CoPropel

Composite material technology for next-generation Marine Vessel **Propel**lers

www. Copropel.com

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Contents

Glossary

Abbreviation / acronym	Description
CA	Consortium Agreement
DMP	Data Management Plan
DOA	Description of action
DOI	Digital Object Identifier
EC	European Commission
FAIR	Fair Accessible Interoperable and Reusable
GA	Grant Agreement
LCA	Life Cycle Analysis
OA	Open Access
OS	Open Science
PDC	Project Data Contact
SHM	Structural Health Monitoring
WP	Work Package
OEM	Original Equipment Manufacturers

1. Executive Summary

This deliverable is a final report on the progress of dissemination, communication and exploitation activities as part of CoPropel project. The main strategy is to disseminate project related information in networks of people who are connected closely through shared objectives and activities to the scientific field of CoPropel, either as affected and/or interested stakeholders, or as end users. The different foreseen dissemination measures involve a major analysis of market segmentation and a detailed evaluation of marketplace potential. The deliverable is providing updates in:

- Communication strategy
- Dissemination and exploitation strategy

The communication section includes information about the communication activities which have been performed between M19 and M36 of the project. These activities include events, press releases, attendance in conferences, and exhibitions, maintenance of the website and updates to the video that describes the project activities. Next, the details about the workshops organized by the consortium for the dissemination and exploitation strategy is included in order to connect with the marine and composites' community. The market outlook is regularly being monitored to ensure the quick uptake of the CoPropel technology into the market right after the finalization of the project.

1.1. Deviations

No deviation from the Grant Agreement (GA) has been identified in relation to this deliverable.

2. Introduction

CoPropel puts forth a holistic approach towards the realization of marine propellers made of advanced composite materials. Compared to their traditional counterparts, marine composite propellers offer gains in propulsion efficiency, noise reduction and weight savings.

The CoPropel project sees an interdisciplinary team of experts drawn both from research and industry, from theoretical considerations and numerical modelling to precision manufacturing - assembly and experimental verification testing. The CoPropel action brings together 9 organizations from 5 countries: 4 Research Institutes – TWI, University of Ioannina, Brunel University London and The Bulgarian Ship Hydrodynamics Centre; 4 Industrial partners – Loiretech, MECA, Danaos and Glafcos Marine with one certification body Bureau Veritas Marine & Offshore. Together, the consortium developed and brought to market a marine composite propeller with an embedded structural health monitoring system. The activities carried out advanced our Technology Readiness Level to 6–7 and significantly de-risked the integration of the investigated solutions into the final propeller. This ultimately led to a reduction in the direct operating costs for operators and a minimized environmental impact. After the sea trial stage, CoPropel project has demonstrated the advantages of using composite materials in propeller design, achieving a significant power gain of up to 26% compared to conventional propellers, which translates into a fuel saving of up to 10% in some cases. These are only preliminary results that need to be verified by further, longer sea trials.

The main objectives of the project are summarized in Table 1.

Table 1 List of Objectives for the CoPropel

No	Objectives	Objective description and means of verification
1	Design a large scale composite marine propeller utilising methodologies and composite materials	The key characteristic of composite materials is the capability to exploit their inherent anisotropy in order to tailor the stiffness and strength of the final product. This will enable the propeller blades to exhibit outstanding hydrodynamic efficiency as well as controlled deformations pertaining to shape-adaptive structures capable of adapting their shape according to the specific regime of the operational envelope. The design activities of the composite propeller are planned for the first 24 months of the project, with a Critical Design Review (CDR) performed at the end of the second year of the project. More precisely, three different CDRs will be performed which will focus on the following items: 1. CDR for the blades in M21 (6 months before the final CDR in order to start full scale manufacturing) 2. CDR for root and fixing in M24 3. CDR for SHM system together with final assessment of full propeller in M27
2	Optimize the manufacturing process for the fabrication of the composite propeller based on closed mold resin Infusion techniques.	Resin infusion/injection techniques are particularly suitable for such structures. Together with the unique process monitoring and online quality control technologies available at the consortium level, they guarantee repeatability and quality assurance at every step of the manufacturing process. Automation processes will be built into the manufacturing system in order to allow increased productivity and error elimination. The novel

