in 2022, and 14.4 GW in 2023, with the European Union accounting for 3.9 GW. The production capacity is forecasted to reach 134.5 GW of yearly capacity by 2023, with European capacity increased to 25.3 GW (Figure 14).

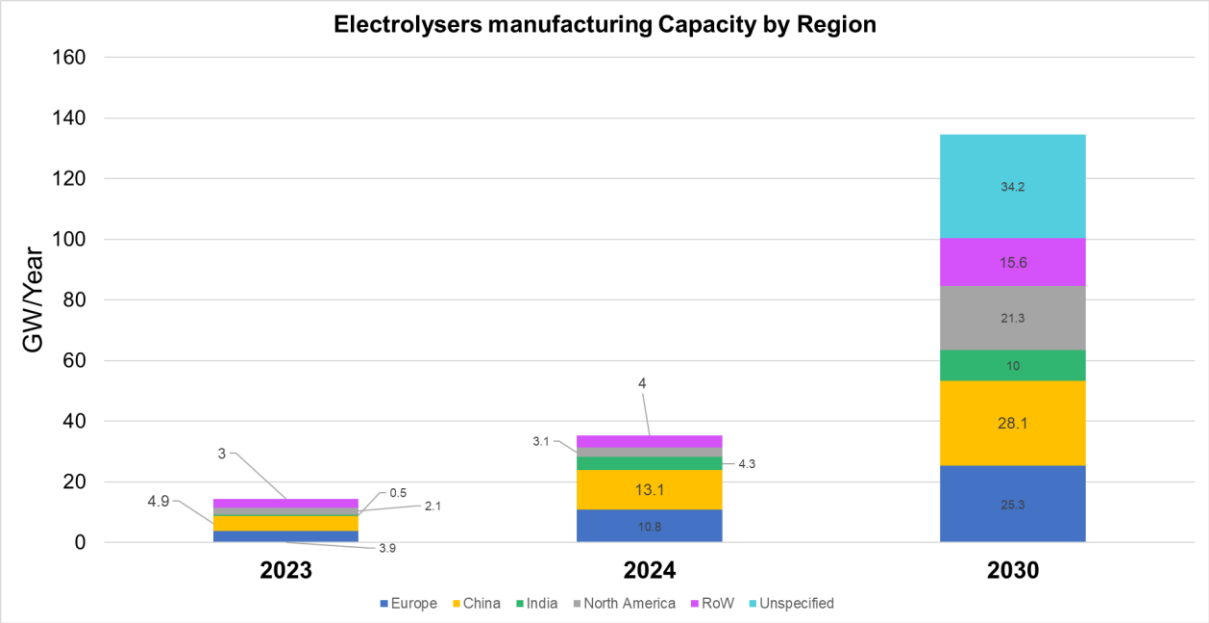


FIGURE 14. FORECASTED ELECTROLYZERS MANUFACTURING CAPACITY TRENDS PER REGION.

On the contrary, from 2021 to 2022 the electrolyzer installed capacity grew by about 20% against the 25% of the increased manufacturing capacity. Although the electrolysis capacity dedicated to hydrogen production has been growing in the past few years, both the manufacturing and the installed capacity require a significant acceleration if the Net Zero Emissions is aimed by 2050 Scenario and the goal is to reach more than 550 GW by 2030.

The realization of all the projects in the pipeline could lead to an increased manufactured and installed electrolyzer capacity worldwide. Together with China and The United States, **the European Union is one of the regions that are making notable progress in advancing electrolyzers**. The European Union installed about 80 MW in 2022, more than twice that installed in 2021. In July 2022 the Commission approved funding of EUR 5.4 billion to support its first hydrogen-related Important Project of Common European Interest (IPCEI), Hy2Tech, with a focus on hydrogen technologies, including incentives for electrolyzer manufacturers [11].

In this framework, the **CleanHyPro OITB** can lead to important technological advancements by bringing together the most recognized experts in Europe on the electrolysis field for clean hydrogen production to offer services and act as facilitators of technology transfer. The CleanHyPro OITB offer shall foster both the manufacturing capacity as well as the advancement and implementation of the four types of electrolyzer-related technologies.

5.2.1 Market Data by Type of Electrolyser

AEL and PEM technologies are commercially available. Although AEL electrolyzers have a longer history than PEM ones, being used in the chlor-alkali industry, they have a comparable technology readiness level (TRL) of 9 for their dedicated use to the production of hydrogen through electrolysis (Figure 15). Yet - to be competitive with respect to the production of hydrogen from fossil resources and to meet the increasing quest for green hydrogen production, both technologies are undergoing further development and improvements. SOEC electrolyzers, now at a TRL between 7 and 8, are quickly and recently approaching commercialization: in April 2023, a SOEC electrolyzer was installed in the Netherlands with a capacity of 2.6 MW, and a few weeks later a 4 MW SOEC system was installed in a NASA research center in California. AEM electrolysers are at earlier stages of development, TRL of about 6: They are produced, but still at a very small scale. In Europe, Enapter – one of the partners of CleanHyPro – is developing the AEM technology [20].

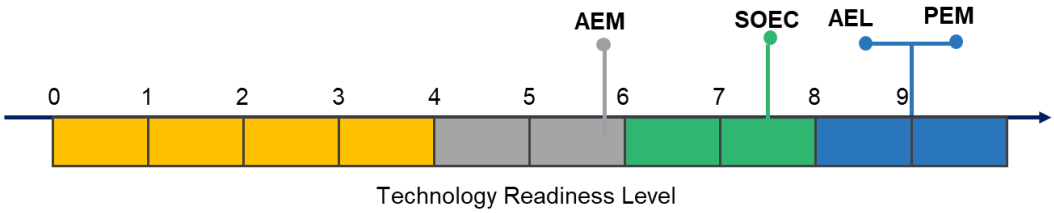


FIGURE 15. TECHNOLOGY READINESS LEVEL OF EACH ELECTROLYZER TYPE.

Despite a slowdown in global electrolyzer capacity in 2022 compared to the previous year, the momentum remains strong: Electrolyzers, primarily used in the chlor-alkaline industry for chlorine and sodium hydroxide production, have seen accelerated deployment for dedicated hydrogen production since the late 2010s. While 2021 and 2022 has a similar installed capacity, yet higher than the previous years; a net increase has been achieved in 2023 (Figure 16). PEM and AEL have been the leading technologies with their installed capacity increasing of about 10 folds over the last five years. In 2023 the installed capacity of other technologies, if negligible for the previous years, contributes to 28% of the total, 811 MW out of 2884. The United States are expected to have a significant role in the development and implementation of SOEC related technologies [21].

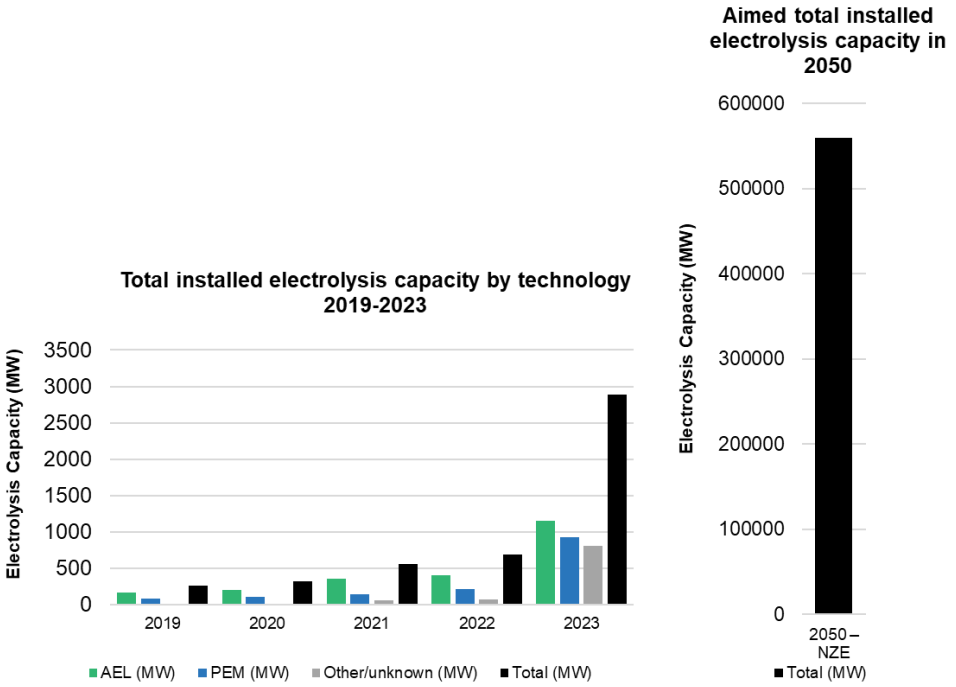


FIGURE 16. INSTALLED ELECTROLYSIS CAPACITY BY TYPE OF ELECTREOLYZER OVER THE PAST 5 YEARS AND TOTAL CAPACITY TO BE INSTALLED TO REACH NET-ZERO 2050.

Looking ahead to 2030, if all pipeline projects materialize, the total installed capacity should achieve GW range against the MW, with Europe being one of leading regions. However - as identified by the CleanHyPro OITB mission - future demand, regulatory clarity, infrastructure limitations, and financing challenges need to be addressed to align with the Net Zero Emissions Scenario, which calls for over 550 GW of electrolyzer capacity by 2050, the project pipeline must scale up significantly faster (Figure 16).

Hence, to reach this capacity goal the existing gap between manufacturing and aimed installed capacity must be filled. Global manufacturing capacity for electrolyzers stood at 8 GW per year in 2021, with two regions, Europe and China, accounting for 80% of global manufacturing capacity. Global manufacturing capacities should reach 65 GW per year by 2030, with the effort in Europe and China expected to continue to grow. AEL dominate today the global manufacturing capacity with a share of 60% global manufacturing capacity, reflecting the maturity of the technology compared to PEM and SOEC electrolysers. By 2030, AEL are projected to account for 64% of manufacturing capacities, followed by PEM (22%) and SOEC (4%). AEM technology has so far been mainly deployed in demonstration projects, but the leading manufacturer Enapter is building manufacturing capacities that aims for 280 MW (Figure 17) [22].

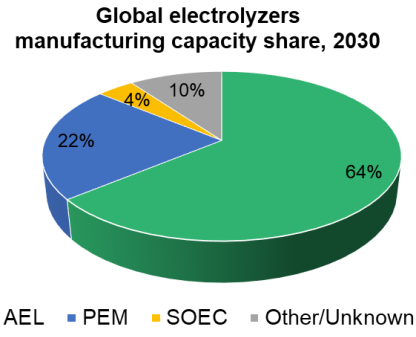


FIGURE 17. GLOBAL ELECTROLYZER MANUFACTURING CAPACITY SHARE IN 2030.

Co-funded by the European Union

5.2.1.1. Electrolyzer Manufacturing Capacity in Europe

As reported by the European Hydrogen Landscape (Figure 18), in 2023 the European manufacturing capacity looked as following: AEL accounts for 53% of the total manufacturing capacity in Europe, with 3.05 GW per year, followed by PEM technologies with 46% (2.66 GW), while SOEC and AEM together represent less than 1% of the total manufacturing capacity (ca. 0.04 GW). If the current ongoing projects materialize as expected by 2025, AEL manufacturing capacity will increase to 4.05 GW per year, accounting for 53% of the total. The manufacturing capacity of PEM electrolyzer is instead expected to remain constant to 2.66 GW per year, representing eventually 35% of the total. Therefore, PEM technologies have a larger share of the European manufacturing market landscape than the global one. A significant increase over the next two years should be observed for SOEC and AEM related technologies, which manufacturing capacity will represent respectively 8% and 4% of the total, i.e., 0.61 GW and 0.33 GW per year of production. The reader should however consider that different reports and scientific publications might estimate and forecast different values of manufacturing capacity at the European level; for instance, a report commissioned by the Scottish Government estimates a value of 17.5 GW of total manufacturing capacity per year by 2025 [23].

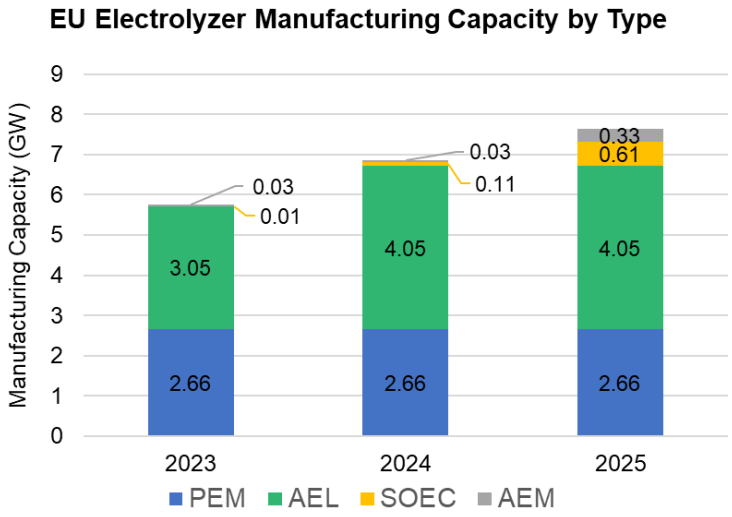


FIGURE 18. ELECTROLYZER MANUFACTURING CAPACITY IN EUROPE BY TYPE OF TECHNOLOGY.

