

LH_2CRAFT - Safe and Efficient Marine Transportation of Liquid Hydrogen

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Exploitation & IP Rights Management Plan

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Lead author(s)	Contributing partner(s)	Reviewer(s)
Alexandros Giannakis (HYD) Astrinos Papadakis (HYD)	ALL	Panagiotis Evangelou, Stathis Platypodis (NTUA) HyunChul Kim (KSOE)

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LIST OF ABBREVIATIONS

Abbreviation	Definition
AiP	Approval in Principle
BoG	Boil-off Gas
CA	Consortium Agreement
CAPEX	Capital Expenditure
CCS	Cargo Containment System
CEN/CENELEC	European Committee for Standardization / European Committee for Electrotechnical Standardization
CFRP	Carbon Fibre Reinforced Polymer
CHJU	Clean Hydrogen Joint Undertaking
DMP	Data Management Plan
EU	European Union
FAIR	Findable, Accessible, Interoperable, Reusable
FEED	Front-End Engineering Design
FMEA	Failure Mode and Effects Analysis
FTO	Freedom-to-Operate
GA	Grant Agreement
GDPR	General Data Protection Regulation
HAZID	Hazard Identification
HAZOP	Hazard and Operability Study
HDMSS	Handling, Distribution and Measurement Subsystems
HE MGA	Horizon Europe Model Grant Agreement
HSSE	Health, Safety, Security and Environment
IACS	International Association of Classification Societies

Abbreviation	Definition
IEA	International Energy Agency
IGC Code	International Code for the Construction and Equipment of Ships Carrying Liquefied Gases in Bulk
IGF Code	International Code of Safety for Ships Using Gases or Other Low-Flashpoint Fuels
IMO	International Maritime Organization
IP	Intellectual Property
IPR	Intellectual Property Rights
ISO	International Organization for Standardization
KER	Key Exploitable Result
KPI	Key Performance Indicator
LCA	Life Cycle Assessment
LCCA	Life Cycle Cost Analysis
LCOH	Levelised Cost of Hydrogen
LH_2	Liquid Hydrogen
LNG	Liquefied Natural Gas
LOHC	Liquid Organic Hydrogen Carrier
NASA	National Aeronautics and Space Administration
NPV	Net Present Value
OPEX	Operational Expenditure
QA/QC	Quality Assurance / Quality Control
QFD	Quality Function Deployment
QRA	Quantitative Risk Assessment
R&A	Reliability and Availability
R&I	Research and Innovation

Abbreviation	Definition
ROI	Return on Investment
RPUF	Rigid Polyurethane Foam
RT	Room Temperature
RTO	Research and Technology Organisation
SME	Small and Medium-sized Enterprise
SRL	Software Readiness Level
TCP	Technology Collaboration Programme
TRL	Technology Readiness Level
VIP	Vacuum Insulation Panel
WP	Work Package
ZEWT	Zero-Emission Waterborne Transport
ZIH	Centre for Information Services and High-Performance Computing (Zentrum für Informationsdienste und Hochleistungsrechnen), TU Dresden

EXECUTIVE SUMMARY

LH2CRAFT aims to enable the safe and efficient marine transportation of liquid hydrogen through the development of a novel membrane-type Cargo Containment System (CCS), associated Handling, Distribution and Measurement Subsystems (HDMSS), and supporting safety, testing, sustainability, regulatory and knowledge-transfer outputs. Within this context, exploitation and intellectual property management are essential to ensure that the project's results are properly identified, protected where appropriate, and positioned for future scientific, industrial, regulatory and commercial use.

This deliverable presents the current version of the Exploitation & IP Rights Management framework for the project. It reflects the status of the project's results at the time of preparation and provides a structured basis for their further refinement as LH2CRAFT progresses towards completion. The work is structured around the LH2CRAFT Key Exploitable Results (KER) register, which serves as the main operational tool for recording the technical, exploitation-relevant and IPR-related profile of each result. The register includes information on each result's originating work package and task, responsible and contributing partners, type of result, Technology Readiness Level (TRL) progression, target users, application sector, ownership, background dependencies, access-rights conditions, protection status, freedom-to-operate considerations and third-party IP risks.

As the project continues to mature, certain elements of this plan, including the composition and scope of the KER portfolio, intellectual property considerations, protection strategies, and exploitation arrangements, remain subject to ongoing assessment and consortium-wide agreement. These aspects will be further refined and consolidated throughout the remainder of the project, with the final version of this deliverable reflecting the consensus and validated positions of all partners.

At this stage, the project has identified a broad portfolio of 27 KERs. These include the core CCS and HDMSS developments, the mock-up/prototype CCS, vessel design and boil-off management results, manufacturing and validation methodologies, cryogenic test-rig outputs, material testing procedures and datasets, safety and risk assessment methodologies, class review and Approval in Principle outputs, sustainability and LCA/LCCA methodologies, circularity guidance, alternative design methodologies, the Knowledge Hub, and thermo-mechanical simulations supporting a digital-twin approach. This confirms that LH2CRAFT's exploitable output is not limited to a single technology, but consists of a wider portfolio of technical, methodological, regulatory, data-driven and knowledge-transfer results.

The identified KERs are organised into five preliminary exploitation and impact pathways: industrial technology development and uptake; manufacturing, testing and validation services; safety, class approval and regulatory uptake; sustainability, economic assessment and circularity; and knowledge transfer, replication and future R&I. These pathways provide a structured view of how different categories of results may generate value after the project. They should be understood as current orientations that will be refined as the technical results mature, ownership and access-rights conditions are clarified, and partner-level exploitation intentions are further defined.

The exploitation approach is closely connected to dissemination and communication under WP11. Public communication, stakeholder engagement, technical workshops, Knowledge Hub activities and training can all support uptake of the project's results, provided that disclosure is managed carefully. For this reason, dissemination activities are linked to the KER clusters and should be checked against ownership, background, protection status, confidentiality, freedom-to-operate (FTO) and third-party IP risks before release.

From an IPR perspective, the deliverable applies the framework of the Grant Agreement and Consortium Agreement to the project's KER portfolio. The IPR & Ownership Matrix is the practical mechanism for recording, for each KER, ownership, background dependencies, joint ownership needs, protection strategies, access-rights conditions, FTO status and third-party IP risks. The field structure and definitions have been established; however, the KER-specific matrices will be completed with partner input and included in the final version of this deliverable as the relevant IP decisions are taken.

Overall, this version establishes a structured exploitation and IP management baseline for the remaining project period. The next steps will focus on consolidating the KER register, resolving open ownership and access-rights questions, refining protection and FTO positions, linking exploitation pathways to the most mature results, and ensuring that the project's technical, safety, regulatory, sustainability and knowledge-transfer outputs are positioned for continued use beyond the project lifetime.

1 INTRODUCTION

1.1 PURPOSE AND SCOPE OF THE PLAN

The purpose of this Exploitation & IP Rights Management Plan is to define a clear framework for protecting, managing, and maximising the use of the results generated within the LH2CRAFT project (*Safe and Efficient Marine Transportation of Liquid Hydrogen*).

The Plan ensures that all knowledge, data, and technological outcomes produced during the project are properly identified, protected, and exploited in line with the principles and obligations set out in Article 16 of the Grant Agreement (GA), Articles 8 and 9 of the Consortium Agreement (CA), and the Clean Hydrogen Joint Undertaking (JU) guidelines.

The main operational tool is the LH2CRAFT Key Exploitable Result (KER) register. The register collects essential technical, exploitation-relevant and IPR-related information for each identified KER, allowing the consortium to maintain a consistent overview of emerging results, their potential uses, ownership status, background dependencies, access-rights considerations and preliminary protection strategy.

More specifically, this document aims to:

- Establish a structured approach for identifying, assessing, and classifying all project results with potential for commercial, industrial, scientific, or regulatory exploitation.
- Define roles, responsibilities, and procedures among partners for Intellectual Property Rights (IPR) protection, ownership, access rights, and licensing.
- Support the translation of technical achievements, such as the innovative membrane-type containment system, the handling and distribution subsystems, and safety and life-cycle assessment (LCA) and life-cycle cost analysis (LCCA) tools, into market-ready products, services, and standards.
- Align exploitation and IPR activities with the project's dissemination, communication, and data-management strategies to ensure coherence across WP11.
- Contribute to the long-term sustainability and impact of LH2CRAFT by preparing the ground for future industrial deployment, policy uptake, and potential standardisation of LH_2 containment solutions in the maritime sector.

Ultimately, this Plan serves as a living document that will evolve as new exploitable results emerge and as the project progresses from research and validation toward demonstration, approval-in-principle (AiP), and market uptake.

1.2 PROJECT DESCRIPTION

The LH2CRAFT project — *Safe and Efficient Marine Transportation of Liquid Hydrogen* — is a Research and Innovation Action (RIA) funded by the Clean Hydrogen Joint Undertaking under Grant Agreement No. 101111972. The project supports the European Union's Hydrogen Strategy and the Zero-Emission Waterborne Transport (ZEWT) Partnership, contributing directly to the decarbonisation of long-distance maritime transport and the creation of a European hydrogen economy.

Liquid hydrogen (LH_2) is expected to become a key energy carrier in global decarbonisation, enabling large-scale storage and transport of renewable hydrogen over long distances. However, no marine transport solution currently exists that can safely and economically handle LH_2 at scale. The technological, regulatory, and safety barriers remain substantial, particularly regarding cryogenic containment, boil-off management, material integrity, and approval processes.

LH2CRAFT addresses these challenges by developing and validating a novel membrane-type cargo containment system (CCS) specifically engineered for LH_2 marine transportation. The project aims to demonstrate the technical feasibility, safety, and cost-effectiveness of such a system, paving the way for commercial deployment of LH_2 carriers that can transport hydrogen between production hubs and demand centres.

The main objectives of LH2CRAFT are to:

- Design, develop, and validate a full-scale hydrogen-compatible membrane CCS based on a metallic primary barrier and multilayer insulation capable of withstanding LH_2 conditions (−253°C).
- Develop Handling, Distribution, and Measurement Subsystems (HDMSS) for cryogenic hydrogen loading, unloading, and transfer, integrating safety-by-design and process monitoring principles.
- Establish a digital design and validation framework, combining multiphysics (thermal, structural, and fluid-dynamic) numerical modelling with experimental validation at subscale and component levels.
- Conduct a comprehensive safety and risk assessment, including Failure Mode and Effects Analysis (FMEA), Quantitative Risk Assessment (QRA), and safety case methodologies consistent with IMO and IGC Code guidelines.
- Perform environmental and techno-economic analyses, including an LCA, LCCA and a cost-benefit evaluation of the proposed LH_2 containment solution.
- Develop a roadmap for type approval and certification, engaging with class societies and regulatory authorities to ensure alignment with maritime standards and future LH_2 transport regulations.
- Prepare the ground for commercialisation and standardisation, identifying business models, exploitation opportunities, and industrial partnerships beyond the project's lifetime.

Consortium and Structure

The LH2CRAFT consortium unites leading industrial partners, research organisations, and classification societies from across Europe, covering the full spectrum of expertise required to realise LH_2 maritime transport:

- Industrial and engineering partners contribute to containment design, materials selection, fabrication, and system integration.
- Research and technology organisations (RTOs) focus on modelling, simulation, experimental validation, and materials testing.
- Classification societies and safety experts ensure compliance with maritime safety, certification, and standardisation frameworks.

- Specialised partners handle exploitation, dissemination, and regulatory engagement, ensuring long-term impact and uptake.

The project is structured into eleven work packages (WPs), spanning materials development, containment design, cryogenic subsystems, safety assessment, environmental analysis, and exploitation. The work culminates in WP7 (Demonstration), where representative prototypes and digital twins are validated under realistic operating conditions, and WP11 (Dissemination, Exploitation and Communication), which ensures visibility, uptake, and sustainability of project results.

Expected Impact

LH2CRAFT will deliver the first European proof-of-concept for a membrane-type LH_2 containment system, achieving TRL 5–6 (Technology Readiness Level) by the project's end. Its results will directly contribute to:

- Reducing technological barriers to maritime transport of liquid hydrogen,
- Strengthening EU leadership in cryogenic containment technologies and hydrogen logistics,
- Providing a basis for future standardisation and class approval,
- Enabling the creation of a safe, scalable LH_2 shipping value chain, aligned with EU Green Deal and REPowerEU targets.

1.3 METHODOLOGY AND UPDATE MECHANISM

The methodology applied in this Exploitation & IP Rights Management Plan is designed to ensure a systematic, transparent, and collaborative process for the identification, protection, and utilisation of the results generated throughout the LH2CRAFT project. It aligns with the GA, the CA, and Clean Hydrogen Joint Undertaking (CHJU) guidelines on exploitation and dissemination of project results.

Overall Approach

The Plan follows a result-oriented and iterative approach, recognising that knowledge and exploitable outcomes emerge progressively across different work packages. It integrates the following complementary methodological streams:

1. Identification and Classification of Results – Potential KERs are identified by the consortium during project meetings. These results are classified by type (technology, process, software, data, methodology, business model, policy tool and other) and mapped against their expected TRL, ownership, and market potential.
2. IPR Assessment and Protection – For each identified KER, the responsible partners assess ownership, background dependencies, and the most appropriate protection strategy (e.g., patent filing, copyright, design rights, trade secret). The process follows the IPR provisions in the CA, ensuring early detection of joint ownership situations and fair access-right arrangements.

Update Mechanism

Given the dynamic nature of research and innovation projects, this Plan is conceived as a living document that evolves throughout the LH2CRAFT lifecycle. Updates will be implemented according to the following process:

- Continuous Monitoring: Partners submit updates on new or modified KERs, IPR status, and exploitation actions via the internal knowledge-management platform.
- Periodic Review: The Plan is reviewed at regular intervals and whenever major project milestones or results are reached.
- Post-Project Continuation: After project completion, the consortium partners commit to maintain cooperation through bilateral or joint exploitation agreements, ensuring that protection and utilisation of LH2CRAFT results continue to generate impact.

This adaptive methodology guarantees that exploitation and IPR management remain aligned with project progress, responsive to new opportunities, and compliant with legal and ethical requirements, thereby maximising the overall impact and sustainability of LH2CRAFT's outcomes.

2 METHODOLOGY

2.1 APPROACH FOR IDENTIFYING EXPLOITABLE RESULTS

Each WP continuously monitors its technical and scientific outputs to identify new results that may have relevance beyond internal research use. This includes innovative materials, validated models, simulation tools, experimental data, prototypes, and process designs. These results are collected and discussed by the consortium during project meetings. A register is created, which includes for each KER information such as the result's title, description, origin (WP and task), responsible partners, ownership, related background, expected TRL and potential applications. Maintaining this register throughout the project's lifetime allows the consortium to maintain a consolidated overview of the knowledge being generated and its exploitation potential.

The recorded results are then assessed collectively by the relevant WP leaders and relevant partners. This evaluation considers criteria such as the novelty of the result, its potential for market uptake, readiness for protection or commercialisation, expected socio-economic or environmental benefits, and alignment with both the project's objectives and the strategic priorities of the ZEWT Partnership.

For each KER, ownership and background dependencies are clarified in accordance with the CA and the relevant provisions of the GA. Partners confirm whether a result is solely or jointly owned and identify any pre-existing intellectual property (background) required for its use. Where joint ownership arises, partners define fair and transparent arrangements for protection, exploitation, and revenue sharing, ensuring compliance with Article 16 of the GA. Protection strategies, such as patent filing, copyright registration, design right, or maintenance as a trade secret, are agreed upon collectively to secure the long-term value of each result.

Depending on the nature of each KER, potential pathways may include industrial use, licensing, follow-up R&I, contribution to class or regulatory frameworks, scientific publication, training activities, sustainability assessment, or controlled dissemination through the Knowledge Hub. This is particularly important because the current KER portfolio is broader than the two core technical results of CCS and HDMSS: it also includes prototype, testing, materials, safety, regulatory, LCA/LCCA, circularity and knowledge-management results. Each partner integrates its relevant results into its individual exploitation plan, while HYD, through a dual role of WP11 leader as well as project coordinator, consolidates the information to form the project-wide strategy outlined in the present document.