		manufacturing process will be approved through a CDR in M21 which will focus on the blades of the propeller. In that way, the outside surface will be fixed and the RTM tools can start getting prepared 6 months before the final CDR which will be done in M27.
3	Develop a condition and structural health monitoring system that will be embedded within the propeller	A network of suitable sensors will be embedded within the propeller structure and transmit information about the "structural health" of the composite structure. This Structural Health Monitoring (SHM) system, apart from the embedded sensors, will be comprised of signal transmission lines, interrogators, and analysis modules that will enable the detection of events such as impacts with objects as well as the identification of inspection and repair intervals. The SHM system will be fully developed and assessed at the CDR on M24 of the project.
4	Validation of the composite propeller	Precursor testing of smaller-scale (1:5) propeller demonstrator will be carried out in the relevant environment, e.g. water tank, in order to de-risk the full-scale testing (WP4). Then, validation testing of a full-scale propeller with a 1.1 m diameter (to be defined based on the available vessel) in a real environment (sea trials) will be conducted. The composite propeller along with the SHM system will be installed in a marine vessel and tested in real operational conditions (WP5). With the sea trials, TRL 7 of the technology will be achieved. Sea trials will take place at the end of the project (M30 to M35), and the experimental data will be compared with predictions.
5	Assist in the formulation of new guidelines regarding the use of composite materials at the propeller	Our consortium partner BV is developing a guidance note NI663 concerning the design assessment of propeller in composites materials. In order to complete and improve this document, BV will use results obtained in the project with regards to 1. the design assessment methods and fatigue investigation, 2. the manufacturing survey, 3. the propeller monitoring 4. the testing procedure including the quality control.
6	Communication and Dissemination of the project outcomes – open science-related objective	CoPropel will be widely promoted across different academic and industrial stakeholders by providing at least 6 open access scientific publications. Within the scope of the project, we will identify and attend at least 4 major Marine and Composite Conferences and Events that will serve as communication channels to promote CoPropel.
7	Define roll out strategy and develop a business plan	Future technical and business development roadmaps will be defined and be available at the consortium level towards the end of the project. Certification issues are the focus of specific activities, and the foreground knowledge during the project's tenure will simplify future applications.

2.1. Deliverable Objectives

This deliverable provides the latest update to the report on dissemination and exploitation including communication activities of the CoPropel project from month 19 to month 36.

3. Communication strategy

The strategy that is being followed for the communication and promotion of the CoPropel project and its results is presented in **Table *2*** along with the naming convection that was selected and used during the first periodic reporting to report the activities on the EC participant's portal.

Table 2 Communication strategy

Communication activity	Short name[1]	Target audience
Attendance at exhibitions and seminars, one-to-one communication, e-mailing stakeholders, periodic newsletters as direct communication means.	CoPropel-Com1.X (seminars and exhibitions) CoPropel-Com2.X (periodic newsletters)	Expert audience in composite engineering and technology and relative manufacturing technologies
Contacting parallel related projects, cross-field events.	CoPropel-Com3.X	Expert audience in the marine composites and structural sensors community that includes academic, engineering and business developing personnel as well as EC personnel.
General communication through the Project website, Social media, press releases, posters and leaflets.	CoPropel-Com3.X	General public and experts.
Conveyance of the new knowledge into University curriculums, publications of MSc and PhD theses.	CoPropel-Com4.X	Academic personnel and engineering students as well as industrial experts.

The communication of the project outcomes is carried out in the following ways:

- **Conferences and Exhibitions**: The project utilized the CoPropel grant to have exhibition stands and/or oral and poster presentations at a number of major European and international seminars, workshops, conferences and trade fairs for the presentation of project results and a prototype demonstration to potential partners and end users and development of a potential sales pipeline.

- **Project website and social media**: The website has been used for the dissemination of information about the project and the individual collaborators to all stakeholders and the general public. A project website will facilitate for general dissemination. In addition, we shall promote the technology using social media tools, such as LinkedIn for project updates.