The current capacity of electrolyser manufacturing is expected to increase, driven by the 'Fitfor55' and 'RePowerEU' policies [24]. The European Commission's hydrogen strategy committed to facilitate and scale up the production of electrolyzers to meet the strategic objective of installing at least 40 GW of renewable hydrogen electrolyzers by 2030. Among the European countries, Germany has committed to the largest individual target of 10GW electrolyzer capacity by 2030. An integrated supply chain is taking shape in Europe and necessitates expansion: the European Clean Hydrogen Alliance is coordinating the effort and in May 2022, twenty electrolyzer manufacturers signing a joint declaration at the European Electrolyzer summit [25].

Co-funded by the European Union

5.2.2 Comparison of the Types of Electrolyzers

Table 5 compares the key technological aspects and the key market data, drivers and barriers for the three types of commercial electrolyzers: PEM, AEL and SOEC. AEM data are instead reported in the following paragraph [26, 27].

	PEM	AEL	SOEC
Cost	CAPEX (USD) required to generate 1 k watts of electrical power (KW_e) is in the range [28]		
	800 - 1800	**350 - 1400**	**2800 - 5600**
Efficiency	56 – 60 (%, LHV)	63 – 70 (%, LHV)	74 – 81 (%, LHV)
Operating Conditions	Temperature = 50 – 80 °C Pressure = 30 – 80 bar	Temperature = 60 – 80 °C Pressure = 1 – 30 bar	Temperature = 650 – 1000 °C Pressure = 1 bar
Advantages	Small footprint Flexible operation High pressure and purity H_2 at low T and P Fast dynamic operation	Mature Technology High efficiency at low T and P and at large scale Suited for continuous operation Lower CAPEX	Low Material Cost Possibility for reverse mode operation High efficiency Possibility to couple with high T heat sources
Disadvantages	Expensive catalysts determine higher CAPEX Precious catalysts Sensitive to impurities, it can degrade over time	Higher footprint, high cost and precious catalysts Corrosive and lower efficiency Oxygen traces as impurity in H_2 Slower than PEM	Least mature technology High operating temperature, heat source needed and short durability Limited commercial availability High manufacturing and installation costs
Main Applications	Portable and distributed hydrogen generation for applications like backup power, small-scale fueling stations, and off-grid power systems Fuel cell vehicles (FCVs) where compactness, efficiency, and fast start-up are crucial Electrolyzers integrated with renewable energy sources for decentralized hydrogen production	Large-scale hydrogen production for industries such as chemical manufacturing, petroleum refining, and metallurgy Power-to-Gas (P2G) projects for grid stabilization and energy storage Hydrogen refueling stations for fuel cell vehicles	High-temperature electrolysis for industrial processes like ammonia production and steel manufacturing. Co-electrolysis of steam and CO_2 for syngas production and carbon capture utilization. Integration with high-temperature heat sources such as nuclear reactors and concentrated solar power plants
Market Drivers	**Compactness:** PEM electrolyzers are compact and can be easily scaled down, making them suitable for portable and distributed hydrogen generation	**Mature Technology:** Alkaline electrolyzers benefit from decades of industrial experience, making them a trusted option for large-scale hydrogen production	**High Efficiency:** SOECs operate at high temperatures, enabling high efficiency and reduced electrical energy consumption, making them attractive for industrial processes

	Efficiency: They offer high efficiency, especially at low loads, making them ideal for small-scale applications and integration with renewable energy systems **Fast Start-Up:** PEM electrolyzers have fast start-up and response times, which is crucial for applications requiring rapid deployment **Fuel Cell Vehicles:** The growth of fuel cell vehicles drives demand for PEM electrolyzers, particularly for on-site hydrogen production at refueling stations	**Efficiency:** They exhibit high efficiency, particularly at large scales, which is attractive for industrial applications **Grid Stabilization:** Alkaline electrolyzers contribute to power-to-gas (P2G) projects, aiding in grid stabilization and energy storage **Hydrogen Infrastructure:** As hydrogen refueling stations for fuel cell vehicles become more widespread, the demand for alkaline electrolyzers is expected to increase	**Syngas Production:** They can co-electrolyze steam and CO2 to produce syngas, offering potential applications in ammonia production, steel manufacturing, and carbon capture utilization **Integration with High-Temperature Heat Sources**: SOECs can integrate with high-temperature heat sources like nuclear reactors and concentrated solar power plants, improving overall energy efficiency
Market Barriers	**Cost:** PEM electrolyzer technology tends to be more expensive, especially for large-scale deployments, due to the cost of materials like platinum **Durability:** They can be sensitive to impurities and have a shorter lifespan compared to other types of electrolyzers, leading to higher maintenance costs **Scaling Challenges**: Scaling up PEM electrolyzer technology while maintaining efficiency and cost-effectiveness remains a challenge **Hydrogen Purity:** PEM electrolyzers require high-purity water, which can be a barrier in certain environments or applications	**Corrosiveness:** Alkaline electrolytes can be corrosive, requiring careful materials selection and maintenance **Cost:** While mature, alkaline electrolyzer technology can still be expensive, particularly for large-scale installations **Precious Metal Catalysts:** They typically rely on precious metal catalysts like platinum, which can drive up costs and limit scalability **Response Time:** Alkaline electrolyzers may have slower response times compared to other types, impacting their suitability for certain applications	**High Operating** Temperatures: Operating at high temperatures requires specialized materials and can lead to durability issues, driving up costs and limiting scalability **Limited Commercial Availability**: SOEC technology is still in the early stages of development, with limited commercial availability compared to other electrolyzer types **High cost of production:** High manufacturing and installation costs associated with operating at high temperatures and specialized materials are a significant barrier to adoption **Complexity:** SOEC systems are more complex compared to other electrolyzer types, requiring careful engineering and control systems
Market Growth Forecast	The global PEM electrolyser market size is forecasted to grow from 2022 to 2027, from USD 737.6 million in 2022 to USD 4.3 billion by 2027 at a CAGR of **42.2%**	AEL electolyser market size is valued at USD 1.6 Billion in 2023 and is projected to reach USD 5.8 Billion by 2030, growing during the forecast period 2024-2030 at a CAGR of **18.6%**	SOEC electrolyser market is expected to grow from USD 800 million in 2022 to USD 3,3 billion in 2029, thus, growing at a CAGR of **59.7%**

TABLE 5. KEY TECHNICAL ASPECTS AND MARKET DATA BY TYPE OF ELECTROLYZER.

PEM, AEL and SOEC are the prominent commercial technologies for the generation of green hydrogen. The cost comparison sees PEM electrolyzers, while showing considerable cost reductions, still having higher CAPEX (approximately 30% more expensive) than AEL technology, which is the most cost-effective technology, although it has comparable efficiency than PEM and operates at similar conditions. The much higher CAPEX of SOEC is primarily due to the complex materials and manufacturing processes involved [28]. Although

SOEC leads to higher efficiency in H2 production, it requires much harsher operating conditions.

PEM electrolyzers are favored for applications requiring high responsiveness and efficiency, such as hydrogen fueling stations and chemical processing industries. AEL technology, being well-established, finds extensive use in large-scale applications like power plants, chemical processing, and transportation. SOECs offer versatility, catering to diverse applications including transportation, industrial processes, power generation, and the co-production of hydrogen and syngas.

Several factors drive the market for electrolyzer technologies, including the growing interest in green hydrogen production, integration of renewable energy sources, government policies promoting clean energy, and the rising demand for hydrogen fuel cells and electric vehicles (which is one of the key drivers for PEM technology). These drivers indicate the shifting paradigm towards sustainable energy solutions and decarbonization efforts across various sectors. Despite the promising prospects, electrolyzer technologies face challenges such as the increasing cost of electricity, competition from cheaper alternatives, and concerns regarding material intensity and the cost and availability of precious metals that act as catalysts. Each technology presents unique advantages and challenges, with ongoing innovations that should therefore drive cost reductions, efficiency improvements, and expanding application possibilities that contribute to the forecasted market growth. **The market trends see in fact AEL and PEM continuously growing, with PEM at a higher CAGR (42.2 against 18.6%) and SOEC rapidly approaching a competitive market share and value by 2029 at a much faster rate, CAGR of 59.7%** [29].

5.2.2.1 AEM Technologies

In addition to the two main low-temperature electrolysis technologies (AEM and PEM electrolysis), recent years have also seen the development of AEM technology. Although, the AEM technology offers advantages compared to AEL and PEM since it avoids the use of expensive and precious metal catalysts while yielding high-purity hydrogen due to the presence of a solid electrolyte, it is the least developed from commercial point of view. The lack of commercial maturity prevents an esteem of the related CAPEX and OPEX, hence AEM is described in this section. Table 6 summarizes the key market data for AEM technology.

AEM is a membrane technology, like PEM, but operates in an alkaline medium, allowing for the use of inexpensive materials and resulting in a smaller footprint. The main advantages and hence, market drivers, of this technology include its efficiency and electricity consumption use of abundant and cost-effective materials in most of the components. Yet- there are currently very few companies in the market selling AEM electrolyzer products, **the market barriers and, hence scalability and commercialization, are mainly the result of the lack of cost-effective and long-lasting membranes suitable for use in an alkaline medium** [26].

AEM	Main application	Advantages	Disadvantages
	Electrolysis systems for small to medium-scale hydrogen production Applications requiring compatibility with non-precious metal catalysts and low-cost materials Integration with renewable energy systems for green hydrogen production	Lower cost compared to PEM due to the absence of expensive platinum catalysts Compatibility with non-precious metal catalysts Suitable for small to medium-scale applications	Limited commercial availability and industrial experience compared to alkaline and PEM Challenges with membrane stability and performance at high current densities Lower efficiency compared to PEM
	Market Drivers		**Market Barriers**
	Cost-Effectiveness: AEM electrolyzers offer lower costs compared to PEM, primarily due to the absence of expensive platinum catalysts, making them attractive for small to medium-scale applications **Non-Precious Metal Catalysts:** They are compatible with non-precious metal catalysts, further reducing costs and improving sustainability **Green Hydrogen Production:** AEM electrolyzers integrate well with renewable energy systems, contributing to the production of green hydrogen		**Limited Commercial Availability:** AEM electrolyzer technology is relatively new and has limited commercial availability compared to alkaline and PEM electrolyzers **Membrane Stability**: Challenges with membrane stability and performance at high current densities need to be addressed for widespread adoption **Lower Efficiency:** AEM electrolyzers may have lower efficiency compared to PEM, impacting their competitiveness in certain markets **Scaling Issues:** Scaling AEM electrolyzer technology while maintaining performance and reliability is still a challenge

TABLE 6. AEM KEY MARKET DATA.

5.3 MAPPING OF POTENTIAL CLIENTS OF CLEANHYPRO OITB

An in-depth analysis of the electrolyzer manufacturers has been performed to identify the key stakeholders and hence, potential clients of the CleanHyPro OITB.

The analysis has identified globally 84 electrolyzer manufactures, which geographical distribution is represented in Figure 19: 41 of them are in Europe, 25 in the North America, 17 in the Asia-Pacific region and 1 in Latin America.

The countries with the highest number of electrolyzer manufactures are the United States with 24 companies, Germany accounts for 17 manufacturers and China with 8. Japan and UK both have 6 manufacturers of electrolyzers (Figure 20). At the European level, France and Norway

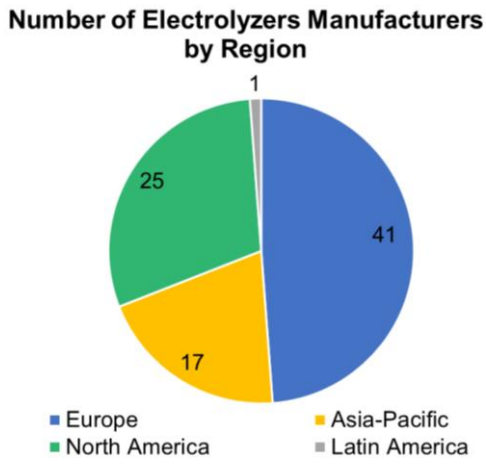


FIGURE 19. NUMBER OF ELECTROLYZER MANUFACTURERS BY GEOGRAPHICAL REGION.

contribute to the list with respectively 4 and 3 companies. The manufacturers' distribution in all the other countries is of mostly of 1-2 companies per country [23].

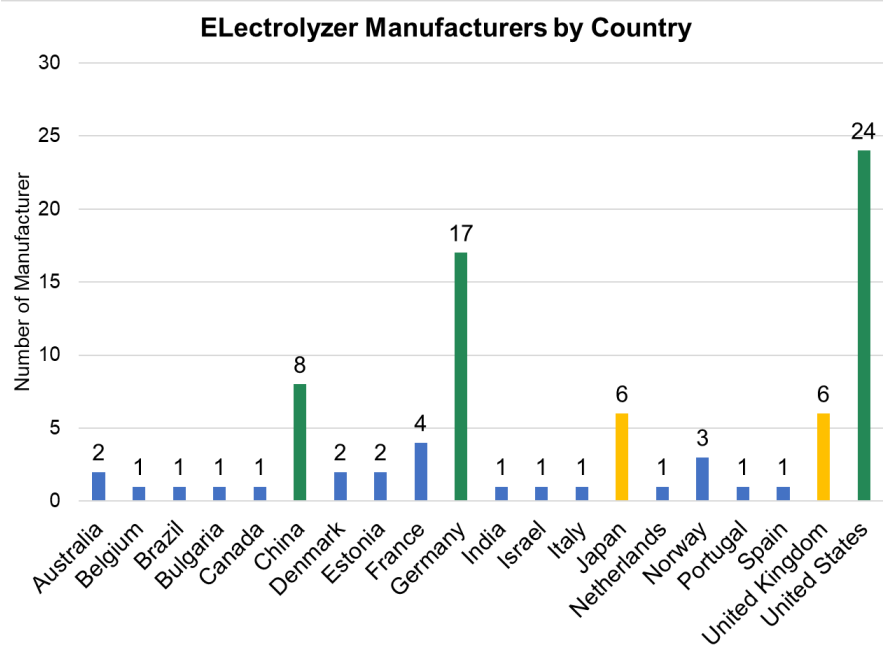


FIGURE 20. NUMBER OF ELECTROLYZER MANUFACTURERS BY COUNTRY.