The identification and assessment process is iterative and continues throughout the project's duration. As technical activities progress from design and modelling to demonstration and regulatory evaluation new results are added and re-evaluated. This continuous feedback mechanism ensures that no significant result remains untracked and that IPR and exploitation actions evolve in step with technical progress. By maintaining this structured and dynamic process, the consortium ensures that all LH2CRAFT results are systematically captured, protected, and positioned for long-term use and impact within the European hydrogen and maritime value chains.

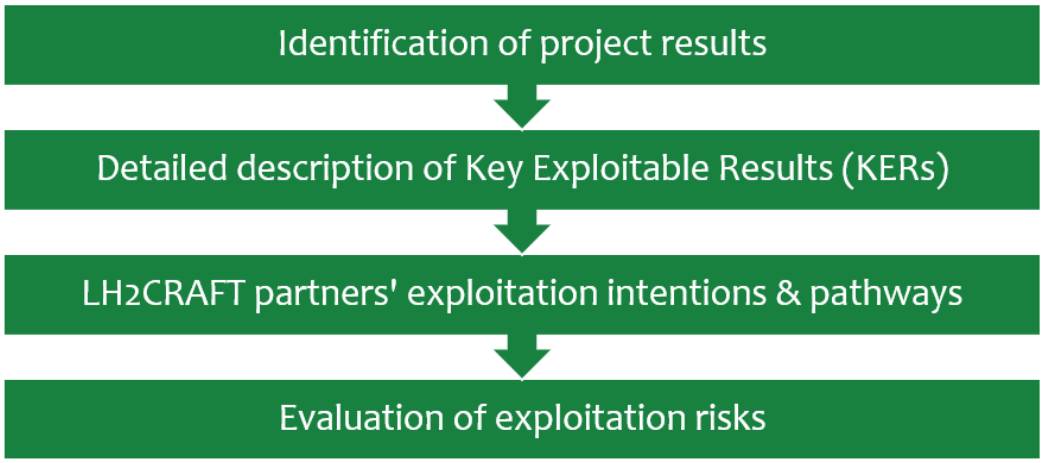


Figure 1. KER identification methodology

2.2 PARTNER INPUTS AND ROLES

Effective exploitation and intellectual property management in LH2CRAFT rely on the active and coordinated participation of all partners. Each partner contributes according to its expertise, role within the project, and the type of results it generates or utilises. The process is managed collaboratively under the supervision of the WP11 leader (HYD), ensuring that responsibilities are clear, actions are coherent, and decisions are taken transparently and in line with the provisions of the GA and the CA.

The project coordinator (HYD) oversees the overall implementation of the Exploitation and IPR Plan, ensuring alignment with project objectives, periodic reporting obligations, and CHJU requirements. The coordinator facilitates the integration of IPR and exploitation considerations into the broader project management structure, ensuring that technical, scientific, and administrative aspects evolve consistently.

HYD is responsible for preparing, maintaining, and updating the Exploitation & IP Rights Management Plan. HYD also collects relevant partner inputs and organises regular reviews of Key Exploitable Results (KERs). In cooperation with the relevant partners, HYD ensures that exploitation and protection actions are properly tracked and reported, and that all partners are informed about upcoming deadlines, updates, and potential IP-related issues.

Each technical work package leader (WPs 2–10) plays a crucial role in identifying exploitable results arising from their respective research, development, and demonstration activities. They ensure that outputs with potential commercial, scientific, or regulatory relevance are described and reported to WP11. The WP leaders collaborate closely with the relevant partners to assess the TRL, novelty, and potential for protection of their results. They also contribute to defining ownership and access rights by identifying relevant background IP and dependencies early in the project lifecycle.

The industrial partners, including shipyards, engineering companies, and technology developers, provide practical insights into market needs, regulatory constraints, and commercial feasibility. They assess the applicability of technical outcomes to real-world maritime operations and contribute to defining exploitation pathways, business models, and potential routes to commercialisation. These partners also play a central role in evaluating patentability, trade secret management, and licensing opportunities for the technologies they co-develop.

The research and technology organisations contribute by developing, validating, and refining methodologies, materials, and simulation tools. They are responsible for scientific publications and contribute to the project's open-science objectives while ensuring that dissemination activities remain consistent with protection requirements. Their inputs are particularly valuable in assessing the scientific novelty of results and preparing background documentation for IP protection.

The classification societies and regulatory partners ensure that project outputs are aligned with maritime safety standards and certification procedures. They provide crucial guidance for regulatory acceptance, type approval, and the integration of LH_2 containment and handling systems into existing and emerging standards. Their role extends beyond validation, as they also support the identification of exploitable regulatory and procedural outputs that may influence international standards and future rules for LH_2 shipping.

Finally, all consortium partners are responsible for reporting and validating their contributions, respecting confidentiality obligations, and safeguarding proprietary information. They collaborate to resolve potential conflicts related to ownership or access rights, with disputes handled through the mechanisms defined in the CA. All partners contribute to the continuous improvement of the Exploitation and IPR framework by sharing information on patent applications, publications, or new business opportunities related to LH2CRAFT results.

The cooperative structure between the coordinator, WP11 leader, technical WPs, and the involved partners ensures that exploitation and IP management are not treated as isolated administrative tasks but are embedded within the technical and strategic development of the project. This coordinated approach guarantees that every partner's contribution is acknowledged, protected, and leveraged toward achieving LH2CRAFT's long-term impact — enabling the safe, efficient, and standardised marine transport of liquid hydrogen.

2.3 EVALUATION CRITERIA

To ensure that the results of LH2CRAFT are effectively prioritised for protection and exploitation, the consortium applies a set of evaluation criteria that allow consistent, transparent, and objective assessment of each potential Key Exploitable Result (KER). These criteria are used throughout the project lifecycle, from the early identification of preliminary results to the validation and exploitation of mature outcomes, and are regularly reviewed under the coordination of HYD.

The evaluation process is designed to distinguish between general project outputs and those with tangible value beyond the immediate scope of the research activities. It provides a structured means to focus resources on the most promising results for commercialisation, standardisation, or regulatory adoption. The main evaluation dimensions are outlined below.

1. Scientific and Technological Novelty

Each result is evaluated for its degree of innovation compared to existing technologies, methods, or scientific knowledge. This includes assessing the originality of the concept, the advancement it represents over the state of the art, and its potential to enable new technological capabilities in liquid hydrogen storage, containment, handling, or safety management. Results that demonstrate clear novelty and technical superiority are prioritised for further protection or validation.

2. Technology Readiness Level and Maturity

The assessment considers the current TRL and its expected progression within the project. Results at intermediate to high TRLs (typically TRL 4–6 by project end) are flagged for targeted exploitation activities, whereas early-stage results (TRL 2–3) are monitored for further research potential or future development. The same principle applies to Software Readiness Levels (SRL) for digital tools and models developed within the project.

3. Market Potential and Value Creation

Each KER is assessed for its potential relevance to identifiable target end-users, application sectors and value-chain needs. This allows the consortium to distinguish between results with direct industrial exploitation potential, such as the CCS membrane-type detailed design, HDMSS basic engineering, boil-off gas (BoG) management and test-rig outputs, and results with primarily regulatory, methodological, scientific or knowledge-transfer value, such as the safety assessment methodology, class review methodology, LCA/LCCA methodology, circularity guidelines and Knowledge Hub.

4. Exploitation Feasibility and Partner Capability

Exploitation feasibility will be assessed by linking each KER to the partner or partners responsible for its development, the type of result generated, the intended users, and the relevant ownership and access-rights conditions. This will allow the consortium to distinguish between KERs that can be exploited directly by a single partner, KERs requiring joint ownership or access-rights arrangements, KERs best suited for scientific or regulatory dissemination, and KERs requiring further validation before exploitation.

This is particularly important for KERs where several partners may contribute to the same result. In such cases, exploitation feasibility will depend not only on technical maturity, but also on whether ownership, background dependencies, access rights and protection strategies are clearly defined.

5. Intellectual Property Position and Protectability

Each result is reviewed for its potential to be protected through appropriate IP instruments such as patents, copyrights, trade secrets, or design rights. The assessment also examines possible conflicts with existing background IP, prior art, or third-party rights. The outcome of this evaluation determines whether a result should be maintained as confidential know-how, made publicly available under open-science principles, or subjected to patent or design protection.

6. Societal, Environmental, and Regulatory Impact

In line with the objectives of the CHJU and the ZEWT Partnership, results are also assessed for their expected impact on safety, sustainability, and regulatory development. This includes their potential to enhance environmental performance (e.g. reduction of greenhouse gas emissions or material waste), contribute to safer maritime hydrogen transport, or support the formulation of new standards and certification processes.

7. Strategic Alignment and Cross-Sectoral Relevance

The final evaluation dimension concerns the strategic positioning of each KER within broader European and international hydrogen initiatives. Results that contribute directly to EU policy objectives, such as the Hydrogen Strategy, REPowerEU, or maritime decarbonisation roadmaps, and those that can generate spill-over benefits to related sectors (e.g. cryogenic logistics, aerospace, or energy storage) receive higher prioritisation.

This structured evaluation process enables LH2CRAFT to focus its exploitation efforts on the most impactful, feasible, and strategically valuable results, ensuring that project outcomes contribute meaningfully to Europe's transition toward safe and efficient hydrogen-powered maritime transport.

2.4 TOOLS AND TEMPLATES USED

The main working tool for exploitation and IPR management is the LH2CRAFT KER register in the form of an Excel workbook. The workbook contains the portfolio of project results to be monitored for exploitation and IP purposes.

Each individual KER sheet contains two main sections: **KER General Information** and the **Intellectual Property (IPR) & Ownership Matrix**. The KER General Information section is designed to capture the basic exploitation-relevant profile of each result, including the KER reference number, title, originating work package/task, lead beneficiary, contributing partners, type of result, TRL progression, short description, problem addressed, target users/customers, market/application sector and geographical target market.

The IPR & Ownership Matrix is designed to capture the key legal and IP-related information needed to manage each result. It includes fields on result ownership, owner(s), whether a joint ownership agreement is required, whether background is used, background owner(s), access-rights conditions, foreground protection status, IP protection strategy, territorial coverage, freedom-to-operate assessment and third-party IP risks.

The register should therefore be treated as the project's central operational tool for KER and IPR monitoring. It allows the consortium to distinguish between KERs with direct industrial exploitation potential, KERs requiring joint ownership or access-rights arrangements, KERs mainly suited to scientific or regulatory uptake, and KERs that should be disseminated through training, policy input or the Knowledge Hub. It also helps identify where additional clarification is needed before exploitation can proceed, especially in relation to background IP, foreground protection, territorial coverage, freedom to operate and third-party IP risks.

Depending on the needs of the project, the KER register may be complemented by additional tools, such as a partner exploitation questionnaire, a detailed IP disclosure form, or a KER prioritisation matrix. To ensure consistency between exploitation, IP management and dissemination, each update of the register should be version-controlled and reviewed by the relevant KER lead and contributing partners. Public dissemination should be checked against the corresponding KER sheet before release, particularly where the result may involve protectable foreground, confidential background, pending freedom-to-operate (FTO) assessment or third-party IP risks.

3 EXPLOITATION STRATEGY

3.1 KEY EXPLOITABLE RESULTS

In the following Form, a detailed description of the key exploitable results produced by LH2CRAFT is presented. All fields have been filled out in cooperation with relevant project partners. It should be noted that KER definitions and properties are refined continuously throughout the implementation of the project, and, as such, some fields are subject to change, until the definitive list will be published in the final version of this document (M48).

KER #1	CCS membrane type detailed design for up to 160,000 m3 capacity
Work Package / Task	WP3 / T3.1-T3.2
Lead Beneficiary	KSOE
Other Contributing Partners	-
Type of Result	☒ Technology ☒ Process ☐ Software ☐ Data ☒ Methodology ☐ Business Model ☐ Policy Tool ☐ Other
Technology Readiness Level (Start → End)	1 → 5
Short Description	Membrane type cargo containment system featuring primary and secondary barriers capable of withstanding liquefied hydrogen temperatures and brittleness, whilst providing adequate thermal insulation performance and mechanical strength against ship motion and sea condition.
Problem Addressed	the appropriate size and insulation performance for large-capacity liquefied hydrogen carriers, in anticipation of the expansion of the liquefied hydrogen maritime transport market.
Target Users / Customers	Industry (Ship owners and charterers)
Market/Application Sector	Energy, Maritime, Hydrogen
Geographical Target Market	Global

KER #2	HDMSS basic engineering and design
Work Package / Task	WP5 / All tasks
Lead Beneficiary	NTUA, HYD
Other Contributing Partners	-

Type of Result	☒ Technology ☒ Process ☐ Software ☐ Data ☒ Methodology ☐ Business Model ☐ Policy Tool ☐ Other
Technology Readiness Level (Start → End)	1 → 3
Short Description	Development of the design for the HDMSS with respect to loading, storage and unloading operations on-board the LH2 carrier. Assessment of the requirements set forth by the technology development of the internal combustion engine design for handling H2 as fuel, and incorporation of the relevant design parameters in the design process. Development of a realistic modular design approach, which will allow for scalability as well as for adapt-ability in different conditions and environments. Assessment by the Classification Societies.
Problem Addressed	Absence of the design of an HDMSS system operating for LH2 as cargo.
Target Users / Customers	Industry, SMEs, research community.
Market/Application Sector	Energy, maritime, hydrogen.
Geographical Target Market	Global

KER #3	Mock-up/prototype CCS
Work Package / Task	WP7 / T7.2 ~ T7.5
Lead Beneficiary	GBD
Other Contributing Partners	HYD, KSOE
Type of Result	☒ Technology ☒ Process ☐ Software ☐ Data ☒ Methodology ☐ Business Model ☐ Policy Tool ☐ Other
Technology Readiness Level (Start → End)	2 → 5
Short Description	As a mock-up for evaluating the constructability of the developed LH2 CCS, it incorporates key components such as flat insulation panels, corner insulation panels, primary barriers, and secondary barriers, along with temporary closing parts capable of reducing pressure within the insulated space. KSOE provides arrangement drawings of insulation panels and barriers for the mock-up using KSOE's own LH2 CCS concept.
Problem Addressed	It verifies whether the developed LH2 CCS can be practically installed.
Target Users / Customers	Industry (Shipbuilding)

Market/Application Sector	Maritime, Hydrogen
Geographical Target Market	Global

KER #4	**CCS manufacturing methodology application**
Work Package / Task	WP7
Lead Beneficiary	GBD
Other Contributing Partners	KSOE
Type of Result	☐ Technology ☒ Process ☐ Software ☐ Data ☒ Methodology ☐ Business Model ☐ Policy Tool ☐ Other
Technology Readiness Level (Start → End)	2 → 5
Short Description	GBD will develop and implement procedures for CCS installation on the Prototype.
Problem Addressed	Industrial application
Target Users / Customers	Vessels' Owners
Market/Application Sector	Maritime
Geographical Target Market	Global

KER #5	**CCS testing and validation methodology application**
Work Package / Task	WP7 / T7.5
Lead Beneficiary	ACT
Other Contributing Partners	KSOE, GBD
Type of Result	☒ Technology ☒ Process ☐ Software ☐ Data ☒ Methodology ☐ Business Model ☐ Policy Tool ☐ Other
Technology Readiness Level (Start → End)	2 → 5
Short Description	Inspection method to verify that the installed primary and secondary barriers are effectively preventing cargo leakage, and method to validate that a low vacuum level pressure is established within the insulation space.