Only 22 of the total 84 of electrolyzer manufactures are large companies, the remaining **62 companies are small and medium enterprises (SMEs)**, Figure 21. As highlighted in section 4.2, SMEs have been the key customers of OITBs.

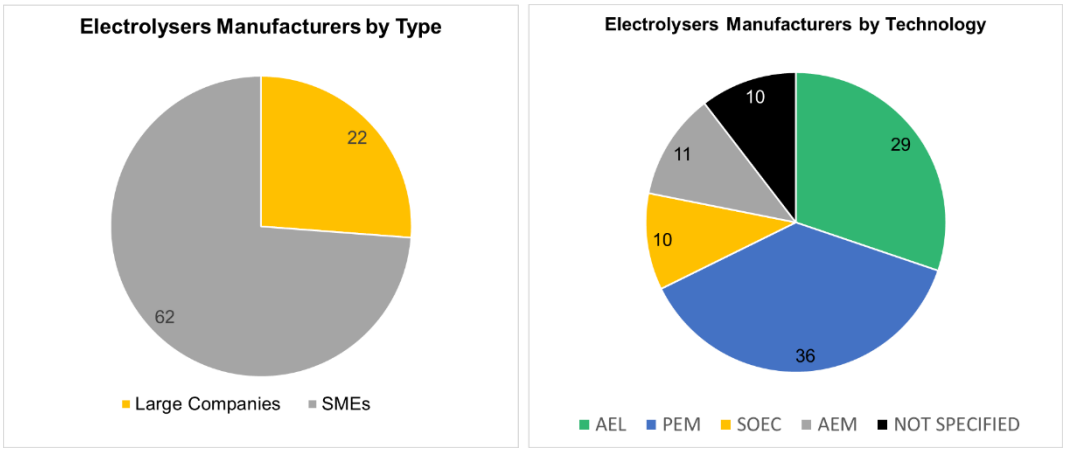


FIGURE 21. ELECTROLYZER MANUFACTURERS BY TYPE OF COMPANY (LEFT) AND BY ELECTROLYZER TECHNOLOGY (RIGHT).

If the electrolyzer manufacturers are classified by the technology type, it emerges that, besides the 10 for which no specifications where identified, 39 of them develop PEM related technologies, 29 AEL technologies, 10 SOEC technologies and 11 of them AEM technologies (Figure 21).

The significant R&D effort of the top key 13 manufacturers is demonstrated by the numbers of their projects, patents, and publications. Indeed, they have been involved in a total of 105 R&D projects in the last 10 years generating as an outcome a total of 850 patents and innovation announcements, and a total of 245 scientific publications. The amount of private investment received from Venture Capitals has also been substantial: It accounts for a total of about 1.8 billion euros over the last 10 years (Table 7).

Top 13 Companies over the last 10 years	
Projects	105
Patents	850
Papers	245
Investment	1.764 billion euros

TABLE 7. R&D EFFORT AND OUTPUT NUMBERS OF THE TOP 13 ELECTROLYZER MANUFACTURERS.

The analysis has also been expanded to the manufactures of electrolyzer components; 14 companies have been identified and 10 of them are in Europe. Hence, the next step in the CleanHyPro project related to this analysis will be to engage the 41 manufactures of electrolyzer and these additional 10 components providers, with special focus on the SMEs at European level, and bring them closer to the OITB as well as to extend the analysis to identify more reachable stakeholders.

6 THE OFFER OF CLEANHYPRO OITB TO THE MARKET

6.1 SURVEY ANALYSIS

The activities, which results are summarized in this report, are the first step towards the materialization of the offer of the CleanHyPro OITB in the market, which is later formalized in a single document integrating the capability of the partners and hence, the services to be deployed for the democases. To construct such a value proposition, the capability and the scientific outreach and their alignment to the market need, a survey was prepared and circulated among CleanHyPro partners.

The content of the survey (Figure 4) was purposely structures to identify the information needed to draw the value proposition of the CleanHyPro OITB. Each of the partners was asked to indicate the type of services their university department/group, research center, industry or SMEs provided under the following categories:

- Ownership of one or more pilot lines;
- Remarkable Lab infrastructures and technological services;
- IP/Technology/Patents;
- Business-oriented services;
- Technological expertise & capabilities;
- Addressed market intended to be reached.

The surveys for each of the partners who participated are reported in the Annexes.

The collected information was deeply analyzed and the expertise of each organization, aligned with the existing pilot lines, was selected, and classified. The preliminary structure of the services is proposed in the following section with the vision of positioning the CleanHyPro OITB in the current technology market landscape, i.e., green hydrogen production and related electrolyzer manufacturing technologies, as well as to clearly distinguish the offered services from the ones provided by the currently operating OITBs at EU level.

6.2 PRELIMINARY SERVICES OF CLEANHYPRO OITB

The preliminary service portfolio is here described by assessing the OITB capability and scientific outreach and aligned with the market needs. The services are classified as technical (Table 8) and business related (Table 9).

The individual capabilities and or technical facilities and expertise of each partner have been integrated into clusters of services to address the four market sectors for each electrolyzer technology, the secondary market associated as well as the general hydrogen and electrolysis market development.

A detailed description of the services, with the specific problem addressed, the required time and resources will later be constructed in the official catalogues of services.

TYPE OF SERVICE	SERVICE NAME	BRIEF DESCRIPTION OF SERVICE	TECHNOLOGY, FACILITIES AND CAPABILITY	PILOT LINES AND PARTNERs INVOLVED	ADDRESSED MARKET(s)
Technical	**Manufacturing and testing of advanced AEL electrolyzers and their components**	Catalyst deposition for AEL electrolyzers Testing of AEL electrolyzers and their components	Equipment and facility for: • the production of sintered (metallic catalysts substrate) electrodes for efficient AEL electrolyzers via the continuous coating strategy, enabling the fabrication of electrodes with long operating times, 100,000 h or more; • the testing of electrochemical and mechanical properties. Capability for the development of AEL pressurized electrolyzers and refuelling stations technology.	PL 1: FHG MCP BTU	AEL electrolyzers manufacturing Secondary market: refineries, steel making, CH_3OH or NH_3 producers
	Manufacturing and testing of advanced PEM electrolyzers and their components	Catalyst deposition for PEM based on: • Spatial atomic layer deposition • Additive manufacturing (3D printing) of nanostructured, porous metallic electrocatalyst Testing of PEM electrolyzers and components	Improved Spatial atomic layer deposition to deposit electrocatalyst layers (e.g., IrO_2) for PEM electrolyzers. Fabrication and depositing of porous electrocatalyst layer (e.g., IrO_2 and Pt) with large surface area so that the amount of required precious metal is lowered – spark ablation to deposit the material without any solvent. Automated test facility for the efficient testing of cells and short stacks under diverse conditions (e.g. temperature, pressure, flow rates)	PL 2: TNO, SparkNano PL 3: VSP PL 4: SparkNano Solvay Hoeller UMICORE	PEM electrolyzers manufacturing Secondary market: electrolyzer component suppliers and catalyst producers

	Manufacturing and testing of advanced AEM electrolyzers and their components	Manufacturing and assembly of advanced CCM Testing of Membrane Electrode Assembly	Equipment for and expertise in homogenous catalyst dispersion (both for cathode and anode) on polymeric membrane to from a single cell. Facility for their semi-automated manufacturing and testing. Facilities for the manufacturing and characterization of single cell AEM – with a testing capability of 50 - 200 cm^2 cell; instrumentation for gas analysis to quantify H_2/O_2; expertise in ink formulation and screen printing on large surfaces (Target: 200 cm2). Target: (50-200 cm2) 5-10 cells.	PL 5: TEC PL 6: CEA Enapter Solvay UMICORE FGH	AEM electrolyzers manufacturing
	Manufacturing and testing of advanced SOEC electrolyzers and their components	Fabrication of complete SOEC cells/stacks via additive manufacturing Manufacturing of advanced electrode nanomaterials for innovative SOEC Testing of SOEC electrolyzers	Equipment and expertise for: • the design and fabrication of electrolyte-supported free-shape solid oxide cells up to 20x20 cm^2 via stereolithography (SLA) of ceramics substrates; and for the digital deposition of electrodes, coatings, and sealants. • the fabrication of SOEC cells and stacks based on advanced electrode nanomaterials – controlling of the deposition and annealing processes of the nanomaterial. Testing facilities for SOEC technology: from cell up to whole systems; analysis of performance and degradation over long runs ca. 25000 h (ca. 3 years) – increased measurements capability to test both single-cell and short-stack integrated with automated data-analysis protocols.	PL 7: IREC PL 8: IREC PL 9 : VTT CPT	SOEC electrolyzers manufacturing

TABLE 8. PRELIMINARY LIST OF TECHNICAL SERVICES OF CLEANHYPRO OITB.

TYPE OF SERVICE	SERVICE NAME	BRIEF DESCRIPTION OF SERVICE AND EXPERTISE	PARTNERs INVOLVED	ADDRESSED MARKET
Business	Labelling and Certification of new Electrolyzers	Definition and assessment of schemes of certification; definition of testing protocols to achieve e.g., CE marking and meet regulation requirements for commercialization.	BV EGHAC	Electrolyzer manufacturing and related technologies SMEs and R&D
	Dissemination and Communication	Outreaching dissemination and communication activities	F6S PNO, CiaoTech	Stakeholders in the entire value chain, public
	Scouting, Networking, and Access to Investors	Networking and access to investors in the field of hydrogen, mobility, circular economy, sustainability and renewable energies	EGHAC F6S PNO	Stakeholders in the entire value chain of green hydrogen, mobility, renewable energy, circularity, and sustainability
	Innovation Services	Market analysis, business plans, grants & funding scouting. Exploitation strategy and business development	STAM PNO, CiaoTech	Stakeholders in the entire value chain of electrolyzer manufacturing, advanced materials, and related technologies, energy, circularity and sustainability

TABLE 9. PRELIMINARY LIST OF BUSINESS SERVICES OF CLEANHYPRO OITB.

A further aim of the CleanHyPro OITB offer to the market is to establish a regional promotion scheme. In such a way, the market needs shall be addressed in a more effectively manner and the end-users be more engaged with the OITB. A preliminary geographical mapping and regional scheme is here proposed, Figure 22, to better visualize the clusters of services.

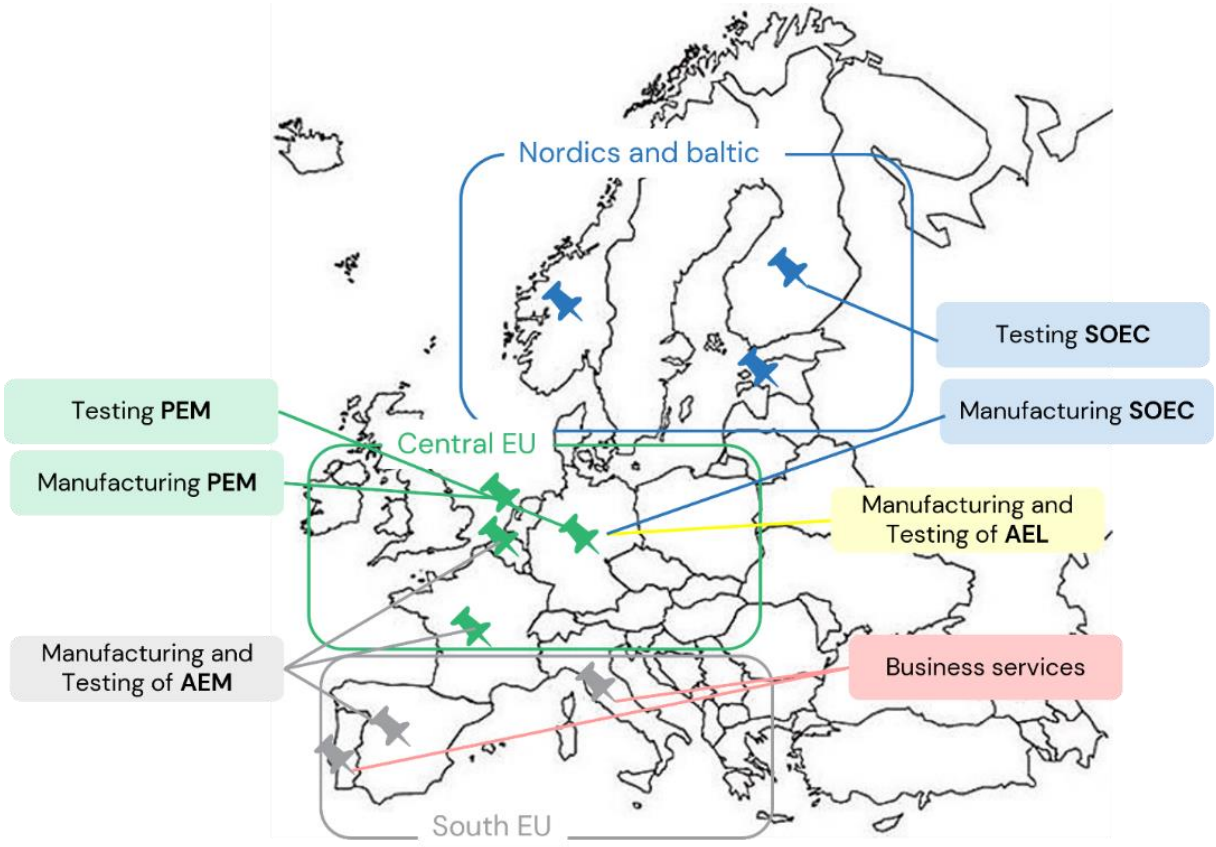


FIGURE 22. PRELIMINARY MAP OF CLEANHYPRO REGIONAL CLUSTERS OF SERVICES.