	KSOE provides test procedures based on the operational philosophy of KSOE's own LH2 CCS concept design.
Problem Addressed	It demonstrates its capability to reduce pressure within the insulated space.
Target Users / Customers	Industry (Shipbuilding)
Market/Application Sector	Maritime, Hydrogen
Geographical Target Market	Global

KER #6	**Risk & Safety Assessment methodology and findings (HAZID, HAZOP, FMEA, QRA)**
Work Package / Task	WP8
Lead Beneficiary	UoS
Other Contributing Partners	TWI, HYD, RINA, ABS
Type of Result	☐ Technology ☐ Process ☐ Software ☒ Data ☒ Methodology ☐ Business Model ☐ Policy Tool ☒ Other
Technology Readiness Level (Start → End)	Not applicable
Short Description	To ensure and enhance the safety of the engineering and detailed LH2 storage design and prototype testing while proposing optimal design solutions for minimizing potential risks so as to achieve Approval in Principle (AiP) and general Class Approvals. The key objectives were: - Safety evaluation of conceptual/detailed designs of the demonstrator and desktop studies. - Optimal solutions for risks associated with designing and testing the demonstrator. - Qualitative and quantitative consideration of key potential hazard elements - Control of identified risks and implementation of safety solutions to the demonstrator and desktop studies. - Design guidelines for general applicability and demonstration of scalability - Comparison with other types of storage systems and highlighting of safety differences and similarities
Problem Addressed	To ensure and enhance the safety of the engineering and detailed LH2 storage design and prototype testing while proposing optimal design solutions for minimizing potential risks so as to achieve Approval in Principle (AiP) and general Class Approvals.
Target Users / Customers	Industry, SMEs, public authorities, research community, policy makers

Market/Application Sector	Energy, maritime, CCUS, hydrogen
Geographical Target Market	EU, Global

KER #7	**Training methodology for safety related to design and integration**
Work Package / Task	WP8 / T8.6
Lead Beneficiary	UoS
Other Contributing Partners	RINA, ABS, TWI
Type of Result	☐ Technology ☐ Process ☐ Software ☐ Data ☒ Methodology ☐ Business Model ☐ Policy Tool ☒ Other
Technology Readiness Level (Start → End)	Not applicable
Short Description	Development of guidelines and training material for the safe handling of LH_2 as cargo onboard ships, covering occupational health and safety for crews and port personnel. Includes quantification of H_2-related social costs and benefits, suggestions for policy measures, and an emergency response plan for H_2-related incidents.
Problem Addressed	Absence of established training standards, guidelines, and emergency procedures for crews and port personnel handling LH_2 as cargo; lack of quantified occupational and social health and safety framework specific to large-scale LH_2 maritime transport.
Target Users / Customers	Industry (ship operators, port authorities, shipowners), public authorities, research community, maritime training institutions
Market/Application Sector	Energy, maritime, hydrogen
Geographical Target Market	EU, Global

KER #8	**LH2 Carrier vessel detailed design (160K)**
Work Package / Task	WP4 / T4.1-T4.2
Lead Beneficiary	HYD
Other Contributing Partners	NTUA, KSOE
Type of Result	☒ Technology ☒ Process ☐ Software ☐ Data ☒ Methodology ☐ Business Model ☐ Policy Tool ☐ Other

Technology Readiness Level (Start → End)	1 → 4
Short Description	Development of the preliminary design and assessment of an innovative LH2 carrier integrating advanced cryogenic CCS technologies, suitable for large-scale hydrogen transport capacities comparable to existing LNG carriers (e.g. ~200,000 m³ LH2). The design includes the development of the vessel hull form, ballast tank operation strategy, manoeuvring and stability assessment considering the low density of liquid hydrogen, and the integration of the cryogenic cargo containment system within the cargo spaces and cargo handling systems. The carrier concept is additionally optimized for compatibility with existing LNG trading routes and terminal infrastructures, while establishing the key vessel design requirements and development concept during the early design stages.
Problem Addressed	Lack of an optimized large-scale LH2 carrier design capable of ensuring adequate draught, vessel stability, and propulsion performance despite the low density of liquid hydrogen cargo.
Target Users / Customers	Industry, SMEs, research community.
Market/Application Sector	Energy, maritime, hydrogen.
Geographical Target Market	Global

KER #9	**Methodology for alternative designs incl. ship design, systems design, R&A for integrated LH2 CCS etc.**
Work Package / Task	WP4 / T4.4, WP5 / T5.4
Lead Beneficiary	HYD
Other Contributing Partners	NTUA
Type of Result	☐ Technology ☐ Process ☐ Software ☐ Data ☒ Methodology ☐ Business Model ☐ Policy Tool ☐ Other
Technology Readiness Level (Start → End)	1 → 2
Short Description	Development of proposals for the integration of alternative LH2 cargo containment system solutions into ship hulls, depending on the CCS size, vessel type, operational profile, and foreseen routes. The KER addresses both LH2 as cargo and LH2 as fuel applications, including cases such as LH2-fuelled cruise vessels. It includes the development of a realistic modular design approach enabling scalability, adaptability, and integration flexibility across different ship types, operating conditions, and environments.
Problem Addressed	Propose conceptual solutions for LH2 storage in different types of ships.

Target Users / Customers	Industry, SMEs, public authorities, research community, etc.
Market/Application Sector	Energy, maritime, hydrogen.
Geographical Target Market	Global

KER #10	**Feedback to regulatory framework for issues related to stability, strength, etc.**
Work Package / Task	WP8 / T8.1
Lead Beneficiary	UoS
Other Contributing Partners	RINA, TWI
Type of Result	☐ Technology ☐ Process ☐ Software ☐ Data ☒ Methodology ☐ Business Model ☒ Policy Tool ☐ Other
Technology Readiness Level (Start → End)	Not applicable
Short Description	Comprehensive review of existing international and EU regulations and Class requirements addressing LH_2 risks as cargo and fuel onboard ships; identification of regulatory gaps including those related to stability, structural strength, and loading conditions; and development of novel qualitative and quantitative risk assessment models appropriate for LH_2 hazard types. Provides structured feedback to regulatory bodies to inform ongoing rule development for LH_2 carriers.
Problem Addressed	Existing international and Class regulations were developed primarily for LNG and do not adequately address the distinct safety, stability, and structural hazards arising from LH_2 as cargo and fuel at −253°C. There are no comprehensive or validated risk assessment models specifically calibrated to LH_2 hazard characteristics, leaving designers and operators without an approved methodological framework.
Target Users / Customers	Classification societies, flag administrations, IMO (CCC Sub-Committee), EU regulators (EMSA), research community
Market/Application Sector	Maritime, energy, hydrogen
Geographical Target Market	Global

KER #11	**Cryogenic test rig design for large scale testing**
Work Package / Task	WP6 / T6.2
Lead Beneficiary	UPAT

Other Contributing Partners	NTUA, TUD, KSOE
Type of Result	☒ Technology ☐ Process ☐ Software ☐ Data ☐ Methodology ☐ Business Model ☐ Policy Tool ☐ Other
Technology Readiness Level (Start → End)	2 → 5
Short Description	Development of a cryogenic test rig for large-scale testing, enabling validation of LH_2 insulation systems under representative cryogenic and vacuum conditions. The design integrates the cryostat, cooling and pre-cooling strategy, instrumentation and process design to ensure controlled boundary conditions and reliable performance assessment of large-scale specimens.
Problem Addressed	Capable of performing evaluations close to real-operation conditions by implementing the actual operating environment: low-level vacuum pressure and liquid hydrogen temperature conditions.
Target Users / Customers	Industry, SMEs, public, research community
Market/Application Sector	Maritime, Automotive, Aerospace, Hydrogen
Geographical Target Market	Global

KER #12	Cryogenic testing and validation results for LH2 CCS insulation subsystem and HDMSS
Work Package / Task	WP6 / T6.3-T6.4
Lead Beneficiary	TUD/NTUA
Other Contributing Partners	UPAT, KSOE
Type of Result	☐ Technology ☐ Process ☐ Software ☒ Data ☐ Methodology ☐ Business Model ☐ Policy Tool ☐ Other
Technology Readiness Level (Start → End)	2 → 5
Short Description	Experimental testing programme conducted on the small-scale test model to validate the performance of the LH2 CCS insulation subsystem and HDMSS under cryogenic conditions. The programme covers insulation effectiveness, tightness of primary and secondary barriers and weldments, thermo-mechanical behaviour of insulation panel connectors, safe handling and distribution of liquefied gas through the HDMSS piping and equipment, characterisation of boil-off parameters (heat leakage, ortho-para conversion, sloshing, flashing), and functionality of the integrated monitoring system including sensors, gas detectors and alarm modules.

Problem Addressed	Certification of the CCS for LH2 cargo storage requires experimental testing of subsystems under cryogenic conditions (−253°C) to verify insulation effectiveness, barrier tightness, thermo-mechanical integrity, safe handling performance and monitoring system reliability. None of these have been validated at scale for membrane-type LH2 containment.
Target Users / Customers	Industry, SMEs, public, research community
Market/Application Sector	Maritime, Automotive, Aerospace, Hydrogen
Geographical Target Market	Global

KER #13	**Test rig equipment**
Work Package / Task	WP6 / T6.2
Lead Beneficiary	UPAT
Other Contributing Partners	NTUA, TUD, KSOE
Type of Result	☒ Technology ☐ Process ☐ Software ☐ Data ☐ Methodology ☐ Business Model ☐ Policy Tool ☐ Other
Technology Readiness Level (Start → End)	Not applicable
Short Description	Large-scale cryogenic test rig equipment designed to experimentally evaluate LH_2 insulation systems under controlled cryogenic and vacuum conditions. The facility integrates a cryostat, cooling subsystems, and instrumentation to enable accurate measurement of thermal performance and structural behaviour of full-scale or representative components.
Problem Addressed	Limited availability of large-scale experimental infrastructure capable of reproducing realistic LH_2 operating conditions, hindering validation, certification, and industrial deployment of cryogenic insulation technologies, and limiting the capability to perform evaluations close to real-operation conditions by implementing the actual operating environment, including low-level vacuum pressure and liquid hydrogen temperature conditions.
Target Users / Customers	Industry, SMEs, research community
Market/Application Sector	Maritime, Automotive, Aerospace, Hydrogen
Geographical Target Market	Global

KER #14	**Metallic material testing procedure definition**

Work Package / Task	WP3 / T3.3
Lead Beneficiary	NTUA
Other Contributing Partners	KSOE, TUD
Type of Result	☐ Technology ☐ Process ☐ Software ☐ Data ☒ Methodology ☐ Business Model ☐ Policy Tool ☐ Other
Technology Readiness Level (Start → End)	Not applicable
Short Description	Development of test methods and procedures for evaluating the suitability of metallic materials for liquefied hydrogen cargo containment insulation systems, including the definition and assessment of the mechanical properties of stainless steels 316L and 304L under room temperature, low-temperature (−196 °C), and cryogenic (−253 °C) conditions, and under various material states and operating conditions such as prestrained, hydrogen-precharged, welded, and combined conditions.
Problem Addressed	Lack of established and class pre-approved test methods and procedures for verifying the suitability of metallic materials for liquefied hydrogen storage and cargo containment systems, as well as the need to provide reliable material mechanical properties under room temperature (RT), low-temperature (LT), and cryogenic conditions through a concise and standardized testing schedule.
Target Users / Customers	Industry, Research Community (University, Test laboratory, etc.)
Market/Application Sector	Hydrogen, Maritime, Automotive, Aerospace
Geographical Target Market	Global

KER #15	**Non-Metallic material testing procedure definition**
Work Package / Task	WP3 / T3.4
Lead Beneficiary	TUD
Other Contributing Partners	KSOE, NTUA
Type of Result	☐ Technology ☐ Process ☐ Software ☐ Data ☒ Methodology ☐ Business Model ☐ Policy Tool ☐ Other
Technology Readiness Level (Start → End)	Not applicable

Short Description	Development of test methods and procedures for evaluating the suitability of non-metallic materials for liquefied hydrogen cargo containment insulation systems, including the definition of testing requirements for VIP, RPUF, adhesives, and CFRP materials under room temperature, low-temperature (−196 °C), and cryogenic (−253 °C) conditions.
Problem Addressed	Absence of systematically defined and standardized test methods, procedures, and testing campaigns for verifying and characterizing the suitability of non-metallic materials for liquefied hydrogen storage and cargo containment system (CCS) applications.
Target Users / Customers	Industry, Research Community (University, Test laboratory, etc.)
Market/Application Sector	Hydrogen, Maritime, Automotive, Aerospace
Geographical Target Market	Global

KER #16	**Metallic material testing results excluding Charpy-V notch and fatigue tests**
Work Package / Task	WP3 / T3.3
Lead Beneficiary	NTUA
Other Contributing Partners	KSOE, TUD
Type of Result	☐ Technology ☐ Process ☐ Software ☒ Data ☐ Methodology ☐ Business Model ☐ Policy Tool ☐ Other
Technology Readiness Level (Start → End)	Not applicable.
Short Description	Experimental results derived from tests performed in accordance with agreed test standards, including hydrogen compatibility and mechanical property testing, for stainless steels 316L and 304L under room temperature, low-temperature (−196 °C), and cryogenic (−253 °C) conditions, and under various material states such as prestrained, hydrogen-precharged, welded, and combined conditions.
Problem Addressed	Lack of experimental data and validated test results enabling the selection and qualification of suitable materials for liquefied hydrogen environments and cryogenic cargo containment system applications.
Target Users / Customers	Industry, SMEs, research community.
Market/Application Sector	Energy, maritime, hydrogen.
Geographical Target Market	Global

KER #17	Metallic material testing results including Charpy-V notch and fatigue tests
Work Package / Task	WP3 / T3.3
Lead Beneficiary	NTUA
Other Contributing Partners	KSOE, TUD
Type of Result	☐ Technology ☐ Process ☐ Software ☒ Data ☐ Methodology ☐ Business Model ☐ Policy Tool ☐ Other
Technology Readiness Level (Start → End)	Not applicable.
Short Description	Experimental results derived from tests performed in accordance with agreed test standards, including hydrogen compatibility and mechanical property testing, for stainless steels 316L and 304L under room temperature, low-temperature (−196 °C), and cryogenic (−253 °C) conditions, and under various material states such as prestrained, hydrogen-precharged, welded, and combined conditions.
Problem Addressed	Lack of experimental data and validated test results enabling the selection and qualification of suitable materials for liquefied hydrogen environments and cryogenic cargo containment system applications.
Target Users / Customers	Industry, SMEs, research community.
Market/Application Sector	Energy, maritime, hydrogen.
Geographical Target Market	Global

KER #18	Non-Metallic material testing results
Work Package / Task	WP3 / T3.4
Lead Beneficiary	TUD
Other Contributing Partners	KSOE, NTUA
Type of Result	☐ Technology ☐ Process ☐ Software ☒ Data ☐ Methodology ☐ Business Model ☐ Policy Tool ☐ Other
Technology Readiness Level (Start → End)	Not applicable
Short Description	Experimental mechanical and thermal test results for VIP, RPUF, adhesives, and CFRP materials under room temperature, low-temperature (−196 °C), and cryogenic (−253 °C) conditions, derived from tests performed in

	accordance with agreed test standards, including hydrogen compatibility and material property testing.
Problem Addressed	Lack of validated mechanical and thermal material property data and test results required for the selection of suitable materials for liquefied hydrogen environments and for the validation of cargo containment system (CCS) designs.
Target Users / Customers	Industry, Research Community (University, Test laboratory, etc.)
Market/Application Sector	Hydrogen, Maritime, Automotive, Aerospace
Geographical Target Market	Global

KER #19	**Methodology/tool for sustainability assessment of CCS insulation panels**
Work Package / Task	WP2 / T2.3
Lead Beneficiary	UPAT
Other Contributing Partners	HYD, KSOE, UoS
Type of Result	☐ Technology ☒ Process ☐ Software ☐ Data ☒ Methodology ☐ Business Model ☐ Policy Tool ☒ Other
Technology Readiness Level (Start → End)	Not applicable
Short Description	Development and implementation through a digital tool of a framework for holistic sustainability assessment of the insulation panels of membrane type CCS, in terms of suitable insulation materials selection
Problem Addressed	Provides a practical methodology to select insulation materials for membrane type tanks with regards holistic sustainability, that did not exist
Target Users / Customers	Industry, SMEs, research community
Market/Application Sector	Energy, maritime, hydrogen.
Geographical Target Market	EU, Global

KER #20	**Methodology for Optimizing LH2 CCS: Balancing Performance, Thickness, and Productivity for BOR Minimization**
Work Package / Task	WP3 / T3.1, T3.5

Lead Beneficiary	KSOE
Other Contributing Partners	Not applicable
Type of Result	☐ Technology ☐ Process ☐ Software ☐ Data ☒ Methodology ☐ Business Model ☐ Policy Tool ☐ Other
Technology Readiness Level (Start → End)	1 → 4
Short Description	This methodology involves developing an cryogenic insulation system for storing liquefied hydrogen with a practically constructible thickness that satisfies specific thermal performance requirements. To achieve this, a hybrid insulation panel structure integrating polyurethane foam and vacuum insulation panels—both recognized for their excellent thermal properties—is implemented.
Problem Addressed	Providing a maritime LH2 CCS that meets economic and productivity criteria to facilitate large-scale ocean transportation of LH2
Target Users / Customers	Industry (Shipbuilding and Engineering)
Market/Application Sector	Energy, Maritime, Hydrogen, Aerospace
Geographical Target Market	Global

KER #21	LH2 CCS and HDMSS Review methodology by IACS Class
Work Package / Task	WP9
Lead Beneficiary	ABS
Other Contributing Partners	Not applicable
Type of Result	☐ Technology ☒ Process ☐ Software ☐ Data ☒ Methodology ☐ Business Model ☐ Policy Tool ☒ Other
Technology Readiness Level (Start → End)	Not applicable
Short Description	Engineers will gain more experience on the plan approval and AiP process related to CCS AND HDMSS which can be used further for better service delivery in the future. In addition, also the surveyors will gain expertise by witnessing the tests the construction of the model.
Problem Addressed	-
Target Users / Customers	Industry, SMEs, public authorities, research community, etc.

Market/Application Sector	Energy, maritime, CCUS, hydrogen, digital, etc.
Geographical Target Market	EU, Global, specific regions

KER #22	**Prototype AiP for LH2 as cargo membrane type CCS design**
Work Package / Task	WP9 / T9.1
Lead Beneficiary	ABS
Other Contributing Partners	KSOE
Type of Result	☐ Technology ☐ Process ☐ Software ☐ Data ☐ Methodology ☐ Business Model ☐ Policy Tool ☒ Other
Technology Readiness Level (Start → End)	1 → 5
Short Description	Concept approval for the developed LH2 CCS.
Problem Addressed	Securing a technically feasible LH2 CCS for ships.
Target Users / Customers	Industry (Shipbuilding)
Market/Application Sector	Maritime, Hydrogen
Geographical Target Market	Global

KER #23	**Concept AiP for LH2 as cargo HDMSS design**
Work Package / Task	WP9 / T9.2
Lead Beneficiary	ABS
Other Contributing Partners	HYD
Type of Result	☐ Technology ☐ Process ☐ Software ☐ Data ☐ Methodology ☐ Business Model ☐ Policy Tool ☒ Other
Technology Readiness Level (Start → End)	1 → 3
Short Description	Approval in Principle of the LH2 HDMSS concept

Problem Addressed	Securing a technically feasible LH2 HDMSS for future LH2 carriers
Target Users / Customers	Industry (Shipbuilding)
Market/Application Sector	Energy, maritime, hydrogen
Geographical Target Market	Global

KER #24	**Methodology development for assessing environmental and economical viability of the solutions (LCA, LCCA)**
Work Package / Task	WP10
Lead Beneficiary	TWI
Other Contributing Partners	UoS, HYD, NTUA, RINA
Type of Result	☐ Technology ☐ Process ☐ Software ☐ Data ☒ Methodology ☒ Business Model ☒ Policy Tool ☐ Other
Technology Readiness Level (Start → End)	Not applicable
Short Description	These tasks evaluate a Cargo Containment System (CCS) across its full life cycle from environmental, economic, and commercial perspectives. They include assessing environmental impacts (LCA), analyzing total costs over time (LCCA), and evaluating technical feasibility and financial performance (e.g., ROI, NPV). Together, they ensure the solution is sustainable, cost-effective, and scalable.
Problem Addressed	These tasks address key problems related to the deployment of CCS. They tackle the lack of clarity on environmental impacts by assessing emissions and sustainability over the full life cycle. They also address uncertainty in total costs by evaluating capital, operational, and end-of-life expenses. Additionally, they deal with challenges in scalability and real-world application by analyzing technical feasibility and financial viability. Overall, they help reduce risks in decision-making and ensure the CCS solution is sustainable, cost-effective, and commercially practical.
Target Users / Customers	Industry, SMEs, public authorities, research community, etc.
Market/Application Sector	Energy, maritime, CCUS, hydrogen, digital, etc.
Geographical Target Market	Global

KER #25	**Guidelines for circularity and treatment of the CCS materials and components**

Work Package / Task	WP2 / T2.3 , WP7 / T7.1
Lead Beneficiary	UPAT
Other Contributing Partners	KSOE
Type of Result	☐ Technology ☐ Process ☐ Software ☐ Data ☒ Methodology ☐ Business Model ☐ Policy Tool ☐ Other
Technology Readiness Level (Start → End)	Not applicable
Short Description	Comparative technical and numerical analyses of novel insulation materials to identify gaps and implementation potential within the maritime sector, together with guidelines for the handling, treatment, and management of CCS materials and components to optimize their circularity potential.
Problem Addressed	Lack of guidelines and specific recommendations for assessing, handling, recycling, and optimizing the circularity potential of cryogenic LH_2 cargo containment system (CCS) materials and maritime membrane tank components.
Target Users / Customers	Industry, SMEs, public authorities, research community
Market/Application Sector	Energy, maritime, hydrogen, aerospace, automotive
Geographical Target Market	Global

KER #26	**Knowledge Hub development**
Work Package / Task	WP11
Lead Beneficiary	UPAT
Other Contributing Partners	WEG, HYD, NTUA, RINA
Type of Result	☐ Technology ☐ Process ☐ Software ☐ Data ☐ Methodology ☐ Business Model ☐ Policy Tool ☒ Other
Technology Readiness Level (Start → End)	Not applicable
Short Description	Development of a knowledge transfer environment for the cross-sectoral experience exchange around hydrogen and towards the training of young engineers - researchers to hydrogen related technologies
Problem Addressed	Absence of cross-sectoral knowledge exchange around hydrogen
Target Users / Customers	Industry, SMEs, public authorities, research community

Market/Application Sector	Energy, maritime, hydrogen, aviation, space
Geographical Target Market	Global

KER #27	**Thermo-mechanical simulations towards a Digital Twin of the Testing Process**
Work Package / Task	WP11
Lead Beneficiary	UPAT
Other Contributing Partners	NTUA
Type of Result	☐ Technology ☐ Process ☐ Software ☐ Data ☐ Methodology ☐ Business Model ☐ Policy Tool ☒ Other
Technology Readiness Level (Start → End)	Not applicable
Short Description	Development of thermo-mechanical simulation models supporting the creation of a digital twin of the cryogenic testing process. The framework integrates thermal and structural behaviour to replicate test conditions, enabling predictive analysis, hybrid virtual - physical experimentation, and optimisation of testing parameters and prediction of specimen performance.
Problem Addressed	High cost, time consumption, and limited flexibility of physical cryogenic testing, along with insufficient predictive capability to anticipate thermo-mechanical behaviour and optimise test conditions prior to experimentation.
Target Users / Customers	Industry, SMEs, research community
Market/Application Sector	Energy, maritime, hydrogen, aviation, space, digital
Geographical Target Market	Global

3.2 EXPLOITATION PATHWAYS AND EXPECTED IMPACTS AND BENEFITS

The exploitation pathways of LH2CRAFT are defined at this stage as preliminary orientations derived from the KER portfolio. They are based on the information collected in the KER register, including the type of result, target users/customers, market or application sector, geographical target market, ownership status, background dependencies, protection strategy, FTO status and third-party IP risks.

Table 1: Indicative Exploitation Pathways for LH2CRAFT Results

Exploitation pathway	Relevant KERs	Expected benefit	Indicative exploitation routes
Industrial technology development and uptake	KER 1, 2, 3, 8, 20	Reduces uncertainty around the feasibility of large-scale LH_2 maritime transport by integrating CCS, HDMSS, vessel design, prototype validation and boil-off management.	Further engineering development, FEED studies, industrial demonstrators, ship-design studies, potential licensing or direct industrial use by technology owners.
Manufacturing, testing and validation services	KER 4, 5, 11, 12, 13, 14, 15, 16, 17, 18, 27	Supports transfer from concept design to practical manufacturing, material selection, testing, validation and qualification procedures.	Testing services, validation procedures, supplier qualification, engineering consultancy, further R&I, support to certification and scale-up.
Safety, class approval and regulatory uptake	KER 6, 7, 10, 21, 22, 23	Strengthens the evidence base for safe LH_2 transport, class review, Approval in Principle and future regulatory feedback.	Class approval services, safety assessment consultancy, training, regulatory input, contribution to future rules, standards and recommended practices.
Sustainability, economic assessment and circularity	KER 19, 24, 25	Enables environmental, economic and circularity assessment of LH_2 carrier solutions and supports comparison with alternative hydrogen transport options.	LCA/LCCA studies, sustainability consultancy, decision-support tools, policy input, future project use, integration into design optimisation.
Knowledge transfer, replication and future R&I	KER 9, 26	Enables reuse of project knowledge for alternative ship/system designs, stakeholder engagement, training and cross-sectoral replication.	Knowledge Hub, training material, scientific dissemination, stakeholder engagement, follow-up R&I projects, cross-sectoral knowledge transfer.

For the core technological KERs, particularly the CCS, HDMSS, prototype, carrier design and boil-off management results, exploitation is expected to focus first on further technical maturation, validation and industrial positioning. These results may support future engineering studies, approval processes, pilot applications and, where appropriate, licensing or direct industrial use. Their exploitation potential will depend on the final technical performance, ownership arrangements, protection strategy and class/regulatory acceptance.

For manufacturing, testing and materials-related KERs, exploitation is expected to be service- and know-how-oriented. These results can support future testing campaigns, material qualification, supplier engagement, validation methodologies and engineering consultancy. Some outputs may remain as

confidential know-how, while others may be disseminated in aggregated or non-sensitive form to support wider uptake.

For safety, regulatory and class-related KERs, exploitation is expected to take the form of regulatory uptake, class services, safety assessment methodologies, training and contributions to future rules or recommended practices. These KERs may not always correspond to conventional commercial products, but they are highly relevant for market adoption because LH_2 maritime transport depends on confidence from classification societies, regulators, shipowners and port authorities.

For sustainability, LCA/LCCA and circularity-related KERs, exploitation is expected through decision-support activities, policy input, sustainability assessment services and integration into future design optimisation. These outputs can help stakeholders compare LH_2 transport solutions, understand lifecycle impacts and assess the economic implications of different design choices.

Finally, the Knowledge Hub and alternative design methodology support the longer-term replication of LH2CRAFT results beyond the immediate consortium. They provide channels for knowledge transfer, training, stakeholder engagement and future research activities, while ensuring that only cleared and non-confidential information is made publicly accessible.

The final version of this Plan will further refine these pathways for the most mature KERs. In particular, it will clarify, where relevant, the responsible owner(s), protection status, access-rights conditions, FTO position, dissemination constraints, potential users and concrete post-project actions.

3.3 SYNERGIES WITH DISSEMINATION AND COMMUNICATION

Dissemination and communication activities under WP11 should directly support KER exploitation while respecting confidentiality, ownership, background dependencies and IP protection requirements.

Table 2. Dissemination and Communication Activities in Relation to LH2CRAFT KERs Indicative Exploitation Pathways for LH2CRAFT Results

KER cluster	Relevant KERs	Suitable dissemination / communication routes	Objective	IPR/confidentiality control
Industrial technology development and uptake	KER 1, 2, 3, 8, 20	Targeted stakeholder briefings, technical workshops, non-confidential conference presentations, class/regulatory exchanges	Build market awareness, collect user feedback, support early adoption discussions	Do not disclose detailed design drawings, proprietary calculations, background know-how or patentable features before clearance.
Manufacturing, testing and validation services	KER 4, 5, 11, 12, 13, 14, 15, 16, 17, 18, 27	Demonstrator updates, technical papers, testing summaries, controlled visits, supplier-oriented workshops, simulation models	Demonstrate credibility, attract industrial interest, support validation and scale-up	Release only aggregated or non-sensitive results unless partners approve disclosure.
Safety, class approval and regulatory uptake	KER 6, 7, 10, 21, 22, 23	Safety guidelines, training material, policy briefs, class/standardisation exchanges, targeted regulatory workshops	Support safety culture, class acceptance and future regulatory uptake	Avoid public disclosure of security-sensitive failure scenarios, vulnerabilities or confidential review comments.
Sustainability, economic assessment and circularity	KER 19, 24, 25	Sustainability factsheets, LCA/LCCA methodology summaries, webinars, policy-oriented communication	Support evidence-based adoption and comparison of LH_2 transport options	Protect proprietary cost assumptions, confidential datasets and partner-sensitive modelling inputs.
Knowledge transfer, replication and future R&I	KER 9, 26	Knowledge Hub, public deliverables, newsletters, stakeholder community updates, training resources	Enable replication, long-term access to public knowledge and post-project visibility	Publish only cleared outputs; separate public material from restricted partner-only knowledge.

The Knowledge Hub's role will be to host or signpost cleared public outputs, organise the project's exploitable knowledge by KER cluster and provide a post-project access point for stakeholders interested in LH_2 cargo containment, HDMSS, safety, sustainability and regulatory outcomes. Stakeholder feedback from workshops, conferences, interviews, class discussions and Knowledge Hub interactions will be used to refine the KERs. In this way, communication activities become a source of exploitation intelligence rather than a separate visibility exercise.

Before any public release, WP11 will apply a simple clearance workflow:

1. Identify the KER(s) concerned.
2. Check whether the relevant KER sheet has completed ownership, background and protection fields.
3. Obtain approval from the KER owner or lead beneficiary.
4. Confirm that publication will not compromise patentability, trade secrets, confidential background, FTO assessment or class/regulatory review.
5. Record the dissemination action and follow-up exploitation relevance in the project tracker.

This approach keeps WP11 communication aligned with the Exploitation & IP Rights Management Plan and ensures that visibility, stakeholder engagement and Knowledge Hub activities actively support exploitation while protecting the consortium's foreground and background IP.

4 MARKET ANALYSIS AND BUSINESS MODELS

4.1 TARGET SECTORS AND STAKEHOLDERS

The exploitation of LH2CRAFT results is intrinsically linked to the emergence of a global liquid hydrogen market, which will build on, rather than simply replicate, today's liquefied natural gas (LNG) trade patterns and infrastructures. In this context, LH2CRAFT targets a set of clearly defined sectors and stakeholder groups along the full LH_2 shipping value chain: from technology development and ship design to infrastructure deployment, regulation and end-use.

Shipbuilders, ship designers and marine engineering companies

This group represents a primary market for the core LH2CRAFT technologies: modular membrane-type CCS designs, insulation systems, CCS manufacturing and erection methods, integration into hull structures and overall LH_2 carrier design.

For these actors, LH2CRAFT delivers:

- Engineering concepts and detailed design know-how for LH_2-compatible membrane containment systems and their integration into newbuild hulls and (where feasible) retrofitted LNG carriers.
- Validated design tools and digital workflows (e.g. modelling, multi-scale testing results, techno-economic and LCA inputs) that de-risk design choices and reduce time-to-market for new LH_2 carrier classes.
- Manufacturing and erection procedures that can be embedded into existing shipyard processes and supply chains, leveraging LNG experience while addressing LH_2-specific challenges (−253°C, hydrogen embrittlement, higher insulation demands).

These companies are expected to be among the first adopters of LH2CRAFT results, using them to differentiate their offering in a nascent LH_2 carrier market.

Shipowners, operators and ship management companies

Shipowners and operators are the ultimate customers for LH_2 carriers and will base investment decisions on safety, reliability, CAPEX/OPEX and regulatory certainty. LH2CRAFT addresses their needs through:

- Demonstrated CCS performance and safety, supported by prototype testing, risk assessments and class involvement (WPs 7–9).
- Techno-commercial assessments, LCCA and KPI-based evaluations that quantify transport costs, boil-off losses, payback periods and competitiveness versus alternative hydrogen carriers or pipeline options (WP10 outputs D10.1–D10.4).
- Operational guidelines and safety assessment procedures that can be translated into company Health, Safety, Security and Environment (HSSE) and maintenance practices.

This stakeholder group is central for post-project deployment, including first-of-a-kind LH_2 carrier orders, chartering strategies and integration of LH_2 transport into broader hydrogen supply portfolios.

Hydrogen producers, energy majors and traders

Large hydrogen producers, integrated energy companies and commodity traders will play a pivotal role in triggering demand for LH_2 shipping between exporting regions (e.g. Middle East, Australia, Latin America) and major demand centres in Europe and East Asia.