7 CONCLUSION AND NEXT STEPS

This deliverable provides a preliminary market analysis performed to make a scenario assessment related to the scope of the CleanHyPro OITB.

The analysis focused on identifying similar OITB initiatives in the EU landscape, demonstrating the competitive and innovative advantage of the CleanHyPro OITB in the scientific and technological outreach as well as economy sector. CleanHyPro is unique in the sector, technology, and products it targets compared to the previously granted OITB: electrolysis related technologies for green hydrogen production. Yet – the analysis provided useful guidelines for the stakeholders' engagement for the future deployment of the democases.

A qualitative and quantitative analysis of the market sectors related to the technologies covered by the OITB demonstrated the existing and forecasted demand to increase both the manufacturing and the installing capacity of electrolyzer. Such a trend is a consequence of significant growth in the green hydrogen demand, which is forecasted to have by 2025 key applications in sectors that differ from the actual uses: e.g. transport and power generation, where hydrogen is expected to replace the current utilized resources.

CleanHyPro assets cover the four most common type of electrolyzers. The preliminary market analysis showed that, besides the already commercially, established PEM and AEL technologies, SOEC technology is growing fast and AEM is also under development. EU, which currently accounts for 27.5% of the global market, is forecasted to have a key role in such a technology development as demonstrated by the number of undergoing initiatives, with Germany as one of the leading countries at global scale of electrolyzer manufacturing. A preliminary mapping of the stakeholders also concluded that most of the identified manufactures, ca. 74%, are SMEs and hence, potential customers of the OITB.

The analysis of these secondary, market data was integrated with an internal survey that engaged the project partners. Such a survey was also utilized to draft an initial list of the services that the CleanHyPro OITB has the capability to offer to the market. The services were classified as technical, and business related. The technical services are divided in four clusters, each of them involving the manufacturing and testing of one of the four electrolyzer type and their components. Hence, CleanHyPro shall foster the development and the transferability of R&D&I in all the four electrolysis technologies. Such a development is further supported by the business-oriented services that cover the regulation and labelling requirements to take these products to the markets, as well as the engagement of stakeholders and investors to support these initiatives, and innovation services to foster the business development.

7.1.1 Next Steps

The D2.1 represents the starting point for the D2.2, which shall include the complete market analysis with a focus on the demand side. Therefore, an expansion of the stakeholders' analysis will be performed with a focus on SMEs operating in the identified market sectors. The analysis will be followed by activities to promote their engagement with the CleanHyPro OITB: for instance, they might provide feedback to the preliminary catalogue of the services

and facilitating its validation and final offer to the market. Moreover, a deeper analysis of the R&D initiatives, patents and publications will also be performed to identify new stakeholders and innovators in the field. The planned steps shall enable the definition of the best value proposition for democases.

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9 ANNEXES

9.1 GENERAL STRUCTURE OF THE SURVEY

Organisation

Organisation name	
Organisation type	

Department/Institution/Division in the organization structure

Specify which department/institution/division or area of the organization is involved in CleanHyPro and explain the positioning and the role it has in the structure of the organization.

….

Motivations to be a service provider in OITB

Please explain your motivation by proving e.g. an answer to the following questions:
Why is your organization willing to be a service provider in CleanHyPro OITB?
What objectives is the organisation pursuing?
How is the involvement in CleanHyPro aligned with the mission of the organisation?
How would success be defined for you in the OITB?
What is the motivation from the perspective of your specific department/division/area?

…

Value proposition

Identify your value proposition in the area of expertise of ClenHyPro. Include pilot lines (if any), relevant IP (technology assets), lab infrastructure, business services, etc. Please, keep the description short (max. half page): it is more an identification of main capabilities rather than an extensive description. The table below is a suggestion on how to structure the information.

Pilot Line(s)	
Technological expertise and capability	
IP/Technology	
Lab Infrastructure and Tech. Services	(add, if possible info about time and resources for each service)
Business-Oriented Services	

Addressed market sectros and potential end-users	

Addressed market

Characterize the market that you address with your value proposition by e.g. answering the following questions:
What customer problems/needs are you addressing?
What part of the value chain are you addressing? (see proposed value chain below).
Are you addressing a specific application area or sector?
Can you identify examples of customers/users (provide names)?

…

Business record

Provide some indication in business figures of the offer in electrolyzers related technology/services in the last 3 years in your organisation. Who are the main customers? What is the average contracted amount per year? Which are the main products/services sold? What is the funding scheme for these contracts: full private contracts? contracts with public funding support?
Provide relevant examples or case studies.

…

Business expectations

What barriers are you currently experimenting and how do you expect that CleanHyPro OITB may help to overcome them?
What are your business expectations regarding CleanHyPro OITB? International expansion? Grow the business overall? Increase the size of the projects? Provide integral support to your strategic customers/partners? Provide higher value to customers? Improve margings? Diversify the business? Get a better competitive positioning? If possible, provide priorities and quantify your expectations.

9.2 SURVEY LIST

9.2.1 Fraunhofer Institute for Solar Energy Systems (ISE)

Organisation

Organisation name	Fraunhofer Institute for Solar Energy Systems (ISE)
Organisation type	Research facility (partly public funded)

Department/Institution/Division in the organization structure
Within CleanHyPro the Fraunhofer-Gesellschaft participates with the Fraunhofer-Institute for Solar Energy Systems ISE. Within Fraunhofer ISE the project is embedded

within the division for Hydrogen Technologies. Further specified, the OITB provision and work is carried out at the group "Electrolysis" within the division. The group "Electrolysis" is involved in extensive practical research on PEM and AEM electrolysis. The focus of the group lays within the characterization, design and optimization of electrolysis cells, stacks and systems.

Motivations to be a service provider in OITB

Fraunhofer ISE is looking forward of being part of the OITB consortium in CleanHyPro! Fraunhofer is Europe's largest applied research organisation with the purpose of supplying immediate benefit to companies as well as the society as a whole. Therefore, the involvement in CleanHyPro aligns optimally with the overall goals of Fraunhofer. The participation in CleanHyPro could be defined as success for Fraunhofer, if the designed and commissioned test bench infrastructure can be successfully used by external companies and institutions to test, qualify and characterise their PEM electrolysis stacks. Within the group "Electrolysis" the project is seen as very valuable starting point to further enter the European PEM electrolysis research and industry market. As well as allowing our extensive knowledge to be introduced to further markets. And ultimately be able to provide the platform and knowledge to conduct highly qualified characterisation and research for the continued improvement of industrial electrolysis technologies.

Value proposition

Pilot Line(s)	Pilot line 4: PEM water electrolysis stack testbench
Technological expertise and capability	Automated PEM test stand for test cells and short stacks to efficiently test CCM materials at cell and stack level under diverse testing conditions (temperature, pressure, flow rates, etc.)
IP/Technology	Extensive knowledge in designing and operating SoA-PEM EL test benches
Lab Infrastructure and Tech. Services	PEM water electrolysis stack testbench up to 2000 A
Business-Oriented Services	Provide accessibility also for SMEs to high-current density PEM electrolysis testing capabilities
Addressed market sectors and potential end-users	Renewable Energy → Hydrogen → Electrolysis → PEM electrolysis End users: SMEs, research institutions, other involved parties (larger companies, etc.)

Addressed market

Within the involvement in CleanHyPro OITB Fraunhofer ISE is addressing the problem of still low availability for high-performance, high-current density beyond-SoA test bench infrastructure. With the infrastructure designed and erected within CleanHyPro, Fraunhofer ISE will be able to provide beyond-SoA services for the qualification of new generation PEM electrolysers. Within this value proposition, Fraunhofer ISE is aiming to the early parts of the electrolyser value chain, comprising R&D of innovative systems. Potential customers lay in companies and research institutions that develop beyond-SoA PEM electrolyser stacks, e.g. Hoeller Electrolyser.

Business record

The largest share of the funding of Fraunhofer ISEs group "Electrolysis" is comprising of publicly funded (EU, national, regional) research projects. Therefore, the main customers are governmental organizations in narrow terms and the whole society in wider terms. The main products comprise of classical academic research output, such as papers, conferences, PhD students etc. Furthermore, the group "Electrolysis" provides characterization infrastructure for PEM electrolyzers to all interested parties as well as providing innovative electrolysis cell and stack concepts.

Business expectations

One of the biggest barrier in electrolysis research market is the still low availability of SoA and beyond-SoA testing infrastructure. Therefore, we expect that OITB will help to provide a better base for future beyond-SoA testing and validation infrastructure on the pathway to more and more standardized PEM electrolyzer development and qualification.

9.2.2 Umicore NV (UMICORE)

Organisation

Organisation name	Umicore NV (UMICORE)
Organisation type	Company

Department/Institution/Division in the organization structure

NBI (New Business Incubation) and CRD (Corporate Research and Development)

Motivations to be a service provider in OITB

Umicore is amongst others a catalyst materials provider. Our aim is to develop catalyst and electrocatalyst solutions for green energy applications which show high performance and stability. CRD is responsible for developing new catalysts and electrocatalysts in close partnership with NBI and a clear focus on our external customer`s requirements. The OITB could help to better understand customer requirements through direct cooperation, evaluate the technological potential for Umicore´s products and enable new business partnerships.

Value proposition

Pilot Line(s)	
Technological expertise and capability	Catalyst development, upscaling and production
IP/Technology	
Lab Infrastructure and Tech. Services	(add, if possible info about time and resources for each service) Development and production facilities for catalyst materials
Business-Oriented Services	Umicore can provide electrocatalyst materials according to partner´s specifications
Addressed market sectors and potential end-users	End users: electrode and MEA manufacturers, OEMs and system builders

Addressed market

See above; Umicore will provide the electrocatalyst material with the required specifications, so potential customers are electrode and MEA manufacturers, OEMs and system builders.

Business record

Please refer to Umicore`s annual report for this question. (Integrated Annual Report 2022 (umicore.com))

Business expectations

Through the network of CleanHyPro and the OITB environment, we hope to strengthen our business network, get a better understanding of current and future value chains in electrolyzers and requirements, assess the technological potential of our products and thereby strengthen our portfolio to grow our business in the upcoming market for electrolysis.

9.2.3 Umicore AG & Co. KG (UMI)

Organisation

Organisation name	Umicore AG & Co. KG (UMI)
Organisation type	Company

Department/Institution/Division in the organization structure

NBI (New Business Incubation) and PMC (Precious Metal Catalysts)

Motivations to be a service provider in OITB
Umicore is a materials provider with a focus on precious metal. Our aim is to develop catalyst solutions for green energy applications which show high performance and stability. PMC is responsible for developing new catalyst precursors in close partnership with NBI and a clear focus on our external customer`s requirements. Catalysts and precursors are part of the portfolio. The OITB could help to better understand customer requirements through direct cooperation, evaluate the technological potential for Umicore´s products and enable new business partnerships.

Value proposition

Pilot Line(s)	
Technological expertise and capability	Catalyst precursor development, upscaling and production
IP/Technology	
Lab Infrastructure and Tech. Services	(add, if possible info about time and resources for each service) Development and production facilities for ALD precursor materials
Business-Oriented Services	Umicore can provide ALD precursors according to partner´s specifications
Addressed market sectors and potential end-users	End users: electrode manufacturers, ALD coating providers

Addressed market
See above; Umicore will provide the coating precursor material with the required specifications, so potential customers are ALD coating service providers or MEA or electrode manufacturers.

Business record
Please refer to Umicore`s annual report for this question. (Integrated Annual Report 2022 (umicore.com))

Business expectations
Through the network of CleanHyPro and the OITB environment, we hope to strengthen our business network, get a better understanding of current and future value chains in electrolyzers and requirements, assess the technological potential of our products and

thereby strengthen our portfolio to grow our business in the upcoming market for electrolysis.

9.2.4 Technical Research Centre of Finland (VTT)

Organisation

Organisation name	VTT
Organisation type	Research institution

Department/Institution/Division in the organization structure
Part of the VTT that is involved to the CleanHyPro is the Hydrogen production team, which is part of Industrial energy and hydrogen, which itself is part of CARO (carbon neutral solutions) organization. We are part of the VTT's clean energy production research services, mainly focused on fuel cells and electrolysers.

Motivations to be a service provider in OITB
We are willing to be service provider as our key business is testing services for SOFC /SOEL cells and stacks. We hope that during the project we can increase our knowledge about the topic and improve our testing capability, in order to provide better services to our customers in the future.

Value proposition

Pilot Line(s)	SOEL stack test benches
Technological expertise and capability	SOC fuel cells and electrolysers electrochemical testing, material, BOP component, and system testing
IP/Technology	SOC fuel cells and electrolysers
Lab Infrastructure and Tech. Services	Multiple SOC fuel cell and electrolyser test benches for single cells to tens of kW stacks, possibility for long-term tests (~ year). Furnaces for (SOFC) material testing. Electrochemical testing and post-mortem analysis.
Business-Oriented Services	All mentioned testing and R&D services
Addressed market sectros and potential end-users	SOC fuel cell and electrolyser manufacturers, component providers and end users.

Addressed market

Our main focus is to test:

- The electrochemical performance of the SOFC/SOEL cells and stacks (degradation, and operation in different conditions etc.).
- BOP component testing
- System testing
- R&D services for SOC developers

At this moment customer/users information is confidential information and we their authorization to share this kind of information.

Business record

Customer/users and business information is confidential information.

Business expectations

VTT is hoping to get more business contacts and customers for our services via CleanHyPro-project. This could help us to expand our business in addition to already existing strategic partners. VTT is expecting to get long duration and large volume contracts from new customers. This could help VTT to improve our services for customers.

9.2.5 McPhy Energy (MCP)

Organisation

Organisation name	*McPhy Energy*
Organisation type	*Private company*

Department/Institution/Division in the organization structure

R&D department of McPhy is involved in Cleanhypro. It coordinates the showcase #1 withing the work package 3.

Motivations to be a service provider in OITB

McPhy is not a service provider.

Value proposition

Pilot Line(s)	*Not applicable*
Technological expertise and capability	*Electrolyzers and refuelling stations developer with internal R&D and engineering teams.*
IP/Technology	*Alkaline pressurized electrolyzer technology and refuelling stations technology.*

Lab Infrastructure and Tech. Services	*Technical infrastructure in McPhy Italy for testing and validating internal components of the stack up to a TRL 7. Lab infrastructure in McPhy Germany for testing electrodes and diaphragms up to a TRL 2-3 (under construction).*
Business-Oriented Services	*Engineering for projects where we sell electrolyzers, commissioning and maintenance services.*
Addressed market sectros and potential end-users	*McPhy is addressing the market (and end-ursers) of mainly large industries for hydrogen production through water electrolysis.*

Addressed market

Characterize the market that you address with your value proposition by e.g. answering the following questions:
What customer problems/needs are you addressing? Production of large amount of H_2 with low carbon foodprint.
What part of the value chain are you addressing? (see proposed value chain below). Electrolysis system supply.
Are you addressing a specific application area or sector? Large industries like refineries, steel making, CH_3OH or NH_3 production
Can you identify examples of customers/users (provide names)?
HMS
https://mcphy-finance.com/images/PDF/cp/gb/2023/PR_18122023_McPhy_HMS_EN_6fed8.pdf
HYCC
https://mcphy-finance.com/images/PDF/cp/gb/2023/20230704-Press_Release-McPhy_and_Technip_contracted_for_Djewels_VEN_410d1.pdf
Plansee
https://mcphy-finance.com/images/PDF/cp/gb/2023/PR_McPhy_Plansee_Group_bf5e0.pdf
Arecelormittal
https://mcphy-finance.com/images/PDF/cp/gb/2023/McPhy_PR_ArcelorMittal_VEO_and_McPhy_32fcb.pdf

Business record

Provide some indication in business figures of the offer in electrolyzers related technology/services in the last 3 years in your organisation.
Turnover 2022: 17.9 m€, 2021: 14.6 m€, 2020: 14.6 m€
Who are the main customers? See previous section
What is the average contracted amount per year? /
Which are the main products/services sold? Alkaline electrolyzers
What is the funding scheme for these contracts: full private contracts? contracts with public funding support? Mainly private contracts
Provide relevant examples or case studies.

Business expectations

What barriers are you currently experimenting and how do you expect that CleanHyPro OITB may help to overcome them? As electrolyzer manufactures, we are interest in having easy access to the OTIB facilities, in addition to our own facilities. As well as having access to standardized tests that will be used in such OITB facilities (for proper comparison with other industries in the field). *What are your business expectations regarding CleanHyPro OITB? International expansion? Grow the business overall? Increase the size of the projects? Provide integral support to your strategic customers/partners? Provide higher value to customers? Improve margings? Diversify the business? Get a better competitive positioning? If possible, provide priorities and quantify your expectations. Not applicable*

9.2.6 European Commission, DG Joint Research Centre (JRC)

Organisation

Organisation name	European Commission, DG Joint Research Centre
Organisation type	EU Institution (international organisation), see at https://joint-research-centre.ec.europa.eu/index_en

Department/Institution/Division in the organization structure

Directorate C - Energy, Mobility and Climate provides among others support for implementing the EU's Green Deal by executing desktop studies and providing expertise to policy makers and testing services to the research community in academia and industry for which it operates an open access scheme to its physical research infrastructures as well as for training and capacity building in energy storage technologies such as fuel cells, electrolyser and batteries.

Motivations to be a service provider in OITB

JRC already operates an open access scheme to its physical research infrastructures as well as for training and capacity building in energy storage technologies such as fuel cells, electrolyser and batteries.

Value proposition

Pilot Line(s)	None
Technological expertise and capability	Testing services for fuel cells and electrolyser
IP/Technology	None
Lab Infrastructure and Tech. Services	(add, if possible info about time and resources for each service)

	Test facilities for low- and high-temperature fuel cells (PEMFC, SOFC) and stacks as well as electrolysis cells (PEM, SOC), see at https://joint-research-centre.ec.europa.eu/laboratories-and-facilities/fuel-cells-and-electrolyser-testing-facilities_en
Business-Oriented Services	None
Addressed market sectors and potential end-users	Stationary fuel cells and hydrogen generation by water/steam electrolysis

Addressed market

Testing low- and high-temperature fuel cells (PEMFC, SOFC) and stacks as well as electrolysis cells to verify R&D progress; development of harmonised test methods, procedures and testing protocols for Clean H2 JU

Business record

Mainly in-kind support to Clean H2 JU governed by framework contract

Business expectations

Experimental validation of developed test methods, procedures and testing protocols for electrolyser, for example, for use to verify R&D progress as programme support to Clean H2 JU

9.2.7 Catalonia Institute for Energy Research (IREC)

Organisation

Organisation name Catalonia Institute for Energy Research (IREC)
Organisation type Research institute (CleanHyPro Beneficiary)

Department/Institution/Division in the organization structure

Department of Advanced Materials for Energy, Nanoionics & FuelCells group.

Our group addresses the challenge of developing highly efficient and clean solid state energy conversion technologies for powering a sustainable society. We use our knowledge in ionic, electronic and thermal transport combined with the expertise in advanced manufacturing to develop new energy concepts from the microwatt to the kilowatt range.

Motivations to be a service provider in OITB

IREC eagerly steps into the role of a service provider in CleanHyPro OITB driven by the ambition to upscale SOEC systems and infuse cutting-edge technologies into the final device. The organization's primary objectives revolve around advancing two distinct pilot

lines, each dedicated to enhancing SOC systems. Specifically, the focus is on developing innovative cell architectures and refining materials processing. This aligns seamlessly with IREC's overarching mission in energy research, particularly in the domain of SOEC systems. Success in the OITB is defined by the successful upgrade of the pilot lines, contributing to the evolution of novel cell architectures and improved materials processing. From the perspective of our department, this involvement serves as a catalyst for pushing the boundaries of technology and contributing valuable advancements to the field, aligning perfectly with our commitment to innovation and progress in energy research. Achieving success in CleanHyPro OITB is indeed tied to the testing and validation of the technologies provided by our group at a high TRL. …

Value proposition

Pilot Line(s)	PL7: 3D printing for fabrication of complete SOEC cells/stacks PL8: Advanced electrode nanomaterials for innovative SOEC
Technological expertise and capability	Our group stands at the forefront of innovation, revolutionizing the production of high-value cells through cutting-edge methodologies. Our primary focus revolves around the utilization of multi-material 3D printers, a technological facility that enables the production of fully printed cells within a single device. This groundbreaking approach goes beyond conventional methods, as we integrate Stereolithography (SLA) methodology with Direct Ink Writing (DIW) to achieve a complete printing facility. The result is a pioneering process that opens up new horizons in the realm of cell production.
IP/Technology	1) Ref. EP3754768A1, "ELECTROCHEMICAL CELL DEVICE FOR USE IN A SOFC AND/OR A SOEC AND METHODS FOR OPERATING A SOFC OR A SOEC BY USING THEREOF". 2) Ref. WO2023021217, "An integrated single 3D priting system-based process for manufacturing a monolithic solid oxide cell (SOC) stack".
Lab Infrastructure and Tech. Services	Large area 3D printer with multi-material robocasters, rapid-thermal processing instrument, ultrafast high-temperature sintering setup, large area screen printer, industrial scale ink mixers, high furnace capacity for material processing, characterisation facilities (electrochemical, morphological, structural…).
Business-Oriented Services	N/A

Addressed market sectros and potential end-users	Addressed market sector: Energy, transport (aviation, shipping). Potential end users may include companies (SME) and researchers seeking high-value, advanced components for energy-related technologies.

Addressed market

The versatility of 3D printing enables the creation of customized ceramic components, meeting specific customer requirements. Rapid thermal treatments further enhance the efficiency of the ceramic production cycle. This is particularly noteworthy as traditional methods are recognized for their high energy consumption, and our technology addresses and mitigates this resource-intensive aspect, encompassing processes like debinding and sintering. The development of these technologies targets the creation of high added value items, providing customers with advanced solutions for their applications, particularly in the realm of energy.

Business record

Over the past three years, our organization has successfully collaborated in various European and industrial projects. The primary objective of these collaborations has been to study from the fundamentals of the materials to the deployment of the SOEC technology.

Business expectations

Our current challenge lies in the insufficient availability of facilities to accommodate the testing needs for our entire production output. We anticipate that CleanHyPro OITB, in collaboration with the diverse partners involved, will provide a solution to surpass these barriers.

We anticipate an enhanced international expansion as CleanHyPro, being the largest project on green hydrogen production, serves as a strategic platform to showcase the feasibility of SOEC technology for green hydrogen production. This visibility is expected to position us favorably in the market, attracting global attention and potentially leading to international expansion opportunities. In addition, we anticipate an overall business expansion as CleanHyPro OITB provides the necessary testing facilities crucial for our production. This, in turn, will potentially allow us to take on larger projects and accommodate increased production demands.

Financially, we anticipate improvements in margins as CleanHyPro OITB addresses the testing facility limitations, allowing for more efficient production processes. This efficiency is expected to contribute to improved cost management and, consequently, enhanced profit margins which will lead into a more competitive market position.

9.2.8 SparkNano

Organisation

Organisation name	SparkNano
Organisation type	SME; Equipment manufacturer

We are an SME and not organized along the lines of departments and divisions. It is the company as a whole that is involved

Motivations to be a service provider in OITB

SparkNano is a capital equipment manufacturer, supplying R&D- and mass production equipment for (amongst others) water electrolyzers. The developments we do in CleanHypro and providing hardware to the pilot line will help us to further improve our products and our value to our customers. The project is successful for us if 1) the added value of our technology is demonstrated and 2) if we can integrate the developed technologie in our products.

Value proposition

Pilot Line(s)	We will supply hardware to Pilot Line 2 at TNO
Technological expertise and capability	Spatial Atomic Layer Deposition of low PGM loading catalyst layers
IP/Technology	Spatial Atomic Layer Deposition equipment
Lab Infrastructure and Tech. Services	We have our Spatial ALD deposition equipment available for benchmarking if required
Business-Oriented Services	Not sure what is meant here?
Addressed market sectros and potential end-users	Not sure what is meant here?

Addressed market

We supply R&D- and mass production Spatial ALD equipment for deposition (ultra) low PGM loading electrocatalyst layers for PEM (current main business) and AEM electrolysis (future).

Business record

Our main customers are suppliers in the PEM value chain (PTL's, membranes, PTEs, CCMs, MEA's) as well and electrolyzer OEMs. We offer both R&D equipment, for product development/optimization and pilot-lines, industrial scale mass production tools as well as commercial sampling. We expect to sell R&D tools mainly in the coming years, where mass

production tools are expected to be ordered from 2024/2025 onwards. In most cases these are B2B contracts. We also participate in funded projects (both national and international), which are mainly oriented at technology development together with customers.

Business expectations

We expect that CleanHypro will further progress the field of electrolysis in general. Zooming in, we expect that the added value of out technology for electrolysis is further demonstrated and that the development of new technology will further improve our added value for our customers

9.2.9 3DCERAM-SINTO (3DCS)

Organisation

Organisation name	3DCERAM-SINTO
Organisation type	SAS French company

Value proposition

Pilot Line(s)	Pilot Line 7: Design and fabrication of electrolyte-supported free-shape solid oxide cells.
Technological expertise and capability	3DCERAM is expert in the 3D-Printing of technical ceramics
IP/Technology	Know-how in formulation for SLA 3D printing from commercial powders of YSZ. Know-how for the full process of SLA applied to ceramic (Cad Design, Printing, debinding, sintering). EP3444049 : Procédé et machine de fabrication de pièces en matériau céramique ou métallique par la technique des procédés additifs. EP3444050 : Procédé et machine de fabrication d'au moins une pièce en au moins un matériau céramique et/ou métallique par la technique des procédés additifs
Lab Infrastructure and Tech. Services	
Business-Oriented Services	
Addressed market sectros and potential end-users	

9.2.10 VSParticle B.V. (VSP)

Organisation

Organisation name	VSParticle B.V.
Organisation type	SME

Department/Institution/Division in the organization structure
Product Development and Applications Development. Product Development is developing the hardware and software for the pilot line, Applications Development uses the pilot line for developing and optimizing catalyst layers.