For these actors, LH2CRAFT provides:

- A credible technical option for large-scale LH_2 marine transport, enabling bankable export–import chains rather than small pilot volumes.
- Evidence on logistics performance and losses (e.g. liquefaction energy needs, boil-off behaviour, containment efficiency), feeding into levelised cost of hydrogen (LCOH) and supply chain optimisation studies.
- A basis for long-term offtake and shipping contracts, supported by clear technology maturity (TRL 5–6) and an approval roadmap with class societies.

These stakeholders are key not only as users but also as potential co-investors in CCS deployment, LH_2 terminals and first commercial routes.

Port authorities, terminal developers and logistics/bunkering operators

Liquid hydrogen trade will require new or repurposed export and import terminals, onshore storage tanks, liquefaction and (where relevant) regasification plants, as well as bunkering facilities.

LH2CRAFT results are relevant to:

- Port authorities and terminal developers, who need robust CCS, HDMSS and safety concepts to plan LH_2 jetties, storage parks and interface with carriers.
- Logistics and bunkering operators, who can reuse LH2CRAFT HDMSS concepts, operational guidelines and safety assessment methods to design ship-to-ship and ship-to-shore transfer systems.

By engaging these stakeholders through the External Stakeholders Committee and the Knowledge Hub (D11.3 and D11.4), LH2CRAFT can accelerate alignment between ship design, terminal specifications and operational procedures.

Classification societies, flag administrations and regulatory bodies

Three major classification societies are partners in LH2CRAFT and act both as end-users of safety and risk assessment tools and as enablers of regulatory uptake.

Target users in this group include:

- Class societies (RINA, BV, ABS and peers), who can use LH2CRAFT models, tests and guidelines to develop rules, notations and approval procedures for LH_2 CCS and HDMSS.
- Flag and port state administrations and IMO/ISO working groups, which can draw on project evidence to refine interim recommendations and move towards formal regulations for LH_2 carriage and bunkering.

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For these stakeholders, LH2CRAFT is a source of validated data, methodologies and use cases that de-risk the creation of new standards and help ensure consistency with the broader ZEWT and EU hydrogen policy framework.

Technology providers, equipment manufacturers and materials suppliers

A wide range of specialised technology providers will benefit from LH2CRAFT outcomes, including:

- Manufacturers of cryogenic tanks, membranes, insulation materials and structural components seeking to adapt their LNG portfolios to LH_2 conditions and qualify new materials and designs.
- Vendors of valves, pumps, compressors, sensors and control systems for CCS and HDMSS, who require validated boundary conditions, duty cycles and safety requirements to design and certify their products.
- Engineering consultancies and testing laboratories, which can exploit LH2CRAFT methodologies, KPIs and QFD-based assessment frameworks in future projects and services.

For these companies, LH2CRAFT provides both reference designs and a clearer view of future performance and certification expectations.

Research organisations, universities and knowledge networks

Research and technology organisations and universities are both partners and long-term users of LH2CRAFT results. They will exploit:

- Experimental datasets, numerical models, safety analysis tools and KPIs to support further R&I projects, PhD work and training programmes on LH_2 technologies, cryogenic materials and hydrogen safety.
- The LH2CRAFT Knowledge Hub as a platform for sharing results with other European initiatives and transferring knowledge across sectors (e.g. from maritime to aerospace or road transport).

This group ensures continuity of innovation beyond the project and helps maintain Europe's scientific leadership in hydrogen logistics.

End-use industrial sectors and energy-intensive clusters

Although not direct users of the CCS or HDMSS, energy-intensive industries (steel, chemicals, refining), mobility sectors (aviation, heavy road transport, other shipping) and large energy consumers are indirect stakeholders: their future hydrogen demand will ultimately drive LH_2 trade volumes and, hence, the market for LH2CRAFT solutions.

Engagement with these actors through the Stakeholders Committee, workshops and interviews foreseen in WP10 and WP11 will help align the project's exploitation roadmap with real demand trajectories and infrastructure planning at industrial clusters and ports.

4.2 MARKET TRENDS IN LIQUID HYDROGEN TRANSPORT AND CONTAINMENT

The market for liquid hydrogen transport and containment is still in its infancy but is evolving quickly as countries and companies start planning large-scale hydrogen imports and exports. Projections used in LH2CRAFT show that internationally traded hydrogen could reach several tens of million tonnes per year

by 2050, with LH_2 expected to capture a meaningful share on long, intercontinental routes where pipelines are not feasible. Export regions with abundant, low-cost renewables (e.g., Australia, Chile, parts of the Middle East and North Africa) are expected to ship hydrogen to structurally import-dependent regions, notably Europe and Northeast Asia, creating demand for a new generation of LH_2 carriers and terminal infrastructure.

Within this emerging trade, the reference case adopted in D2.1 "Analysis of H2 Trade and Demonstration Requirements" is a 160,000 m^3 LH_2 carrier, operating on routes such as Middle East–Europe, Middle East–Far East, Australia–Far East, Chile–Europe and Australia–Singapore, typically at around 20 knots and up to 20–24 round trips per year for the shorter distances. These operating profiles highlight the importance of long-distance endurance, compatibility with canal constraints and high annual utilisation to make LH_2 shipping competitive. At the same time, they underline how sensitive the economics are to boil-off rates and cargo losses over voyages lasting 10–20 days or more.

On the infrastructure side, today's LH_2 chain largely reflects aerospace and niche industrial use: small liquefaction plants, a handful of large spherical tanks (e.g., the NASA tanks of 3,200–4,732 m^3) and a single pilot-scale LH_2 carrier such as the Suiso Frontier. The trend, however, clearly points towards much larger liquefaction plants and onshore tanks (concepts up to 40,000–50,000 m^3), so that economies of scale can reduce the very high energy consumption and CAPEX of liquefaction and storage. Commercial LH_2 projects will therefore require carriers and terminal tanks that can be scaled up significantly beyond the current state of the art, while still delivering acceptable losses and safety performance.

In this context, LNG offers both a template and a warning. LNG and LH_2 supply chains share the same basic architecture, i.e., liquefaction, storage, shipping, regasification, but LH_2 is more challenging: its boiling point is at −252.9 °C instead of −161.5 °C and it has a much lower volumetric energy density. LNG shipping experience nevertheless points to clear market preferences. Over the last decades, membrane-type cargo containment systems have come to dominate LNG, with more than 80% of new LNG carriers using membrane tanks because of their superior volumetric efficiency and reduced boil-off rates.

At the same time, attempts to directly repurpose LNG infrastructure for LH_2 face non-trivial technical and economic barriers. Importantly, while some elements of LNG terminals (foundations, jetties, parts of control and power systems) might be reused, key components such as storage tanks, piping and insulation require major redesign because of hydrogen embrittlement, much higher insulation demands (two to three times LNG thickness in some concepts) and permeation issues. Complete conversion of existing LNG terminals to LH_2 is therefore only partially feasible, which is pushing the market towards "LH_2-ready" concepts for new terminals and carriers rather than full retrofit of existing assets.

From a containment perspective, several structural trends are visible. First, there is a clear push to maximise ship size and transported volumes in order to drive down specific transport costs: conceptual LH_2 carriers around 160,000 m^3, with four membrane tanks of about 40,000 m^3 each, are already under development and have received Approval in Principle from leading classification societies. However, because of LH_2's low density, such ships carry only on the order of 11,000–12,000 tonnes of hydrogen, resulting in relatively low deadweight and specific stability and structural challenges that must be reflected in CCS design, integration and sloshing behaviour.

LH2CRAFT sets an ambitious target boil-off rate of 0.2% per day for its membrane CCS, recognising that any competitive LH_2 solution must reduce energy and volume losses substantially compared with legacy systems. This in turn favours innovative insulation concepts, multi-layer barriers, careful management of

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thermal bridges and, where possible, the use of boil-off gas as fuel rather than re-liquefying it, to avoid the additional CAPEX and OPEX of on-board reliquefaction plants.

Third, CAPEX pressure on tanks is very high, especially for smaller ships where specific costs can be an order of magnitude higher than for large vessels. Tank construction is one of the largest cost items in LH_2 carriers, driving a search for modular, standardised containment concepts that can be manufactured in series, adapted to different hull shapes and sizes, and integrated efficiently into shipyards' existing production lines. LH2CRAFT's core technologies—design of the insulation system, modular and adaptable CCS design, CCS integration and manufacturing technologies—are explicitly positioned as responses to these market drivers.

The LH_2 market is also shaped by competition with alternative hydrogen carriers, notably ammonia and liquid organic hydrogen carriers (LOHCs). LH_2 can be more energy-efficient than derivatives because it avoids additional conversion and reconversion steps; however, ammonia and other carriers benefit from higher current technological maturity and existing infrastructure. As a result, LH_2 shipping is likely to focus on use cases where direct hydrogen use, purity requirements and very low lifecycle emissions justify the more complex cryogenic chain, while derivatives capture other segments of the international trade. This competitive landscape reinforces the need for high-performance, low-loss containment systems to make LH_2 a credible option in techno-economic comparisons.

Finally, regulatory and standardisation dynamics are themselves a major market trend. Complete and coherent rules, standards and guidelines for LH_2 marine transport do not yet exist, and classification societies are only beginning to develop frameworks for lifecycle safety and efficiency assessment of zero-emission fuels. Experience from LNG shows that once containment concepts are codified into rules and class notations, they can shape technology choices for decades. LH2CRAFT's combination of CCS development, safety and risk assessment, and environmental/techno-economic evaluation is therefore not only a technical response to market needs but also a contribution to the future regulatory "reference framework" for LH_2 shipping. By providing validated designs, test data and safety cases to International Association of Classification Societies (IACS) members and other regulators, the project positions its solutions at the centre of the standards that will govern—and ultimately structure—the emerging LH_2 transport and containment market.

4.3 VALUE CHAIN AND COMPETITIVE POSITIONING

The liquid hydrogen (LH_2) shipping value chain stretches from hydrogen production and liquefaction, through export terminals and marine transport, to import terminals and final end-use in industry, power and mobility. LH2CRAFT does not address every element of this chain; instead, it is positioned around the core maritime transport segment, the shipborne containment and handling of LH_2, while interfacing closely with upstream and downstream infrastructure requirements.

At the upstream end, hydrogen is produced (ideally from renewable electricity - green hydrogen), purified and liquefied in large, centralised plants. These facilities feed export terminals that require large LH_2 storage tanks, loading arms, safety systems and integration with carriers. LH2CRAFT does not develop liquefaction technology, but its specifications for tank size, allowable boil-off rates and operating envelopes feed directly into the sizing and design of liquefaction and storage assets, reinforcing the project's role as a technology "anchor" for terminal developers and energy majors planning long-distance LH_2 trade.

The central segment of the value chain is the marine transport of large LH_2 cargoes. Here, LH2CRAFT's core technologies sit at the heart of the ship system:

- the insulation system design,
- the modular and adaptable membrane-type CCS,
- the integration technology between CCS and hull,
- the manufacturing and erection technology and
- the overall LH_2 carrier design process.

These technologies collectively provide a "one-stop" containment solution that spans from concept and detailed design to prototype validation and approval in principle, raising the maturity of LH_2 marine transport solutions from today's TRL 2–3 state of the art to TRL 5. This is complemented by HDMSS designs, safety and risk assessment methods, and LCA/techno-economic tools, which together allow shipyards, shipowners and class societies to evaluate not only technical feasibility but also lifecycle performance and cost.

At the downstream end of the chain, LH2CRAFT results interface with import terminals, bunkering activities and end users. Scalable, modular CCS concepts and associated safety frameworks inform the design of onshore tanks and transfer systems, and the boil-off characteristics and operating envelopes defined in LH2CRAFT feed into value chain optimisation and LCOH assessments for industrial clusters and power producers.

Within this value chain, LH2CRAFT competes and collaborates with several categories of solutions and projects. On the technology side, the current baseline for large LH_2 storage is dominated by pressurised Type-C and independent tanks, such as NASA's large spherical tanks and the Suiso Frontier's 1,250 m^3 shipboard tank; these solutions are technically proven but difficult to scale to LNG-like capacities at acceptable cost. In LNG, by contrast, membrane containment systems have captured over 80% of the carrier fleet because of their superior volumetric efficiency and lower boil-off, and the LH2CRAFT concept explicitly seeks to transfer this membrane paradigm to LH_2, with appropriate redesign of barriers, insulation and integration to cope with −253 °C and hydrogen embrittlement.

On the project and R&I landscape, several initiatives focus on hydrogen maritime applications, including Task-39 of the IEA Hydrogen TCP, sHYpS, and other projects targeting fuel cell vessels, hydrogen containers or green LH_2 supply chains. Many of these efforts address parts of the value chain (fuel system safety, bunkering concepts, derivative fuels like ammonia in NH3CRAFT project (GA No. 101056831) rather than delivering an integrated large-scale LH_2 cargo containment system with prototype demonstration and multi-class involvement. LH2CRAFT is therefore positioned as a complementary but distinct initiative, focusing on the high-impact bottleneck of large-scale shipborne LH_2 storage, while actively building synergies and knowledge transfer links to neighbouring projects through its External Advisory Board and ZEWT-related activities.

In competitive terms, LH2CRAFT's proposition can be summarised along three dimensions:

- Integrated "one-stop" solution: Rather than offering a standalone tank concept, LH2CRAFT combines CCS design, HDMSS, integration, safety, LCA and techno-economics into a coherent package, as a one-stop solution that is more reliable, more efficient and safer than fragmented approaches.
- Strong positioning in the industrial value chain: The presence of KSOE (global No.1 shipbuilder), three IACS classification societies (ABS, BV, RINA), leading universities and research and technology

organizations gives LH2CRAFT a direct route from R&I to industrialisation, rule-making and training, strengthening its position vis-à-vis competing concepts developed outside Europe or in isolated industrial projects.

- Alignment with EU policy and market needs: By targeting scalable, modular membrane CCS with low boil-off rates, clear approval pathways and decision-support tools, LH2CRAFT is tightly aligned with EU Green Deal, REPowerEU and ZEWT objectives, and with the identified market need for adaptable, scalable LH_2 storage solutions that can be fitted to new and potentially existing vessels.

Overall, LH2CRAFT is positioned in the LH_2 shipping value chain as a reference technology and knowledge provider for the central maritime transport segment, with strong upstream and downstream interfaces. Its competitive advantage stems from combining a next-generation membrane CCS concept with industrial partners, multi-class approval and comprehensive safety and techno-economic assessment, in a landscape where alternative LH_2 and derivative-fuel solutions are still fragmented and at lower TRLs.

4.4 BUSINESS MODELS AND GO-TO-MARKET SCENARIOS

The business perspective of LH2CRAFT builds on the idea that the project does not deliver a single product, but a portfolio of exploitable results around a next-generation membrane-type CCS, its associated HDMSS auxiliaries, and a set of safety, LCA/LCCA and techno-economic tools. Together, these elements allow partners to position themselves in the emerging LH_2 shipping market as providers of high-value engineering solutions, design packages, certification services and decision-support tools, rather than as commodity suppliers.

For the core technological KERs (CCS and HDMSS), the dominant business logic is a combination of design/licensing and high-end engineering services. The Exploitation & IP Rights Management Plan foresees that key design elements (membrane architecture, insulation arrangements, integration details) will be protected where appropriate through patents or confidential know-how, opening the door to non-exclusive licences for shipyards, containment manufacturers and system integrators. In practice, this translates into design packages and related IP that can be licensed on fair and reasonable terms, complemented by engineering contracts for adapting the generic CCS and HDMSS concepts to specific hulls, routes and operational profiles, and for supporting Approval in Principle and later type-approval stages with class societies. The Plan encourages such a mix of patenting, licence selling, consulting, training, creation of course material and direct industrial use of the CCS by shipbuilding partners.

Around these core technologies, several service-oriented business models emerge. Safety and regulatory deliverables (risk assessments, safety case methodologies, class-aligned guidelines) can be embedded into approval, audit and training services offered by the participating classification societies and specialist partners, who will capitalise on their early familiarity with LH2CRAFT concepts to develop new rules, notations and recommended practices for LH_2 carriers and terminals. Similarly, the LCA, LCCA, KPI based evaluation and techno-commercial assessment tools developed in WP10 underpin consultancy offerings aimed at shipowners, energy majors, ports and policy makers, supporting decisions on fleet composition, infrastructure investments and policy design through robust, project-tested models rather than ad-hoc analyses. The QFD-based KPIs and evaluation framework established in WP2 provide an additional layer by enabling structured co-design workshops and option-screening exercises with customers, which can themselves be framed as paid services or embedded into larger engineering assignments.