Motivations to be a service provider in OITB
VSParticle is an equipment OEM and its main objective is selling equipment. The pilot line is a demonstrator of VSParticle's technology. Participation in the OITB would be a success if the samples made with the pilot line convince potential customers to purchase VSParticle equipment for the production of catalyst layers.

Value proposition

Pilot Line(s)	Tool for producing catalyst layers using a unique liquid-free (dry) process that converts bulk materials into a deposited catalyst layer in one step. The tool will both synthesize nanoparticles through spark ablation and will deposit these particles as a nano-porous catalyst layer, all in a single step. The pilot line can process 62 elements out of the periodic table (most metals and many semiconductors) and can also mix multiple elements and create allloys. Therefore, the pilot line can produce many different electrocatalysts, for example for PEM WE, AEM WE, but also for applications like CO_2 conversion. Also applications beyond electrocatalysis are feasible, for example gas sensors and battery materials.
Technological expertise and capability	Equipment development, materials development.
IP/Technology	Spark ablation combined with printing using impaction.
Lab Infrastructure and Tech. Services	Fully equipped lab including materials/applications development services.
Business-Oriented Services	Equipment sales, applications and materials development services.

Addressed market sectros and potential end-users	Electrolyzer stack manufacturers, electrolyzer component manufacturers, catalyst producers

Addressed market

Customer needs addressed:

- Lower critical raw materials usage (e.g. iridium for PEM WE) due to increased catalyst activity.
- Improved electrolyzer efficiency through improved catalyst layers.

Sector addressed is the electrolyzer manufacturing sector. We enable different players in the electrolyzer value chain to deposited catalyst layers, e.g. electrolyzer (stack) manufacturers, electrolyser component suppliers (e.g. CCMs, PTLs and GDLs), and catalyst producers. Additionally, universities and research institutes working on electrocatalysis or other applications that require nanoparticles or porous thin films or potential customers for VSP's R&D equipment.

Business record

VSP currently sells R&D equipment that synthesizes nano-porous layers with many different elemental compositions. One of the use-cases is the development of new catalyst layers for electrolyzers. VSParticle is in the process of developing high-volume production equipment for coating catalyst layers on electrolyzer components. The market for R&D equipment is growing quickly and VSP didn't enter the marker for production equipment yet, so data regarding the last 3 years does not add any valuable information.

Business expectations

Participation in CleanHyPro helps in further improving our equipment and creating exposure for VSParticle's solutions.
The most important objective is to grow the business overall by entering the market of production equipment for coating catalyst layers on electrolyzer components. Second objective is growing the existing market for R&D equipment.

9.2.11 Ceramic Powder Technology AS (CPT)

Organisation

Organisation name	Ceramic Powder Technology AS
Organisation type	SME, private

Motivations to be a service provider in OITB

Cerpotech is manufacturing high quality advanced ceramic oxide powders, and we want to be a part off the value chain for commercialization of the cases in this project. Our goal is to be a supplier for larger volumes of the materials we supply to the project.

A success is to be a qualified supplier and to receive orders of > 10 kg of the materials and indications of future orders/contracts.

The company´s mission is to be a qualified supplier for various materials for SOC manufacturing, so the OITB we are involved in fits well with the company strategy.

Value proposition

Pilot Line(s)	Spray pyrolysis manufacturing line
Technological expertise and capability	We have expertise in the preparation of high quality powders by use of spray pyrolysis.
IP/Technology	We have one patent and two applications and a lot of internal know how that we keep secret.
Lab Infrastructure and Tech. Services	None
Business-Oriented Services	We sell high quality advanced ceramic oxide powders
Addressed market sectors and potential end-users	For this OITB is it materials for SOC manufacturing. Our customers will be the cell manufacturers such as Elcogen AS etc.

Addressed market

Cerpotech are manufacturing high quality advanced ceramic oxide powders.
We target the need for sub-micron particle size and homogeneous compositions are important for the functionality.
We are supplier of advanced materials, between raw material sourcing/mining and cell manufacturer, in the value chain.
We have more than 200 protocols for material, so we are addressing a broad area in many sectors, but SOC cells are one of three main focus sectors while we are uncertain about how many materials and functions we can cover.

Business record

We cannot reveal such information as most of it is confidential.

Business expectations

Barriers: We have a high number of protocols and need to narrow it down to prepare for larger volume manufacturing sp that we can be cost effective and competitive.
Expectations: We would like to get focus on some of our materials to narrow down the number of candidates for large volume manufacturing and expand our business internationally.

It would be great if the project could qualify our powders for the application in the OITB and that we can be a qualified supplier in the value chain in the OITB , but also to other cell manufacturers worldwide.
We want to find a price point for our material that can be approved by our customers and give us a margin. This means that both cost effective manufacturing and proof of quality/better performance towards competitive materials is important.
We would like at least to achieve a agreement with future orders of larger volumes >100 kg as a result of the project.
As it is not decided what material and amounts needed for the application I cannot quantify this in more detail at this point.

9.2.12 KIC Innoenergy (EGHAC)

Organisation

Organisation name	Innoenergy
Organisation type	Private company

Department/Institution/Division in the organization structure
EGHAC (European Green Hydrogen Acceleration Center) is the area involved in CLEANHYPRO. EGHAC creates industrial players which we help to de-risk and accelerate their green hydrogen initiatives. We do this through early-stage investment and acceleration services which we deliver in collaboration with our ecosystem.

Motivations to be a service provider in OITB
Innoenergy is willing to be a service provider in cleanhypro since our mission is to bring clean technologies to market which is compatible with the OITB.
The main objective from EGHAC is to decarbonise industrial value chains.
The involvement in CLEANHYPRO is fully aligned with Innoenergy's mission. InnoEnergy brings people and resources together, catalysing and accelerating the energy transition. New ideas, products and solutions that make a real difference, and new businesses and people to deliver them to market. Operating at the centre of the energy transition, we build connections worldwide, bringing together innovators and industry, entrepreneurs and investors, graduates and employers.
Success would be bringing at least one of the technological solutions from CLEANHYPRO to market.
Motivation from EGHAC is to foster and bring innovation on green hydrogen technologies into market. EGHAC could be the bridge between tangible outcomes from CLEANHYPRO and the reality of the market.

Value proposition

Pilot Line(s)	All pilot lines
Technological expertise and capability	Thematic field leaders on Hydrogen, mobility, circular economy, sustainable buildings and cities, renewable energies.
IP/Technology	No IP
Lab Infrastructure and Tech. Services	No lab infrastructure.
Business-Oriented Services	InnoEnergy's scope is on how to bring an innovation to the market. Several possible outcomes: - A possibility of equity investment into the project to bring it to the market to make it reality. - A wide network both from the public and private sectors (+35 shareholders of which some are oil and gas, others from the financial sectors, Top 1 engenering schools etc) of roughly 500+ partners - In-depth sector knowledge and experience (+7000 startups screened in the past 13 years, +10 companies created from scratch in the scope of the company building activity) - When screening startups, InnoEnergy is used to validated proof of concept and conduct due diligence across all key areas: team, finance, technology and market. - Investment team all over Europe (international view) - Sales team all over Europe (international view and network) founding deals in the day-to-day activities for the startups we invested equity in.
Addressed market sectors and potential end-users	

Addressed market

InnoEnergy in addressing the market of renewable energy when EGHAC is focusing on the market of green hydrogen.
In green hydrogen, EGHAC is focusing its activities on Hard-to-abate sectors such as:

- Aviation (SAF/eSAF) – Customers/users: Air France, Repsol, Lufthansa, Total, Galp etc.
- Shipping (Methanol) – Customers/users: CMA-CGM, Maersk etc.
- Green Iron (DRI) – Customers/users: Schaeffler, Faurecia, Engie etc.

- Fertilizers (ammonia) - Customers/users: Heineken, PepsiCo etc.

Business record

We don't sell/buy electrolyzers. Track record in the field of electrolyzers :

- GravitHy : We created this industrial player from scratch with Plug Power as Shareholder. Full private contract.
- Hymeth: we invested equity into this startup. Full private investment.

Business expectations

We are currently building projects with a future need of electrolizers of 300 to 600MW. We expect that CleanHyPro OITB is going to help us to overcome the potential barriers we can see nowadays. We expect CleanHyPro to scale up the circular innovative material and components for electrolysis to leverage the market.
Our business expectations are: grow the business overall and increase the size of the projects.

9.2.13 MONDRAGON ASSEMBLY S COOP (MASS)

Organisation

Organisation name	MONDRAGON ASSEMBLY S COOP.
Organisation type	Cooperative - Large Enterprise

Department/Institution/Division in the organization structure

The R&D team of theat Mondragon Assembly has been created since the beginning of the Energy/Solar activity in Mondragon Assembly, in year 2001. Currently, it is comprised by around 10 senior mechanical and electrical engineers, as well as process engineers. The main objective of this Team is to develop projects from TRL 4-5 to 6-7 within collaboration program framework with other company R&D Teams as well as R&D Research centers. This teamis aimingto solve the industrialization of news technologies, defining from the earliest product and process development phase the automated assembly solution for large scale production.It benefits from a large support of the engineering and project teams for each businesswho areinvolvedin themaindevelopments done to the solar and battery assembling equipment conceived and assembled at Mondragon, that later on could be incorporated to the MA brochure. Recently, a specific subgroup is dedicated with digitalization of the machines (4.0), enabling a high quality of control and traceability of the processes being developed.

Motivations to be a service provider in OITB

Mondragon Assembly aims to develop new products in the most important areas within the energetic industry, once reached to beone of the main players in the European PVmanufacturingindustry.

Mondragon Assembly has experience at the H2 fuell cell stack assembly, since its Germanand Frenchsubsidiaries have been developing various projects during the last 10 years.StartingforH2 Storage automationto PEM stack automatic Assembly and control.
The objectives of integrating CleanHyproconsortium are different: First objective is to acquire the knowledge about the production H2 Electrolizers and the requirements of this technology. In addition,for MAit is importantto create new cooperation ways with the main playersof the European H2 industryanddevelopa clearerunderstanding of the electrolysersand propose automated assembly solutionsthat fulfills both the needs of the market and our skills.
A successful consequence of the Cleanhypro project would be to add a new reference into our standard brochure offering a H2 electrolyzerproduction line in any of the possible scales (lab/medium/high throughput).

Value proposition

Pilot Line(s)	This is the first Pilot line for the H2 Electrolizer production, but MA has experience at building these flexible laboratory-oriented lines for multiple purposes: • Battery assembling pilot lines. • PV production pilot lines. • Medical sector pilot lines • Etc.
Technological expertise and capability	MONDRAGÓN ASSEMBLY directs its activity towards the conception and manufacture of Flexible Automatic Assembly Systems, based on standard elements of design and manufacture in-house and on the basis of commercial elements. These elements are usually structured around rotary, linear and free-flowing transfer systems and have allowed our Company to have extensive experience and multiple references of achievements for national and foreign companies in the sectors of locksmithing, electrical switchgear, automotive auxiliary, household appliance components and other diverse sectors. The automatic assembly systems used in the sectors to which MONDRAGON ASSEMBLY's Assembly Activity is directed are commonly known as "Specific Purpose Systems", which means that they are systems that are conceived and built with the aim of fulfilling specifically defined tasks and purposes that are clearly differentiated from general purpose systems. Its usual structure consists of an appropriate combination of articulated positions on a free-flowing, modular or circular transfer machine, on which a set of plates or fixings that serve as a base or reference for the product is placed. Either as a resultof the rotation or the advance of the transfer, the

	different fasteners or pallets are successively placed on the vertical of the different active elements of the system, which proceed to feed, handle, compose and test the different pieces of which the product to be assembled by the system is composed. Consequently, the usual components of an automatic and flexible assembly system manufactured by MONDRAGON ASSEMBLY are the following: • Circular vibrators, linear vibrators and separators, for the purpose of feeding components of a certain size. • Vibrators and smartfeeders for feeding small or small components. • Selection mechanisms and servo-fed combs for the insertion of small components. • Manipulators and grippers of small dimensions for the purpose of achieving the movements and actions of product composition. • Presses, riveting machines and other elements that ensure the fixing of the various components to each other. • Robots. • Leak control systems, torque control systems, etc.
IP/Technology	Over the last few years, Mondragon Assembly has carried out a series of important research projects in the area of assembly and automatic testing, which has led it to hold the following patents: • Spanish Invention Model No. 111509, which records the development of a Scara-type Assembly and Handling Robot. • International Invention Model No. 74711, which records the development of a Scara-type Assembly and Handling Robot. • Invention Patent No. 8703784, which registers the construction architecture of a Free Flow Transfer for 200 -200 mm saucers. • Industrial Model No. 114062, which records the development of Extruded AluminumProfiles for the development of Modular Benches for Automatic Assembly Systems. • International Industrial Model No. 75048, which registers the construction architecture of our current range of Electropneumatic Manipulators, developed by MONDRAGON ASSEMBLY and commonly used in the construction of our manufactured products.

	• Invention Model No. 860023, which records the construction architecture of a range of Mechanical Manipulators Driven by Cams and destined for Automatic Assembly Systems of very high production. • Invention Patent No. 8900803, "Improvements Introduced in the Assembly of Components for Lock Cylinders". • Invention Patent No. 548543, relating to an "Installation for Electrical Safety Testing for Household Appliances". • Invention Patent No. ES1160038Y relating to a "soldering device" • Invention Patent No. ES2754874A1 relating to a "Method and Installation for Framing a Solar Panel" • Invention Patent No. ES1301661Y relating to a "Solar Cell interconnection device" • Invention Patent No. US8680444B2relating to a "Soldering apparatus for connecting solar cells" • Invention Patent No. FR3055739B relating to a "METHOD FOR ENCAPSULATING PHOTOVOLTAIC CELLS OF A LIQUID PHOTOVOLTAIC MODULE" • Invention Patent No. ES1159709U relating to a "Interconnection device" • Invention Patent No. US8748212B2 relating to a "Method and device for producing solar cell strings" • Invention Patent No. EP3859797A1& WO2022253696A1relating to a "Method and apparatus for arranging ribbons and solar cells" • Invention Patent No. EP4293730A1relating to a "Interconnection element, photovoltaic string and related methods"
Lab Infrastructure and Tech. Services	Mondragon Assembly Group has six productive plants around the world, that are located in Queretaro (Mexico), Stockach (Germany), Orange (France), Kunshan (China), Americana (Brazil) and the headquarters in Aretxabaleta (Spain). MONDRAGON ASSEMBLY's main plant has the following characteristics: • Plant 1500 x 3 = 4500 m2 own + 2000m2 offices (with engineering software) • Cranes up to 200 tonnes • It employs 200peopleIn headquarters, and over 600worldwide.

	For this project, Mondragon Assembly Aretxabaleta (Spain) will be the location where the design, conception, purchasing and assembling of the flexiblemanufacturing line . Mondragon Assembly is equipped with 3D cad tools, PLC programming tools and all the required logistics facilities (purchasing, administrative personnel) for the correct development of the task described in the DoA.
Business-Oriented Services	Manufacturer ofH2Electrolyzer production line.
Addressed market sectors and potential end-users	H2 Electrolyzer providers, big H2 fuel cell producers.

Addressed market

Manufacturer of H2 Electrolyzer production line.The development of innovative H2 Electrolyzertechnologies, and the associated manufacturing processes, as well as the associated capital goods.

Business record

Thisis the first project where Mondragon Assembly will be involved at the development of H2 Electrolyzer production line.

Nevertheless, Mondragon Assembly Gmbh. has carried out two large scale projects for the Assembling of the Fuell Cell Stack during the last 5 years , and currently it is building a new production Mondragon Assembly S.A. has also been involved in automating H2 reservoirs for McPhy in its earliest start of H2 activities, supporting industrialization phase. The n PEM stack assembly and end controls were also developed for automotive final use of the fuel cell.

Business expectations

The development of innovative H2 Electrolyzertechnologies,and the associated manufacturing processes, as well as the associated capital goods, is directly linked to the commitment that Mondragon Assembly Solar has made to become a benchmark in the H2industry.

Mondragon Assembly's goalto be perceived as a benchmark in state-of-the-art turnkey lines will allow an increase in direct sales (estimated) of €3 million per year in the coming years, through sales of industrial or pilot linesbased on this technology. For the calculation of the Business Case, we have assumed sales of Electrolyzer productionlines in the years 2025, 2027and 2028, understanding that from that last year the business is consolidated at a stationary regime.

In addition to the direct sales of industriallines, the possible sale of individual key equipment to customers with a long history in the sector, and who are able to complete the value chain with third-party equipment, is expected, which can bring in around €1million per year. For the

calculation of this revenue item, we have assumed equipment sales in the years in which no manufacturing lines are sold, with the exception of 2027 and 2028, which is when the business would be consolidated. This may be a conservative assumption since both sources of income could be combined in the same year if demand requires it.

In addition to the H2business, the developments in the ultrasonic spray coatingprocessand layer characterization processwill be transferable andwill be a differential for the special machinery business, in which coatingprocesses are constantly in demand. Although it is difficult to estimate the economic impact in this regard, the special machine business currently has a turnover of ~€19million per year, of which 10% have some coatingoperations (painting, etc.). Therefore, it is to be expected that the impact is relevant in the traditional business as well.

9.2.14 BUREAU VERITAS SOLUTIONS IBERIA SLU (BV)

Organisation

Organisation name	Bureau Veritas
Organisation type	Testing, inspection and certification.

Department/Institution/Division in the organization structure
Bureau Veritas Solutions Iberia provides specific technical services on renewable energies and hydrogen. Also develops new schemes of labelling and certification for the BV group.

Motivations to be a service provider in OITB
Why is your organization willing to be a service provider in CleanHyPro OITB?
BVS aims to build trust between the different players in the hydrogen sector, i.e. Clients and OEMs, by developing certification schemes and labelling of products.
What objectives is the organisation pursuing?
The final objective BVS wants to achieve in CLEANHYPRO is to develop a quality label and safety scheme for electrolysers that will be possible to implement in the industry in the near future. As well, BVS wants to build relationships with the different laboratories and technological centres.
How is the involvement in CleanHyPro aligned with the mission of the organisation?
BV group is a business to business to society company that develops and works with quality label and certificates in every sector.
How would success be defined for you in the OITB?
The success of BVS in this OITB would mean that the development of the final quality label is in equilibrium in terms of cost and information included, so it can be recognized and adopted widely in the electrolyser and sub-components OEM sector.

What is the motivation from the perspective of your specific department/division/area?
BVS currently is one of the most important electrolyser technical centre inside the BV group, so participating in these projects is part of our main objectives.

Value proposition

Pilot Line(s)	None.
Technological expertise and capability	Expertise in certification, quality labels, safety, electrolysers.
IP/Technology	BVS does not develop technology.
Lab Infrastructure and Tech. Services	BVS does not invest in electrolyser testing facilities. Tech. Services include the definition of the different tests for the quality label and verify.
Business-Oriented Services	Develop a quality label with strategic information for final Clients that allow the classification of OEMs with an equilibrated cost.
Addressed market sectors and potential end-users	OEMs and sub-component manufacturers of electrolysers. Technology buyers.

Addressed market

What customer problems/needs are you addressing?
Customers at the moment have no possibility of comparison between different OEMs. The quality label will provide a way of comparison between them addressing the most important characteristics.

What part of the value chain are you addressing? (see proposed value chain below).
Create trust in the market with a quality label and safety scheme.
Allow OEMs to demonstrate to the market why their product is above others. Allow purchasers of technology the ability to compare between OEMs.
Are you addressing a specific application area or sector?
Testing, Inspection and Certification.
Can you identify examples of customers/users (provide names)?
Stack manufacturers, and sub-component manufacturers.

Business record

BVS in the last 3 years has conducted several TDDs of projects regarding hydrogen generation via electrolysis for main players around the world.
(Examples cannot be provided due to NDAs)

Business expectations

The main barrier that can be found regarding the quality label is not finding an equilibrium in cost and information provided, not achieving suitable answers to the Clients requirements. OEMs may consider this label as a risk in terms of IP protection.

We expect this quality label to become a global reference in the market.

9.2.15 Brandenburgische Technische Universität (BTU)

Organisation

Organisation name	Brandenburgische Technische Universität, BTU
Organisation type	University

Department/Institution/Division in the organization structure

The Hydrogen Research Center, in collaboration with the Chair of Thermal Energy Technology, is a pivotal entity within the Faculty for Mechanical Engineering, Electrical and Energy Systems, and the Institute for Electrical and Thermal Energy Systems at BTU. Here, our esteemed scientific and technical staff members are dedicated to advancing education, conducting cutting-edge research, and facilitating technology transfer across a diverse spectrum of topics concerning energy conversion and storage, with a primary focus on hydrogen technologies.

Our research initiatives encompass:

1. Hydrogen Production Technologies: We explore various methods including pressurized alkaline electrolysis, AEM electrolysis, and PEM electrolysis to efficiently generate hydrogen.
2. Hydrogen Storage and Fuel Cell Systems: Our investigations extend to the development and optimization of stationary fuel cell systems alongside innovative approaches to hydrogen storage solutions.
3. Thermochemical Energy Storage: We delve into gas-solid reactions for thermochemical energy storage, striving for breakthroughs in this crucial aspect of sustainable energy.
4. Technology Development and Modeling: Our expertise extends to the development and meticulous modeling of complex energy systems and components. This includes analysis of stationary and transient behavior, thermal design, and energy optimization strategies.

Within the framework of CLEANHYPRO, BTU plays a significant role in advancing hydrogen production methodologies, particularly in the domain of pressurized alkaline electrolysis. Through our collaborative endeavors, we aim to pioneer transformative solutions that contribute to a sustainable energy future.

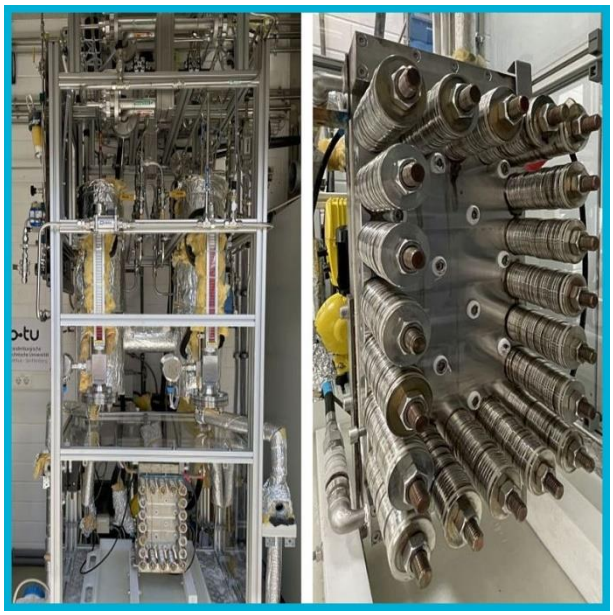
Motivations to be a service provider in OITB

BTU, with a special emphasis on its Hydrogen Research Center, is steadfastly committed to advancing technology, fostering widespread dissemination, and providing comprehensive training in the realm of electrolysis. In pursuit of this mission, the OITB CLEANHYPRO serves as an ideal ecosystem, facilitating collaborative efforts with industrial partners keen on leveraging our extensive testing and development capabilities and services.

The alignment between the missions of CLEANHYPRO and BTU is strikingly evident. Our shared objective revolves around enabling industrial partners to seamlessly integrate technical innovations and expertise garnered from collaboration with BTU into their operations, thereby enhancing their products and overall business performance.
True success is achieved when our industrial partners can effectively harness the wealth of knowledge, experimental results and advancements generated through collaboration with BTU, resulting in tangible improvements and innovations within their respective business domains.

Value proposition

Pilot Line(s)	
Technological expertise and capability	Our commitment to innovation in the field of pressurized alkaline electrolysis is evidenced by our comprehensive R&D services: • **Scientific Expertise**: Leverage our expertise and insights, including our scientific consulting and comprehensive literature reviews, to ensure that your projects are anchored in the most current research and methodologies. • **Technical Mastery**: Engage with our pre-technical studies, material development, and rigorous testing of components and prototypes.
IP/Technology	
Lab Infrastructure and Tech. Services	With an alkaline pressure electrolysis system and further test rigs, we conduct research on the following topics: • Component tests (electrodes, diaphragms) • Investigation of different dynamic modes of operation • In-operando analysis at single-cell level Single-cell test rig: A unique single-cell test rig is used to test cell components such as electrodes or separators in operando or to study the behavior of gas-bubble-electrolyte flow

	
Business-Oriented Services	
Addressed market sectors and potential end-users	• Electrolyzer manufacturers (McPhy, Sunfire, thyssenkrupp, NEL, Stargate, Cummins etc.) • Component manufacturers for electrolysers (electrode, diaphragm, sealings cell frames etc.)

Addressed market

BTU's industrial clientele in the field of alkaline electrolysis consists of companies facing technical challenges related to materials, component design, component longevity, simulation of physical and chemical processes, and, critically, system testing. For these clients, BTU develops new technical solutions, processes, materials, or prepares computer models that describe the physical-chemical intricacies of technical installations, providing, for example, insights into long-term stability. Therefore, BTU occupies a pivotal position within the value chain, either at the forefront in the development of new technologies or in the intermediary realm, addressing scientific troubleshooting needs for existing technologies on the market. Due to confidentiality agreements, specific names cannot be disclosed. However, rest assured that the industrial project partners of CLEANHYPRO have also collaborated with BTU outside of this project.

Business record

As a university, BTU does not have “business” records. We can provide budget figures, but only for BTU as a whole. Funding schemes are public basic funding from the local government and third-party funding projects by public and private customers.

- Budgetary funds for 2022 (state basic allocation): approx. 98 million euros.
- External funding revenue for 2022: 51.2 million euros.

- Third-party funding approved in 2022 for the following years: 176.2 million euros.

Business expectations

As a technical university, BTU is a non-profit organization. However, BTU competes with other universities and research institutions in the field of hydrogen technology development. BTU's involvement in CLEANHYPRO exemplifies its leading role in the European research arena of alkaline pressure electrolysis. This distinguishes BTU from its competitors and positions it to anticipate numerous future technology research projects, thereby benefiting society as a whole through the expansion of knowledge and expertise, the education of young engineering generations, and the promotion of economic development through technology transfer.

9.2.16 ENAPTER GMBH

Organisation

Organisation name	Enapter GmbH
Organisation type	Company

Department/Institution/Division in the organization structure

The R&D department of Enapter is involved in Cleanhypro. It is responsible for testing new stack or cell designs as well as materials or operating conditions.

Motivations to be a service provider in OITB

Enapter wants to ensure further optimization and development of the AEM technology. We strive to lower the price of hydrogen produced by electrolysis to provide a viable alternative to hydrogen produced from fossil resources as well as establishing hydrogen as an important medium for energy storage. Standardized testing procedures and benchmarking will strongly enhance the capabilities of AEM electrolysis and will streamline the R&D process.