Because the LH_2 shipping market is only just emerging and the CCS/HDMSS are expected to reach TRL 5 by the end of the project, the go-to-market approach is necessarily phased. In the short term (during the project and the first years after completion), exploitation is expected to be dominated by reference projects, FEED studies and further R&I. Consortium partners will use LH2CRAFT results in follow-up EU and national projects on LH_2 carriers and terminals, in conceptual and feasibility studies for early LH_2 routes, and in the preparation of AiP and general approval dossiers with class. Revenue in this phase primarily comes from consulting, joint development agreements and early licensing negotiations, while tools such as the KER register are used internally to steer which results are pushed first and by whom.

In a medium-term horizon, once class approvals are in place and techno-economic assessments confirm competitiveness, the focus shifts towards first-of-a-kind commercial projects: demonstration or early commercial LH_2 carriers and associated terminal systems. In this scenario, LH2CRAFT outputs underpin turnkey design and licensing deals for the CCS with major shipyards and containment manufacturers, ideally bundled with HDMSS and safety frameworks into an integrated “cargo system package” for shipowners and energy companies. Business models here combine upfront licence fees linked to the number or volume of installed tanks, project-based engineering contracts for integration and verification, and possibly performance-linked elements related to achieved boil-off rates or capacity. Parallel to this, LCA/LCCA and KPI-based tools are used in final investment decision support studies, anchoring them as standard instruments in LH_2 shipping project development.

Looking further ahead, if LH_2 trade develops along the trajectories outlined in D2.1 and the CCS becomes a recognised solution, business models gradually pivot towards scale-up and standardisation. In such a mature market, the CCS could appear as a catalogue option in shipyard portfolios, with streamlined licensing and integration procedures; HDMSS concepts and safety frameworks would be reflected in class rules, ZEWT-aligned standards and possibly IMO/IGC-related guidelines, thereby generating stable demand for approval, auditing and training activities. LCA and KPI tools evolve into long-term optimisation and fleet-management services, offered under recurring contracts rather than one-off studies. Revenues in this phase are less dependent on bespoke engineering and more on recurring licence income, software maintenance, training and certification programmes, but they rest directly on the foundations laid by the early exploitation work captured in this Plan.

Across all these scenarios, the exploitation and go-to-market strategy remains embedded in the governance and tools defined under WP11. A mechanism is provided to continuously refine business models, resolve ownership issues and detect opportunities for joint exploitation as the project advances and as external market and regulatory conditions evolve. This iterative, portfolio-based approach ensures that LH2CRAFT results can move from research outputs to market-relevant offerings in a controlled way, while keeping enough flexibility to adapt to the actual pace at which the LH_2 shipping market materialises.

5 IPR MANAGEMENT STRATEGY

5.1 LEGAL FRAMEWORK

The IPR management strategy of LH2CRAFT is grounded in a clear legal hierarchy. At the top sits the Grant Agreement (No. 101111972) with the CHJU. This is complemented by the project's CA, which further specifies and operationalises rights and obligations among beneficiaries, and by the Exploitation & IP Rights Management Plan (this document), which translates these legal provisions into concrete procedures and tools for day-to-day project management.

Grant Agreement

Article 16 of the GA provides the core legal framework for ownership and protection of results generated in LH2CRAFT. Results are owned by the beneficiary or beneficiaries that generate them. Where several partners jointly generate a result and their respective contributions cannot be separated, the result is jointly owned. In such cases, the GA requires the joint owners to agree on arrangements for exercising their rights, including terms for protection, exploitation, licensing and revenue sharing, failing which the default joint ownership regime of the GA applies.

Article 16 further establishes the framework governing access rights, exploitation and protection of results that may reasonably be expected to have commercial or industrial application, taking into account the partners' legitimate interests and the prospects for exploitation. Beneficiaries must therefore decide, within a reasonable period, whether to seek appropriate protection (e.g. patents, utility models, design rights, copyright, trade secrets) and must ensure that dissemination activities are coordinated with protection measures so as not to compromise novelty, confidentiality or commercial value. The GA also sets out obligations concerning exploitation of results, transfer and licensing arrangements, and safeguards relating to transfers of IP or exclusive rights to entities established in non-associated countries where EU strategic interests may be affected.

The IPR strategy also relies on other interlinked GA provisions, notably those on exploitation and dissemination of results, access rights, data management and ethics. As such, LH2CRAFT is required to develop an Exploitation and Business Plan, to report on exploitation efforts throughout and after the project, and to ensure that communication and dissemination activities are compatible with IP protection and confidentiality obligations. These obligations are explicitly reflected in WP11, where Task 11.1 foresees an IPR management plan covering background, relevant IP assets, and procedures for defining IP origination, protection, exploitation and access rights for project participants. In practical terms, this means that:

- ownership of results always follows the GA rules and cannot be overridden by internal arrangements;
- decisions on whether and how to protect results must be taken in a timely manner and recorded, with clear responsibilities;
- dissemination (including publications, conference presentations and public deliverables) is systematically checked against ongoing or planned IP protection to avoid prejudicing novelty;

- exploitation and access-rights arrangements must remain compatible with the minimum rights for the JU and with EU interests, including safeguards for transfers of IP to non-associated countries.

Role of the Consortium Agreement

The Consortium Agreement supplements the GA by tailoring IPR and exploitation provisions to the specific needs and business models of the LH2CRAFT partners, within the limits set by EU rules. While the GA defines the framework, the CA clarifies practical aspects such as the detailed identification of background, internal access-rights regimes, joint ownership arrangements, licensing principles, and procedures for conflict resolution.

In particular, the CA and the project description foresee that access to the core technologies will rely on a mix of partners' own IP, licensing and acquisition of IP, with new IP owned by the originating partner and specific rights granted to others on fair and reasonable terms. For jointly owned results, the baseline principle is that each joint owner is entitled to use the joint foreground as it sees fit, and to grant non-exclusive licences to third parties (without sub-licensing rights), subject to prior notice to the other joint owners and fair and reasonable compensation where applicable.

The CA also introduces tailored provisions for software tools and models developed in LH2CRAFT. Partners may request access to the latest versions of such tools for internal evaluation purposes, free of charge, for a defined period (e.g. up to five years after project completion). This regime supports internal exploitation, follow-up R&I projects and continued collaboration, while preserving the possibility for commercial licensing or service-based exploitation of more mature software assets.

Furthermore, the CA operationalises:

- the formal identification of background (pre-existing IP and know-how) that each partner makes available to the project, together with any limitations or conditions;
- the granting of access rights to background and results needed for the implementation of the project and for exploitation, under royalty-free or fair-and-reasonable terms as appropriate;
- the procedures for handling invention disclosure, decision-making on protection (e.g. who files, who bears cost, cost-sharing rules), and representation of joint owners vis-à-vis patent offices or third parties;
- internal rules on confidentiality, including the handling of sensitive technical and commercial information, and the alignment with the Data Management Plan and JU reporting obligations.

Integration into the LH2CRAFT IPR management strategy

The Exploitation & IP Rights Management Plan builds directly on this legal framework. The tools and processes described in Section 3 are designed to ensure that ownership and protection decisions are taken in compliance with Article 16 of the GA, and that they respect the detailed arrangements set out in the CA.

Concretely, whenever a new result is identified as a potential KER, the responsible partners must:

- verify its ownership status and any background dependencies under the CA;
- assess whether the result has commercial or industrial potential warranting protection under the GA;

- decide on an appropriate protection strategy;
- ensure that any planned dissemination is consistent with this strategy and with confidentiality obligations.

By anchoring these operational steps in the combined framework of the GA and the CA, LH2CRAFT ensures that all IPR-related decisions are legally robust, transparent for all partners, and aligned with the long-term exploitation ambitions of the project.

5.2 BACKGROUND IDENTIFICATION AND ACCESS RIGHTS

Effective IPR management in LH2CRAFT relies on a clear and shared understanding of what constitutes "background" and on transparent rules for granting access to that background for both implementation and exploitation purposes. In line with the GA and the CA, background is understood as any data, knowledge or information – including patents, design rights, copyrights, software, databases and confidential know-how – which is held by a beneficiary prior to joining LH2CRAFT (or acquired independently of it), is needed to carry out the action or to exploit its results, and has been explicitly identified as such in the project documentation. Typical background in LH2CRAFT includes existing membrane containment concepts and design rules, proprietary materials data and simulation models, safety and risk-assessment platforms, and pre-existing guidelines and rules developed by classification societies for cryogenic containment and alternative fuels. Only assets that partners have explicitly listed, including any conditions or limitations, are treated as background for the purposes of access rights; partners remain free to withhold IP that is not needed for the project.

Background identification is carried out as a structured, iterative process rather than a one-off exercise. For each KER, partners identify whether background is used and, where applicable, who owns it and under what access-rights conditions it may be used. This is done using the KER register to capture the nature of each asset, the owner, any third-party rights and specific access conditions or field-of-use limitations. As KERs are identified and described in the KER Register, the responsible partners indicate which background items are required to use or further develop each KER, thereby making dependencies explicit and linking background directly to the exploitation planning. The register is updated when new background becomes relevant (for example, newly granted patents or updated software versions), provided that such changes do not undermine commitments already made for project implementation.

Access rights to background for implementation of LH2CRAFT follow the Horizon Europe principles, as detailed in the CA. Partners must grant one another the rights needed to perform their tasks under the Description of Action, but only to the extent that the specific background is objectively necessary for those tasks. Requests should be made in writing and in good time so as not to delay the work. As a general rule, and unless otherwise specified in the CA or the KER Register, access for implementation is granted on a royalty-free basis, with "fair and reasonable" financial conditions only envisaged in justified cases (for example, for high-value proprietary software), and always in a way that does not jeopardise project execution. Access is provided under confidentiality obligations and does not entail any transfer of ownership; beneficiaries may use each other's background strictly for the implementation of LH2CRAFT, unless separate agreements extend that use. For software tools, the GA provisions on post-project access are mirrored: partners may request access to the latest versions of relevant models and software, free of charge and for evaluation purposes, for a defined period after project completion (typically five years), which supports follow-up collaboration and benchmarking without immediate commercial licensing.

Beyond implementation, partners may also need access to background owned by others in order to exploit their own results, for instance when a KER builds on proprietary design tools, materials databases or safety models. Here, the project applies the “need-to-use” principle: access is granted only where the requesting partner can demonstrate that the background is technically necessary for exploitation of its results. Conditions are negotiated on a case-by-case basis under fair and reasonable terms, taking into account the nature and value of the background, its contribution to the envisaged exploitation activity (e.g. licensing of CCS design packages, consulting services based on safety software) and the commercial potential of the target application. Background remains the property of the originating partner, and background made available for project purposes will only be open to commercial exploitation by others if the parties involved agree accordingly. Access rights for exploitation can typically be requested up to a defined period after project end (for example, one year, as specified in the CA), with longer periods foreseen in some cases for software evaluation.

The project also recognises that certain background items may be constrained by third-party rights, export-control rules or competition-law considerations. In such cases, the owning partner must clearly flag any restrictions, describe the limitations on access (for example, geographic scope, user categories or security requirements) and ensure that LH2CRAFT does not create obligations that would conflict with pre-existing commitments. Transfers of background or related access rights to entities in non-associated third countries are handled in line with safeguards on protection of EU interests (following the provisions of the GA), which is particularly relevant for globally active shipbuilding, classification and energy partners.

Finally, background identification and access rights are operationally linked to KER management. For each KER, the KER register records the required background, its owner(s), the agreed access conditions for implementation and exploitation, and any sensitivities such as joint ownership or export control. This integrated approach allows potential IP bottlenecks to be detected early, gives partners a clear view of how they can use each other’s pre-existing assets, and creates a sound basis for the later commercialisation of CCS, HDMSS and related tools.

5.3 OWNERSHIP AND PROTECTION OF RESULTS

Ownership and protection of results (“foreground”) in LH2CRAFT follow the principles of the GA and the CA and are further specified in this Plan. In line with Article 16 of the GA, all results produced in the project are owned by the beneficiary or beneficiaries that generate them; the granting authority does not obtain ownership but only certain rights of use for policy and dissemination purposes. Where several beneficiaries jointly generate a result and their respective contributions cannot be separated, or the result cannot be protected or exploited separately, joint ownership arises and must be governed by a written joint ownership agreement, either through the CA or through KER-specific arrangements.

For LH2CRAFT, this general framework is interpreted as follows. Results include all tangible and intangible outputs of the project, such as designs and engineering documentation for the CCS and HDMSS, experimental data, models and software, safety methodologies, LCA/LCCA tools, training material, and regulatory guidelines, together with any intellectual property rights attached to them. Each result is linked to the work package and task where it arises and to the partners involved, and its ownership status (sole or joint) is recorded in the KER register. This ensures that, as soon as a result is recognised as potentially exploitable, its ownership is formally captured alongside background dependencies and planned exploitation routes.

In the default case of sole ownership, the partner that has generated the result is free to decide on protection and exploitation, subject to the obligations in the GA and the CA regarding access rights, protection, dissemination and transfer of ownership. New IP will generally be owned by the originator, with specified rights for other parties on fair and reasonable terms where needed for project implementation or exploitation. Sole owners are responsible for initiating protection (e.g. patent filing or registration), bearing the associated costs (unless cost sharing is agreed), and informing the consortium and the JU where required (for instance if they decide not to protect or to abandon protection).

Where joint ownership arises, LH2CRAFT applies the rules set out in the GA, the CA, and the CHJU guidelines. Joint owners must agree, in writing, on how the jointly owned result will be protected, exploited, licensed and managed, including cost sharing and revenue distribution. Unless a different regime is agreed in the joint ownership agreement or the CA, each joint owner is entitled to use the joint foreground for its own purposes, and to grant non-exclusive licences to third parties (without sub-licensing) on condition that the other joint owners receive prior notice within the agreed period (e.g. 60 days) and fair and reasonable compensation. This default regime is particularly relevant for joint results around CCS and HDMSS designs, safety frameworks and software tools, where several industrial and research partners may contribute to the same KER. In such cases, partners are encouraged to negotiate joint ownership agreements early, in parallel with the technical work, to avoid delays when protection or licensing opportunities arise.

The protection of results is treated as an integral part of the KER management process. For each result flagged in the KER register as having commercial or industrial potential, the responsible partners assess, with support from WP11, whether protection is justified and which form is most appropriate. Options include:

- patent or utility model applications for novel technical solutions (e.g. specific membrane architectures, insulation concepts, integration details);
- design rights for certain structural or component designs;
- copyright for software, documentation, training material and databases;
- protection as trade secrets for know-how that is best kept confidential (e.g. process parameters, detailed algorithms, internal design rules).

Decisions are documented and reflected in the KER register. In all cases, the consortium must ensure that patent filings or other registration actions are coordinated with dissemination activities (public deliverables, papers, conference presentations) so that novelty is not compromised. This is handled through the internal publication clearance procedure and the interaction between WP11 and the Project Management Board.

For software and models, the project anticipates both protection and structured access. Software developed in LH2CRAFT (e.g. risk-assessment tools, digital twins, LCA/LCCA models) may be protected by copyright and, where appropriate, by keeping key elements as trade secrets. At the same time, project partners will be able to request access to the latest versions of such software, free of charge and for evaluation purposes only, for up to five years after project completion. This regime supports follow-up R&I collaboration and benchmarking, while leaving room for commercial licensing or service-based exploitation towards external customers. Any open-source or open-access releases of software will be carefully assessed to ensure compatibility with protection strategies and with the legitimate interests of other partners.

The geographical and temporal scope of protection will be tailored to each KER, taking into account expected markets, competitive dynamics and cost-benefit considerations. LH2CRAFT will favour protection strategies that are robust enough to support commercial exploitation (e.g. filings in key jurisdictions for CCS/HDMSS technologies), without unnecessarily inflating costs or creating obstacles to standardisation and regulatory uptake. When considering transfers or licences of results to entities in non-associated third countries, the consortium will comply with safeguards on strategic interests and the requirements that results remain free from undue control or restrictions, as set out in the GA.

Ownership and protection decisions are not static. As technical work progresses and the market or regulatory context evolves, partners may decide to strengthen protection (e.g. extend patent families, file continuation applications), adjust strategies (e.g. shift from patenting to trade secret), or, in some cases, allow rights to lapse if exploitation prospects no longer justify maintenance costs. The WP11 leader will periodically review the status of key IP assets, using inputs from the KER register, to ensure that the protection portfolio remains aligned with the exploitation pathways described in Section 3.

Overall, the LH2CRAFT approach ensures that ownership of results is clearly allocated, that joint ownership situations are handled transparently, and that protection measures are proportionate, well-timed and fully integrated with dissemination and exploitation planning. This provides a solid legal and operational basis for turning the project's technical achievements into long-term value for partners and for the wider hydrogen and maritime ecosystem.

5.4 CONFIDENTIALITY AND KNOWLEDGE MANAGEMENT

Confidentiality and knowledge management in LH2CRAFT are designed to protect sensitive information and IP, while still enabling efficient collaboration, dissemination and exploitation. The approach combines the binding obligations of the Horizon Model Grant Agreement (Articles 13, 15–17 and Annex 5) with the internal tools and procedures established under WP11.

At legal level, Article 13 of the HE MGA requires all parties to keep confidential any data, documents or other material that is identified as sensitive in writing, during the implementation of the action and for at least the period specified in the Data Sheet. Sensitive information may be used only for implementing the Agreement and may be disclosed internally solely on a need-to-know basis to personnel or other participants who are bound by confidentiality obligations. These obligations also extend, via Articles 9 and 25, to associated partners, subcontractors and third parties giving in-kind contributions, which must be contractually bound to the same confidentiality and security standards as beneficiaries. Annex 5 adds specific rules for "sensitive information with a security recommendation", requiring additional approvals, record-keeping and, where relevant, prior written consent from the granting authority before such information is disclosed or disseminated.

These generic Horizon Europe rules are complemented in LH2CRAFT by the more specific commitments laid out in the GA. Therein, it is explicitly stated that background and foreground IP and know-how will be treated as confidential during and after the project, except where publication or other dissemination has been approved both by the Project Board and by the owner of the IP. All data access, sharing and exploitation are subject to the regulations and controls implemented through the CA, which formalises how partners handle confidential information and align it with access-rights and exploitation arrangements. Communication activities are similarly constrained: the communication strategy explicitly notes that all communication must be compatible with IP protection, confidentiality obligations and the legitimate

interests of the IP owners and foresees central coordination to ensure that public messages do not inadvertently disclose confidential or commercially sensitive information.

Confidentiality also interacts with data protection and open science duties. Article 15 of the HE MGA obliges beneficiaries to process personal data in compliance with GDPR and applicable EU and national law, and to ensure appropriate security of personal data, including safeguards on access, retention and integrity. At the same time, Article 17 requires dissemination and open access to publications "as soon as feasible", but always subject to restrictions arising from IP protection, security rules or legitimate interests. In LH2CRAFT this is operationalised through a publication-clearance process under WP11: planned publications, public deliverables and conference presentations are notified in advance to partners, who can object if their legitimate interests or confidential background would be seriously harmed, triggering mitigation measures such as delaying publication, anonymising data, or removing sensitive details.

Knowledge management is the complementary side of this confidentiality framework. The project aims not only to protect IP but also to systematically create, structure and share knowledge among partners. Explicit objectives are defined for "knowledge creation and transfer": work-package leaders monitor progress, identify synergies, and contribute to a shared knowledge pool, including strategic position papers, joint publications, review papers and a knowledge database of key-enabling technologies for LH_2-based waterborne transport. The Exploitation & IP Rights Management Plan reinforces this with a register that captures, for each significant result, its content, ownership, background dependencies, protection status and exploitation intentions.

Operationally, LH2CRAFT integrates these tools into a secure digital collaboration environment hosted on the project's internal platform. All templates, registers and supporting documents are stored in this environment with controlled access, version control and traceability of updates and decisions. Access rights to this platform follow the same need-to-know and confidentiality principles as defined in the GA and CA, with differentiated visibility for, for example, internal drafts, confidential annexes and public-ready versions of deliverables. This set-up allows the consortium to capture tacit and explicit knowledge in a structured way, while ensuring that sensitive elements (detailed design rules, proprietary models, commercially valuable datasets) remain restricted to authorised users.

Finally, confidentiality and knowledge management are explicitly linked to exploitation and dissemination governance. The Project Management Board oversees the classification of information (public, restricted, confidential), reviews KER descriptions and associated IP strategies, and ensures that exploitation actions (such as licensing talks or preparation of AiP dossiers) are supported by appropriate information flows without breaching confidentiality undertakings towards partners or the JU. In this way, LH2CRAFT's approach goes beyond merely protecting information: it establishes a controlled knowledge-management framework that underpins internal collaboration, regulatory engagement and future commercialisation, while remaining fully compliant with the confidentiality, security, IP and data-protection obligations of the GA and the CA.

5.5 KER-SPECIFIC IPR & OWNERSHIP MATRICES

To operationalise the IP, ownership, access-rights and exploitation framework established under the GA and the CA, LH2CRAFT maintains a dedicated IPR & Ownership Matrix for each identified KER. The matrix captures, for each result, the full range of IP-relevant information required under GA Annex 5; from ownership and background arrangements through to protection status, exploitation strategy, territorial

coverage, FTO assessment and identified third-party risks. Table 3 provides a concise definition of each field and its available options.

Table 3: IPR matrix definitions

Field	Available Options	Definition
Result Ownership	Sole ownership / Joint ownership	Whether ownership of the result rests with one beneficiary (sole) or is shared by two or more who jointly generated it and whose contributions cannot be separated.
Owner(s)	Entity name(s)	The name(s) of the owning beneficiary or beneficiaries, as registered in the GA.
Joint Ownership Agreement Required?	Yes / No (if yes, status)	Whether a formal written agreement on the exercise of joint ownership rights is required beyond the CA default provisions, and if so its current drafting or signature status.
Background Used?	Yes / No	Whether pre-existing IP held by a beneficiary before accession to the GA was used or needed to generate this result.
Background Owner(s)	Partner name(s)	The beneficiary or beneficiaries owning the background identified above. Determines who controls access-right conditions and whose consent may be needed for exploitation.
Access Rights Conditions	Royalty-free / Fair & reasonable / Other	The terms on which other beneficiaries may access this result. Royalty-free: at no cost. Fair & reasonable: negotiated terms reflecting commercial value. Other: specific conditions outside those two regimes.
Foreground Protection Status	Not protected / Under evaluation / Patent filed / Copyright / Trade secret / Design right / Trademark	The IP protection instrument(s) applied or planned. Multiple options may be selected. • Not protected: no formal protection applied or needed • Under evaluation: instrument still being assessed • Patent filed: novel technical invention • Copyright: automatic protection for original authored documents, reports and software upon creation • Trade secret: result kept confidential; protection is lost if publicly disclosed • Design right: visual appearance of a product protected • Trademark: distinctive sign (name, logo) protected through registration.
Territorial Coverage	EU / National / International	The geographical scope of IP protection sought. Particularly significant for patents which require jurisdiction-by-jurisdiction filing and provide no protection in undesignated territories.
IP Protection Strategy	Patent, know-how secrecy, licensing, open source, standardisation, etc.	The intended approach to exploiting or disseminating the result, combining the chosen protection instrument with a commercial or dissemination logic (e.g. patent and licensing; know-how secrecy; contribution to standardisation).
Freedom to Operate (FTO) Assessment	Performed / Planned / Not required	Whether an analysis of potential infringement of third-party patents has been completed, is planned, or is not applicable. A planned FTO represents an unresolved commercial risk to be managed.

Clean Hydrogen Partnership
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Field	Available Options	Definition
Third-party IP Risks Identified?	Yes / No (brief explanation)	Whether specific third-party IP rights that could constrain exploitation have been identified. A No response indicates no risks found to date; it is not a guarantee of freedom to operate where assessment is still pending.

The matrix will serve as an operational IP management tool supporting the implementation of the GA, particularly with respect to ownership of results, access rights, protection, exploitation and transfer or licensing of intellectual property. It will also support coordination between dissemination and protection activities by ensuring that publication and communication decisions remain compatible with confidentiality obligations and preservation of commercial value.

At the current stage of the project, a number of KERs remain under active development and several IP-related decisions — including confirmation of protection status, outcomes of FTO assessments, and finalisation of joint ownership arrangements — have not yet been taken across the consortium. Including partially completed matrices in this intermediate version risks embedding provisional positions that could be misconstrued as confirmed by consortium partners or third parties. The KER-specific IPR & Ownership Matrices are therefore deferred to the final version of this deliverable, once the relevant decisions have been reviewed and agreed.

The fields comprising each matrix, along with their available options, are defined in Table 2 above. Where detailed arrangements concerning joint ownership, licensing, access rights or exploitation responsibilities require further specification beyond the matrix fields, these will be addressed through the Consortium Agreement, dedicated Joint Ownership Agreements or bilateral arrangements between the beneficiaries concerned.

5.6 IP RISK MANAGEMENT AND DISPUTE RESOLUTION MECHANISM

IP risk management in LH2CRAFT is conceived as a preventive and iterative process, rather than a purely reactive one. The aim is to identify and mitigate potential conflicts or non-compliance issues early, so that protection, dissemination and exploitation of results can proceed smoothly and in line with the GA and the CA. This process is embedded in the governance and tools described in earlier sections and is closely linked to project management and quality assurance.

From an IP perspective, the main risks for LH2CRAFT include: uncertainty or disagreement about ownership (especially in joint results), conflicts between background conditions and intended exploitation, inadvertent infringement of third-party rights, breaches of confidentiality or data-protection rules, misalignment between protection strategies and open-science obligations, and non-compliance with Horizon Europe rules on access rights, transfers and licensing (including the safeguards regarding EU strategic interests and control by non-associated countries).

Risk prevention starts with systematic recording and monitoring of IP-relevant information. The KER register captures, for each KER, who owns what, which background is needed, what protection has been or will be sought, and what exploitation routes are envisaged. This mapping makes it easier to detect, for example, overlapping ownership claims, background that cannot legally be used for certain applications, or results that might conflict with existing third-party IP. When a new result is reported, the responsible

partners are expected, where applicable, to carry out a basic freedom-to-operate and prior-art check (drawing on their internal IP offices or external counsel where necessary) and to flag any potential infringement concerns to the consortium.

A second layer of risk management concerns alignment between protection, dissemination and access-rights obligations. Before any public dissemination (deliverables, publications, conference papers), partners must follow the internal publication-clearance process, which allows other beneficiaries to object if their legitimate interests or confidential background would be significantly harmed. This mechanism reduces the risk of destroying patentability through premature disclosure or inadvertently revealing trade secrets. In parallel, WP11 and the coordination team monitor that access rights to background and results for implementation and exploitation are handled in accordance with the GA and the CA (royalty-free for implementation, fair and reasonable for exploitation, written requests within the agreed time windows), thereby avoiding later disputes over “unexpected” conditions or missed deadlines.

A third dimension relates to transfers and licensing of results, especially to entities outside the EU or associated countries. Transfer of ownership and exclusive licences is allowed as described in the GA, but only if access rights of other beneficiaries are preserved and, where the right to object applies, if the granting authority does not consider the transaction contrary to EU strategic interests. LH2CRAFT therefore requires that any intention to transfer or grant exclusive rights over significant KERs (e.g. CCS or HDMSS designs, core software tools) be communicated to the consortium in advance and, where relevant, to the granting authority, together with an assessment of the implications for access rights and EU interests. This allows potential objections to be handled before contractual commitments are made, reducing the risk of later non-compliance, blocking of transfers or grant reduction measures.

On the operational side, IP risks are monitored through regular IPR and exploitation reviews, at least once per reporting period, with a view to detecting: results that should be protected but are not, joint ownership situations that have not yet been formalised, background dependencies that could block exploitation, and conflicts between intended business models and access-rights or standardisation obligations. Where necessary, mitigation measures are recommended (e.g. negotiation of a joint-ownership agreement, clarification of background conditions, adjustment of dissemination timing, or revision of an exploitation pathway) and reports critical issues to the Project Management Board.

When IP-related disagreements nevertheless arise, LH2CRAFT relies on a graduated dispute-resolution mechanism, anchored in the CA and consistent with the HE MGA. In the first instance, disputes should be resolved amicably at the lowest appropriate level, typically between the directly involved partners, facilitated by the WP leader. If no agreement is reached, the matter is escalated to the Project Management Board and, where required, to the General Assembly of partners for a formal decision, informed by the legal and IP focal points of the organisations concerned. Only if internal mechanisms fail would the dispute be handled according to the formal procedures defined in the CA (for example, mediation or arbitration before a competent body or court), always taking into account the need to avoid jeopardising the project or breaching obligations towards the granting authority.

The same graduated approach applies in cases of non-compliance with IP-related obligations under the provisions of the GA (for instance, failure to grant agreed access rights, unauthorised disclosure of confidential information, or misuse of results). The consortium first seeks corrective actions and internal remedies; however, partners are reminded that serious or persistent breaches can lead the granting authority to apply measures such as grant reduction, recovery of funds or, in extreme cases, termination

of the beneficiary's participation. This external enforcement risk is itself a strong incentive to resolve IP issues promptly and transparently within the consortium.

Overall, IP risk management and dispute resolution in LH2CRAFT are conceived as integral parts of the Exploitation & IP Rights Management Plan: they combine early identification of risks through structured registers and reviews, preventive alignment of protection, dissemination and access-rights practices, careful handling of transfers and licensing, and clear internal escalation paths for resolving disagreements. This integrated framework is intended to safeguard the consortium's collective and individual interests, while ensuring full compliance with the Horizon Europe rules and enabling effective exploitation of the project's results.

6 REGULATORY AND LEGAL CONSIDERATIONS

6.1 STANDARDS AND CERTIFICATION PATHWAYS

The exploitation of LH2CRAFT's core technologies is inseparable from their alignment with evolving maritime standards and certification pathways. From the outset, the project has been framed as both a technology demonstrator and a regulatory enabler for large-scale LH_2 carriage, explicitly addressing the lack of mature rules, regulations and standards for cryogenic hydrogen cargo systems and associated handling equipment. The regulatory and standardisation dimension therefore underpins the project's business models, since market uptake of the CCS and HDMSS depends on their acceptance by classification societies, flag administrations and, ultimately, the IMO and related standardisation bodies.

On the international side, LH2CRAFT takes as its primary reference the IMO framework for gas carriers and alternative fuels. The project builds on the International Code for the Construction and Equipment of Ships Carrying Liquefied Gases in Bulk (IGC Code) and the International Code of Safety for Ships Using Gases or Other Low-Flashpoint Fuels (IGF Code), as well as the Revised interim recommendations for carriage of liquefied hydrogen in bulk adopted by MSC.565(108), which update the earlier MSC.420(97) Interim Recommendations. These revised recommendations are intended to provide the basis for future minimum requirements for LH_2 carriage and currently include general requirements and specific parts for independent vacuum-insulated and gas-insulated cargo tanks. Ongoing discussions at IMO's CCC Sub-Committee (e.g. CCC 10/14 series) address the extension of these recommendations to membrane-type containment systems, which is directly relevant to LH2CRAFT's CCS concept. In parallel, the project monitors related work on hydrogen as fuel (draft Interim Guidelines under the IGF context) and the broader environmental and safety framework captured in EMSA's hydrogen-fuel studies and associated ISO references.

At the level of classification societies, LH2CRAFT leverages the presence of ABS, RINA and BV as full partners and IACS members with long-standing experience in LNG and alternative-fuel shipping. These partners are positioned as "regulatory system" enablers, responsible for developing rules, interpretations and guidelines, and for translating the project's lessons learned into class requirements and best practices. Within WP9, ABS leads the formal AiP and General Approval processes for the CCS and HDMSS, with RINA and BV contributing to the review and test witnessing. The work culminates in public deliverables D9.1 and D9.2 (AiP for CCS and HDMSS, due M30) and D9.3 (General Approval of the CCS, due M48), which document compliance with applicable rules, standards and engineering principles and define the roadmap from AiP to full approval. These approvals are themselves key exploitable results, as they de-risk early commercial projects and provide a strong signalling effect to shipyards, owners and regulators.