Value proposition

Pilot Line(s)	-
Technological expertise and capability	Leading in AEM technology. Capacity for testing cells and stacks. Expertise in investigating degradation mechanisms, ex-situ and post-mortem analysis such as SEM, optical microscopy, ICP, IR, …
IP/Technology	
Lab Infrastructure and Tech. Services	Enapter has several labs for testing cells, stack and electrolysers. Equipment is available for various types of

	material analysis, such as SEM, EDX, IR, optical microscopes and others.
Business-Oriented Services	
Addressed market sectors and potential end-users	

Addressed market

Enapter is a B2B electrolyser manufacturer that sells to system integrators, project developers, or end users of hydrogen. Enapter sells full electrolyser systems which are ready to be integrated into projects with the appropriate power and water feed. With a strong upstream vertical integration of activities from making its own components to building its own AEM stacks and systems, Enapter can develop new products quickly, responding to the fast-growing green hydrogen market. With its modular and scalable nature, Enapter's electrolysers are application agnostic. They can and are used today in refuelling stations for road and aviation needs, they are used to provide long term storage for homes to communities and manufacturers decarbonizing their activities, while also providing clean hydrogen industrial players with process heat needs. With its product size, Enapter meets the demand of hydrogen projects of up to 100 MW. Examples of projects and customers can be found online, https://www.enapter.com/applications ranging from installations for Tokyo Gas, to Wilo and many more.

Business record

Enapter has the following product portfolio:
Electrolyser EL4 – Uses a single module for smaller green hydrogen needs starting from 2.4 kW. Option to reach several kW by combining many single-core electrolysers.
AEM Flex 120 – The Flex 120 enables a streamlined launch of green hydrogen in pilots ranging from industrial process heat to refueling. Flexible configuration from 70 kW to 480 kW by employing various modules.
AEM Nexus 500 - Containerized AEM electrolyser for applications up to 500 kW with an hourly production rate of 105 Nm3/h.
AEM Nexus 1000 - Many AEM Electrolyser cores for optimum reliability and reactivity to fluctuating renewable energy at any load. Up to 1 MW with an hourly production rate of 210 Nm3/h.
Since their launch in 2022, six AEM Nexus have been ordered. Of these, two have been built and commissioned. More than twenty-five AEM Flex 120 have been ordered since their launch in 2023, one has been delivered and is in commissioning. To date, 4,000 single-core EL 4 electrolysers have been delivered. In 2023, Enapter's demand pipeline was 433 Mio EUR and customer enquiries tripled from 433 Mio to 1.6 Bio EUR in 2023. The revenues from 2020 to 2023 have doubled as per the guidance communicated by Enapter AG. Enapter achieved a positive EBITDA for the first time in the company's history according to preliminary figures for financial year 2023.

In addition to the products sold and mentioned above, Enapter provides consulting services as the market is still in its infancy and players are going through their learning curve. Enapter's products are competitively priced, and the small units require no project financing. For bigger products and projects, customers use a mix of financing instruments, from tenders, to grants to debt.

Business expectations

We are expecting to increase our production capabilities and push the development of less expensive materials that will outperform internal benchmarks and will decrease the LCOH.

9.2.17 F6S Network Ireland Limited

Organisation

Organisation name	F6S Network Ireland Limited
Organisation type	SME

Department/Institution/Division in the organization structure

F6S leads Work Package 6 (WP 6) in the CleanHyPro project, focusing on Dissemination, Clustering, and Exploitation. Our role is pivotal as we oversee all communication and dissemination activities within the project. Furthermore, we leverage our open innovation platform to connect various stakeholders, including start-ups, SMEs, research centres, universities, and industry partners, facilitating the dissemination of open calls associated with the project.

Within our team, we have a dedicated project manager, communications manager, and financial manager overseeing CleanHypro's activities. Additionally, we enlist the support of designers and web developers to enhance communication and dissemination efforts. This collaborative approach ensures a comprehensive skill set is applied to each task, maximising our effectiveness in achieving project objectives. Our team members are carefully selected based on their specialised skills and knowledge, aligning with our crucial roles in the project, including dissemination and communication, as well as open calls management and scouting. This strategic alignment ensures a well-rounded and impactful contribution to the project's success.

Motivations to be a service provider in OITB

Although we are not industrial/technical partner, F6S is committed to leverage its expertise in Dissemination, Clustering, and Exploitation. By leading these work packages, F6S aims to play a pivotal role in communicating the project's goals, achievements, and opportunities to a broader audience.

F6S aligns its involvement in CleanHyPro with its mission by leveraging its strengths in project management, communication, scouting and networking. F6S aims to facilitate effective

communication within the consortium and beyond, ensuring that the project's outcomes are disseminated widely and contribute to advancements in the field.
Success for F6S in CleanHyPro OITB would be defined by the efficient execution of Dissemination, Clustering, and Exploitation activities as well as the successful implementation of the Open Calls, the creation of engaging content for the project website and social media, and the organisation of impactful events. Additionally, success would involve active participation from the community and stakeholders.
F6S's motivation lies in effectively communicating the groundbreaking nature of CleanHyPro and its contributions to clean hydrogen production. The Dissemination, Clustering, and Exploitation team at F6S is motivated to showcase the project's achievements, promote collaboration, and ensure that the CleanHyPro OITB becomes a focal point for innovation in the electrolysis field.

Addressed market

As F6S assumes the role of a dissemination and communication leader rather than a conventional technology provider or industrial partner, our primary aim is to actively support all fellow partners in their endeavours within the CleanHyPro project. Our focus lies in ensuring that the project's outcomes are effectively disseminated on a broad scale, thereby contributing significantly to advancements in the field. In addition, we are dedicated to ensuring that the general public and relevant stakeholders are well-acquainted with our project and the noteworthy contributions of our partners. Through strategic dissemination and communication efforts, we strive to create awareness, foster understanding, and promote the impactful work conducted within the CleanHyPro project, thereby maximising its reach and influence.

Business expectations

Our participation in the CleanHyPro project is focused towards broadening our network of partners, expanding our project portfolio, and delivering heightened value to our project partners. We aim to achieve this by executing robust and high-quality dissemination and communication processes, thereby enhancing visibility, fostering collaboration, and maximising the impact of our involvement in the project.

9.2.18 STAM

Organisation

Organisation name	STAM Srl (STAM)
Organisation type	SME

Department/Institution/Division in the organization structure

In the CleanHyPro project, the STAM team is actively involved through its Research and Innovation Business Area. This division is responsible for overseeing all tasks associated with the provision of OITB (Open Innovation Test Beds). The team's

primary role within the project is twofold: acting as the Single-Entry Point (SEP), where it defines and enforces the SEP's guidelines, and serving as the Project Manager. In this capacity, the team oversees the expansion of the Pilot Line. Additionally, the Research and Innovation Area is tasked with establishing the guidelines for the Data Management Plan, ensuring that project data is handled efficiently and in compliance with project standards.

Motivations to be a service provider in OITB

STAM is eager to join the CleanHyPro Open Innovation Test Bed (OITB) as this represents a strategic opportunity to engage with leading entities in the hydrogen production sector. Our motivation stems from the desire to immerse ourselves in emerging technologies and to play a pivotal role as project managers in the upscaling of the pilot line. This aligns perfectly with our commitment to innovation and our goal to make a significant impact in the realm of advanced, sustainable technologies. As a company founded on the principles of an Innovation strategy, our involvement in CleanHyPro is in perfect harmony with our mission to "mastering excellence". By contributing to the development of hydrogen as a future fuel, we see a direct correlation with our vision. For STAM, defining success within the OITB involves the successful creation of a dynamic network capable of transitioning cutting-edge technology from concept to practical application, thereby making a tangible impact on the industry and society.

Value proposition

Pilot Line(s)	Not applicable
Technological expertise and capability	- Materials Science; - Project Management principles; - Business Model Creation.
IP/Technology	Not applicable
Lab Infrastructure and Tech. Services	Office
Business-Oriented Services	- Link between technology provider and potential customer; - Helping Pilot line with project management tools in a smoothly upgrading process.
Addressed market sectors and potential end-users	- Technology Provider (Focus on materials, automation and sustainability);

	- End users willing to integrate hydrogen technology into their daily basis activities and helping them into integrate it in their existing process.

Addressed market

In our engagement with the CleanHyPro Open Innovation Test Bed (OITB), STAM is tackling a critical challenge: the gap between pioneering technology and its practical, real-world application. This issue often arises due to the prohibitive costs and complexities associated with integrating new technologies into existing systems. Leveraging our extensive expertise in innovation and the realization of innovative solutions, STAM is poised to transition some of the most promising technologies into impactful real-world applications.

Our approach is twofold: we support technology providers in refining and advancing their innovations, and we assist end-users and potential customers in actualizing these solutions. This comprehensive strategy ensures that cutting-edge advancements are not only viable but also accessible and implementable across a broad spectrum of industries.

We do not limit our focus to a specific sector; instead, we recognize the universal potential of hydrogen energy to revolutionize production processes across all industries. By facilitating the development and integration of hydrogen technology, we aim to enable diverse sectors to leverage this clean, efficient energy source, thereby contributing to a more sustainable and innovative future.

STAM's value proposition addresses a crucial part of the value chain: the transition from innovation to commercialization. By acting as a conduit between technology developers and the market, we play a pivotal role in overcoming the barriers that often prevent groundbreaking technologies from achieving widespread adoption. Our mission is to create a robust ecosystem where innovative solutions can thrive, addressing the pressing needs of customers and users while fostering a sustainable, technologically advanced future.

Business record

Currently, we are actively engaged in drafting a proposal for the Innovation Fund, focusing on projects related to the production of electrolyser systems. Our role is not to sell electrolyser directly; instead, we are committed to assisting our clients in establishing and optimizing their production capabilities for electrolyzes. This involves providing support throughout the development process, from concept to completion, ensuring that our clients can successfully create high-quality, efficient electrolyser systems to meet the growing demand for sustainable energy solutions.

9.2.19 PNO

Organisation

Organisation name	PNO

Organisation type	Consultancy

Motivations to be a service provider in OITB

Please explain your motivation by proving e.g. an answer to the following questions:
Why is your organization willing to be a service provider in CleanHyPro OITB? PNO's role inthis precise assignment is linked with the willingness of increasing the number of clients and new potential entities interested in the topic of green hydrogen production. Ensuring that the 16 project will have SME's willing to participate in the open calls with enough information and informed participation.
What objectives is the organisation pursuing? Gather data, Ensure a sound participation of new SME's, Guarantee the involvement of SME's already interested in previous OC's, Identification and Mapping the most relevant services.
How is the involvement in CleanHyPro aligned with the mission of the organisation? PNO as group has per its mission assist and pursue innovation for their clients in multiple areas. Turning their intention in concreate and feasible opportunities.
How would success be defined for you in the OITB? Accomplishing with the involvement of SME's in all the 16 projects, in a sound way.

Addressed market

Characterize the market that you address with your value proposition by e.g. answering the following questions:
What customer problems/needs are you addressing? As a consultancy company we tackle in multiple areas that are dealing or willing to deal with Green hydrogen. In a holistic way from the perspective of the producer until the user – deployment of the product into the market, passing through the entire supply chain
What part of the value chain are you addressing? (see proposed value chain below). PNO can contribute to the entire supply chain as PNO can address the:
1- Technology Assessment and Selection recommending the appropriate technologies bases on the specificities of each client. Always focusing in the green hydrogen technologies innovation in infrastructure or processes.
Sustainability and Carbon Footprint Reduction
2- Feasibility Studies: Can elaborate and assess the applicability of Green hydrogen in multiple projects and deliver technical economic and regulatory advisory reports
3- Market Analysis: perform market analysis, identify demand, and competition which will contribute to clients' informed decisions concerning investments, partnerships, or market entry.
4- Financial Modelling and Funding Assistance: Design and develop financial and business models. Assist clients in securing funding, grants, subsidies, or other financial incentives for green hydrogen projects.
5- Supply Chain Optimisation: Optimise the supply chain for green hydrogen production, including sourcing renewable energy, managing raw materials, and optimizing logistics for hydrogen transportation.
6- Project Management and Implementation: Provide project management services to oversee the implementation of green hydrogen projects, ensuring timely completion, adherence to budget, and compliance with quality standards.

7- Risk Assessment/Id Mitigation Measures: Assist in the identification of potential risks associated with green hydrogen projects contributing for the identification of strategies to mitigate those risks, ensuring resilience in the project.
8- Assist clients in using green hydrogen in their sustainability strategies contributing towards the carbon footprint reduction and achievement of environmental goals.
9- Transferability of knowledge through Training and Education initiatives for clients and their teams with the aim of raising awareness on green hydrogen technologies, market and best practices.
Are you addressing a specific application area or sector? No
Can you identify examples of customers/users (provide names)? Public authorities, retailers, energy providers etc.

...

Business record

Provide some indication in business figures of the offer in electrolyzers related technology/services in the last 3 years in your organisation. Who are the main customers? What is the average contracted amount per year? Which are the main products/services sold? What is the funding scheme for these contracts: full private contracts? contracts with public funding support? Not applicable
Provide relevant examples or case studies.

...

Business expectations

What barriers are you currently experimenting and how do you expect that CleanHyPro OITB may help to overcome them?
What are your business expectations regarding CleanHyPro OITB? International expansion? Grow the business overall? Increase the size of the projects? Provide integral support to your strategic customers/partners? Provide higher value to customers? Improve margings? Diversify the business? Get a better competitive positioning? If possible, provide priorities and quantify your expectations.
For the time being is quite early to really address this question, after the 1st OC it will be better to really understand how and where are the main obstacles and identify measures to overcome them enhancing the expansion