The certification pathway is closely intertwined with the safety and environmental work in WP8. Tasks 8.1–8.4 develop qualitative and quantitative safety evaluations, including HAZID/HAZOP, FMEA and QRA, which are fed directly into class reviews and the demonstrator design. Task 8.5 then consolidates these outputs into safety assessment guidelines and recommendations for CCS design, integration and LH_2 handling, with explicit objectives to provide key input to regulatory frameworks, including IGC/IGF Codes and ISO standards for cargo handling and storage. This creates a two-way interaction: design and testing activities are performed "under the shadow" of emerging IMO and class requirements, while the project's evidence base and guidelines are used to inform future revisions of those same requirements. The resulting

guidelines, together with the AiP and General Approval, form a coherent package that can be referenced by early adopters and policy makers when assessing new LH_2 projects.

Beyond IMO and class, LH2CRAFT's standardisation and certification strategy is explicitly aligned with the Zero-Emission Waterborne Transport (ZEWT) Partnership. The project positions itself as a beacon project for LH_2 transportation vessels and includes specific responsibilities for partners to ensure synergies with ZEWT and broader EU policy frameworks. This involves positioning LH2CRAFT outcomes, such as the membrane CCS, HDMSS, safety assessment methodology and LCA/LCCA tools, as reference solutions that support ZEWT's objectives on zero-emission fuels, safety and sustainability, and that can feed into European and international standardisation work (e.g. CEN/CENELEC, ISO) beyond the immediate maritime domain. In this sense, standards and certification are not just compliance constraints but an integral exploitation channel, enabling partners (especially class societies and technical consultancies) to capitalise on their role in rules development, advisory services and training.

Operationally, the Exploitation & IP Rights Management Plan connects these regulatory developments with the project's KER management. For each KER related to the CCS, HDMSS and safety/regulatory frameworks, its status is monitored with respect to class approval, relevant IMO/ISO references and ZEWT priorities, so that exploitation pathways (e.g. licensing of CCS designs, consultancy on LH_2 risk assessment, training on new rules) can be timed to key milestones such as issuance of AiP, General Approval or publication of new guidelines. In this way, LH2CRAFT's exploitation strategy is structurally tied to standards and certification pathways, ensuring that technical innovations are developed "with approval in mind" and are ready to be rolled out as soon as the regulatory window opens.

6.2 SAFETY, ENVIRONMENTAL, AND COMPLIANCE ASPECTS

Safety, environmental performance and regulatory compliance are not just boundary conditions for LH2CRAFT; they are core value propositions of the project and decisive factors for the exploitation of its results. LH2CRAFT acts as a "one-stop solution" that is more reliable, safer and more environmentally efficient than existing LH_2 transport concepts, emphasising that safety and regulatory compliance are prerequisites for introducing large-scale LH_2 storage and transportation technologies to the market. The Exploitation & IP Rights Management Plan therefore needs to ensure that any commercial, scientific or policy uptake of the CCS, HDMSS and associated tools remains fully aligned with the safety and environmental safeguards built into the project's design and work plan.

On the safety side, WP8 provides the main framework for ensuring that the CCS and HDMSS designs, the prototype and the integrated ship concept are developed under rigorous risk management. WP8.1 starts with a gap analysis of existing and upcoming international and EU regulations, class rules and policies addressing hydrogen risks as cargo and fuel and develops qualitative and quantitative risk assessment models where current frameworks are insufficient. Subsequent tasks carry out HAZID/HAZOP studies, qualitative and quantitative risk assessments and integrity analyses for the detailed design and the demonstrator, optimising the CCS and HDMSS for safety and feeding results back into WP6–7. This work culminates in safety assessment guidelines and recommendations for CCS design and integration (D8.4–D8.5), which are explicitly intended to provide generally applicable guidelines for LH_2 risk assessment and to act as de facto common standards for safe LH_2 carriage on ships. From an exploitation perspective, this means that any deployment or licensing of LH2CRAFT technologies should be anchored in these guidelines: the KER descriptions and business models must consistently reflect that the CCS and HDMSS are to be used within the operational envelopes, safety assumptions and risk control measures defined in WP8.

Safety is not limited to technical risk assessment. Task 8.6 focuses on occupational and social health and safety enhancement, quantifying the impact of hydrogen-related risks on social costs and benefits and proposing policy measures, regulations, incentives and educational actions to enhance health and safety in LH_2 transport. It will also develop training manuals for crews and port personnel and an emergency response plan for hydrogen incidents. These outputs create a bridge between technical design and operational practice and are directly relevant to exploitation: partners planning to commercialise CCS/HDMSS concepts or safety tools should position training, crew education and emergency preparedness as integral components of their offerings, rather than optional add-ons. In practical terms, this may translate into combined technology-plus-training packages, advisory services on emergency planning, and integration of LH2CRAFT guidance into company HSSE systems and port procedures.

Environmental and economic aspects are addressed primarily in WP10, which delivers the LCA, the LCCA, techno-commercial evaluations and KPI-based roadmaps for the CCS solutions. The project emphasises that the life-cycle model will be a "significant tool enabling comparison between different new design or retrofit strategies". In particular, the LCA will assess environmental impacts from cradle to grave, including sustainability and recyclability, and quantify environmental benefits relative to alternatives. These analyses are not merely scientific outputs; they are compliance and market-shaping tools. They allow partners to demonstrate alignment with EU climate and environmental policy objectives (e.g. Green Deal, REPowerEU, Fit for 55), support conformance with emerging sustainable finance/taxonomy criteria, and substantiate claims on GHG reduction and resource efficiency that will be key in commercial negotiations and regulatory scrutiny. Exploitation activities must therefore treat the LCA/LCCA and KPI results as reference baselines, ensuring that any marketed configurations or derivative products remain consistent with the validated environmental and economic performance envelopes.

More broadly, compliance aspects cut across safety, environment and legal/regulatory requirements. WP8.1's review of regulations and class requirements and D8.1's "Regulatory gaps and risk assessment models" deliverable provide a structured understanding of where current IMO, EU and class frameworks are incomplete for LH_2 transport and how LH2CRAFT's methodologies fill those gaps. WP9, in turn, operationalises compliance by leading the AiP and General Approval processes for CCS and HDMSS, resulting in public deliverables that document statements of compliance and approval roadmaps.

Finally, safety, environmental and compliance aspects are tightly integrated into the overall exploitation governance. The WP11 leader coordinates with WP8 and WP10 leaders to ensure that KER descriptions, IP strategies and business models do not conflict with safety assumptions, environmental findings or regulatory obligations, and that exploitation actions (e.g. licensing negotiations, demonstrator follow-ups, standardisation initiatives) are aligned with the guidance and evidence produced in these WPs. In this way, the Plan ensures that the long-term utilisation of LH2CRAFT results reinforces, rather than dilutes, the project's core commitments to safe, environmentally sound and compliant LH_2 marine transportation.

6.3 DATA PROTECTION, ETHICS, AND SECURITY

Data protection, ethics and security form a cross-cutting framework that underpins all exploitation and IPR activities in LH2CRAFT. The project's ambition to develop and commercialise safe LH_2 containment and handling technologies must be pursued in full compliance with the HE MGA, in particular Articles 13–15 on confidentiality, security, ethics and data protection, as well as with the open-science and data-management obligations and the additional rules set out in Annex 5. This subsection explains how these requirements

are interpreted in LH2CRAFT and how they interact with WP8, the Data Management Plan (D1.2) and the Exploitation & IP Rights Management Plan.

From a legal perspective, Article 15 of the GA requires that any personal data processed under LH2CRAFT is handled lawfully, fairly and transparently, collected only for specified and legitimate purposes, limited to what is necessary, kept accurate and up to date, retained no longer than needed, and protected by appropriate technical and organisational security measures. These obligations sit alongside Article 14 on ethics and EU values, which mandates compliance with the highest standards of research integrity and with EU and national law on fundamental rights, and Article 13 on confidentiality and security, which sets strict conditions for handling sensitive information and, where applicable, EU-classified information. Together, these provisions define a boundary within which any exploitation, dissemination or sharing of LH2CRAFT results – including data sets, models and safety analyses – must remain, during and after the project.

The primary operational instrument for data protection and research-data governance in LH2CRAFT is the Data Management Plan (D1.2), led by TUD under WP1. The DMP, prepared early in the project and updated as needed, describes the rules, guidelines and procedures for storage, protection, publication and long-term preservation of project data, in line with the FAIR principles and Horizon Europe open-science requirements. A professional digital database is set up at the Centre for Information Services and High-Performance Computing (ZIH) of TU Dresden to host engineering results, experimental and simulation datasets, designs and technical documentation. Data will be stored in compliant information-security management systems with regular backups and offsite archiving and preserved for at least five years after project completion to ensure reusability, while access is controlled via individual accounts and role-based permissions. The DMP also implements the principle “as open as possible, as closed as necessary” for open science: data and other research outputs are made openly accessible via trusted repositories whenever this does not conflict with IP protection, confidentiality, security or legitimate interests, and any restrictions are explicitly justified.

In practice, personal data in LH2CRAFT is expected to arise mainly from project management (contact details, meeting records), stakeholder engagement (workshops, External Stakeholders Committee, surveys) and training or consultation activities related to WP8 on occupational and social health and safety. Each beneficiary acts as data controller for the personal data it collects, applying GDPR-compliant procedures for consent (where required), information to data subjects, retention limits and data-subject rights. The GA emphasises that ethics and data-protection approvals must be obtained before starting any task that raises ethical or data-protection issues and that such approvals must be documented and kept on file. The DMP and the project’s QA/QC and Risk Management Plan under WP1 provide the internal framework to ensure that personal data is minimised, pseudonymised or anonymised where possible, and not included in shared research datasets or exploitable outputs unless fully compliant with Article 15 and national law.

Ethical considerations go beyond data protection. LH2CRAFT is explicitly committed to high standards of research integrity, respect for fundamental rights and EU values, gender equality and the “do no significant harm” principle. WP8 plays a central role here: in addition to conducting technical risk assessments, it evaluates occupational and social health and safety impacts of LH_2 implementation (Task 8.6), quantifies social costs and benefits, proposes policy measures, and develops training manuals and an emergency response plan. These activities may involve consulting experts, operators or other stakeholders, and must therefore be designed to avoid undue burden or discrimination, ensure voluntary participation, and respect privacy and confidentiality. Their outputs – guidelines, training content, emergency procedures – are

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exploitable results in their own right, but they must be commercialised or disseminated in a way that does not expose individual participants or sensitive operational details.

Security considerations are addressed both at the level of information handling and in relation to the project's subject matter (hydrogen safety). At information level, Annex 5 of the HE MGA imposes specific rules for sensitive information "with a security recommendation" and for any EU-classified information, including the need to obtain approvals before starting such tasks, to keep evidence of those approvals on file, and to seek written consent from the granting authority before disclosing or disseminating certain information. Although LH2CRAFT is not expected to generate EU-classified data, it does produce detailed safety analyses, failure scenarios and risk models which may be considered sensitive from a security perspective (e.g. if they reveal vulnerabilities in containment systems, terminals or emergency procedures). The consortium therefore uses internal classification (e.g. SEN vs PU deliverables, restricted access to certain datasets in the ZIH database) and the confidentiality provisions in the CA to ensure that such information is shared only with authorised parties and in a controlled way.

Data protection, ethics and security are also relevant for the mandatory annual data reporting to the CHJU (D1.3–D1.7), which requires the submission of technical and performance data through a secure platform. While this reporting is "by default" public, the GA allows the consortium to request that specific fields be treated as confidential, in particular where they reveal commercially sensitive information, IP-relevant details or data that could be linked to individuals. The Exploitation & IP Rights Management Plan and the DMP must therefore be coordinated so that data provided for JU monitoring is consistent with IP and confidentiality strategies and does not undermine protection or security considerations.

Operationally, these aspects are integrated into exploitation governance through internal publication-clearance and communication procedures under WP11, which require that planned publications, deliverables and external communications are checked not only for IP and confidentiality impacts but also for consistency with the DMP, data-protection rules and any ethics or security restrictions.

In summary, LH2CRAFT treats data protection, ethics and security as enabling conditions for sustainable exploitation. By anchoring exploitation decisions in the DMP, ethics and security provisions of the Grant Agreement, and the safety and social impact work of WP8, the consortium ensures that commercially or scientifically valuable results are used and shared in ways that respect individuals' rights, protect sensitive information and support the long-term credibility and legitimacy of LH_2 technologies in the maritime sector.

7 CONCLUSIONS AND FUTURE WORK

This deliverable consolidates the current status of LH2CRAFT's exploitation and intellectual property management activities. It confirms that the project has generated a broad and diverse portfolio of Key Exploitable Results, ranging from core technological outputs such as the CCS, HDMSS, prototype and vessel-design results, to supporting methodologies and datasets in the areas of manufacturing, testing, materials, safety, class approval, sustainability, circularity, knowledge transfer and digital simulation.

A key conclusion from the work carried out so far is that exploitation in LH2CRAFT should be understood as a portfolio-based process rather than as the commercialisation of a single project output. Some results may support future industrial development, design licensing, engineering services or demonstrator activities. Others are more likely to generate value through testing services, material qualification, safety assessment, class approval, regulatory input, sustainability studies, training, scientific dissemination or follow-up R&I. This diversity is reflected in the five exploitation and impact pathways defined in Section 3.2.

The KER register has become the central tool for structuring this portfolio. It allows the consortium to connect each result with its technical origin, target users, application sectors, ownership status, background dependencies, protection strategy and potential IP risks. At the same time, the current version of the register shows that several entries still require further consolidation. Some KERs remain partially described, some ownership and background fields require confirmation, and certain protection, FTO and third-party IP risk assessments are still under evaluation. This is expected at this stage, given that several technical, validation and approval activities are still ongoing.

During the final year of the project, the main priority will be to move from identification and preliminary structuring towards consolidation and exploitation readiness. The KER register should be reviewed with the relevant partners to confirm the scope, ownership and maturity of each result. Particular attention should be given to KERs involving multiple partners, background IP, class review, confidential technical know-how, material datasets, software or simulation models, since these are the areas where access-rights, protection and dissemination decisions are most likely to require careful coordination.

The final project-end version of this deliverable should also distinguish more clearly between different levels of exploitation maturity. Some KERs may be ready for concrete post-project actions, such as use in follow-up engineering studies, class or regulatory work, training, consultancy, Knowledge Hub activities or further R&I proposals. Others may remain at an earlier stage and require additional validation, partner agreement, FTO assessment or market development before exploitation can proceed. Making this distinction will help avoid treating all KERs as equally mature or equally commercial, while still recognising the value of methodological, regulatory, scientific and knowledge-transfer results.

Another important focus for the final year will be the alignment between exploitation, dissemination and protection. As more technical outputs become available, the consortium will need to ensure that publications, public deliverables, stakeholder workshops, Knowledge Hub content and training material do not compromise patentability, confidential background, trade secrets, FTO assessments, class review processes or security-sensitive information. The dissemination and communication routes identified in Section 3.3 should therefore continue to be used together with the KER register as a practical clearance reference.

The market and regulatory context will also need to be revisited before the final update. LH_2 maritime transport remains an emerging market, and the exploitation potential of LH2CRAFT results will depend not

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only on technical performance, but also on class approval progress, evolving IMO and IACS discussions, future hydrogen trade routes, infrastructure investment, and demand from shipbuilders, shipowners, energy companies, ports and public authorities. The final version should therefore refine the business-model and go-to-market discussion for the most mature KERs, without overstating commercial readiness where the market or the technology is still developing.

By the end of the project, the final version of the Exploitation & IP Rights Management Plan will provide a consolidated view of which LH2CRAFT results are ready for post-project exploitation, which require further development, and which are best positioned for regulatory, scientific, training or knowledge-transfer use. It will also identify any KERs requiring further bilateral agreements, joint ownership arrangements, access-rights clarification or post-project partner coordination.

In conclusion, LH2CRAFT has already established a strong basis for exploitation through its structured KER portfolio, its preliminary exploitation pathways, and the IP management framework established in this Plan. The final year will focus on turning this basis into a clear post-project roadmap, ensuring that the project's results can continue to support safe, efficient and scalable marine transportation of liquid hydrogen after the formal end of the action.