- **Electronic and printed material**: Results and reports are communicated by mail, email, a dedicated protected project workspace on SharePoint and via the planned project meetings. Suitable dissemination materials in a range of standard formats (electronic and printed) for distribution through targeted campaigns of mail, email and web will be produced. Activities will include:

[1] The communication activities mentioned in Table 2 are broad categories of the activities performed in CoPropel. Therefore a serial number has been included in the short name to take into account the different activities within each category when reporting on the EU portal.

- Press releases on the project website, which will also be distributed to trade journals in the aeronautics and composite manufacturing sectors.

- Preparation of brochures with a generic outline of the project, its benefits and the format of use for potential collaborators and end-users.

- **Coordination with other EU and national projects**, identified as relevant to CoPropel, especially those in the Horizon Europe programs.
- **Coordination with European, national and regional trade associations and technology networks** to make their members aware of the development of the project, gather interest and aid use of the CoPropel technologies down the supply chain.

3.1. Communication activities

Consortium partners attended several events, and a list of key events and exhibitions was compiled to ensure that important opportunities relevant to the CoPropel project were not missed and that appropriate partners were present. The following communication events (Table 3) took place between Month 19 and Month 36 which were then also communicated through the social media and website of the project:

Table 3: List of communication events

Short name	Description	Communication channel	Outcomes
CoPropel-Com1.1	Attendance at JEC2024	Event	Engagement with relevant end users from composite, marine sector
CoPropel-Com3.1	JEC2024 LinkedIn post	Social media	engagement of marine and other relevant audience with the project's activities
CoPropel-Com3.2	JEC 2024 – Website press release	Social media	engagement of marine and other relevant audience with the project's activities
CoPropel-Com3.3	Invitation to the Synergies Kick-off meeting of DT4GS	meeting	engagement of marine and other relevant audience with the project's activities
CoPropel-Com1.2	Attendance at ECCM21	Event	Engagement with Expert audience in composite engineering and technology and relative manufacturing technologies
CoPropel-Com3.4	ECCM21 – LinkedIn post	Social media	engagement of marine and other relevant audience with the project's activities

CoPropel-Com3.5	Workshop #1 – Invitation email and LinkedIn post, April 2024	Email, Social media	General public and experts.
CoPropel-Com1.3	Attendance at 3rd Hellenic EU maritime research workshop	Event	Engagement with relevant end users from composite, marine sector
CoPropel-Com3.6	Hellenic EU maritime research workshop – LinkedIn post	Social media	General public and experts.
CoPropel-Com1.4	International composite summit, Sept 2024	Event	Engagement with relevant end users from composite, marine sector
CoPropel-Com3.7	International composite summit, Sept 2024 – LinkedIn post	Social media	General public and experts.
CoPropel-Com3.8	Workshop #2 – Invitation email and LinkedIn post, October 2024	Email, Social media	General public and experts.
CoPropel-Com3.9	CGI video - LinkedIn	Social media	General public and experts.
CoPropel-Com3.10	CGI video - Website	Website	General public and experts.
CoPropel-Com3.11	Waterbourne TP – LinkedIn post	Social media	General public and experts.
CoPropel-Com3.12	Workshop #3 – Invitation email and LinkedIn post, October 2024	Email, Social media	General public and experts.
CoPropel-Com1.5	Attendance at JEC2025	Event	Engagement with relevant end users from composite, marine sector
CoPropel-Com3.13	JEC2025 LinkedIn post	Social media	engagement of marine and other relevant audience with the project's activities
CoPropel-Com3.14	JEC 2025 – Website press release	Social media	engagement of marine and other relevant audience with the project's activities
CoPropel-Com3.15	Promotional video#1 - LinkedIn	Social media	General public and experts.
CoPropel-Com3.16	Promotional video#2 - LinkedIn	Social media	General public and experts.

1) Loiretech booth at JEC 2024, March 05 – 07, 2024, Paris

Figure 1 Partners TWI, Loiretech and BUL at Loiretech booth presenting the project update

2) ECCM21 event held in between July 02-05, 2024 at Nantes - France

Figure 2: Copropel session organized at ECCM21- 2024 conference

3) October 31st , 2024 - 3rd Hellenic EU maritime research workshop held in Piraeus, Greece

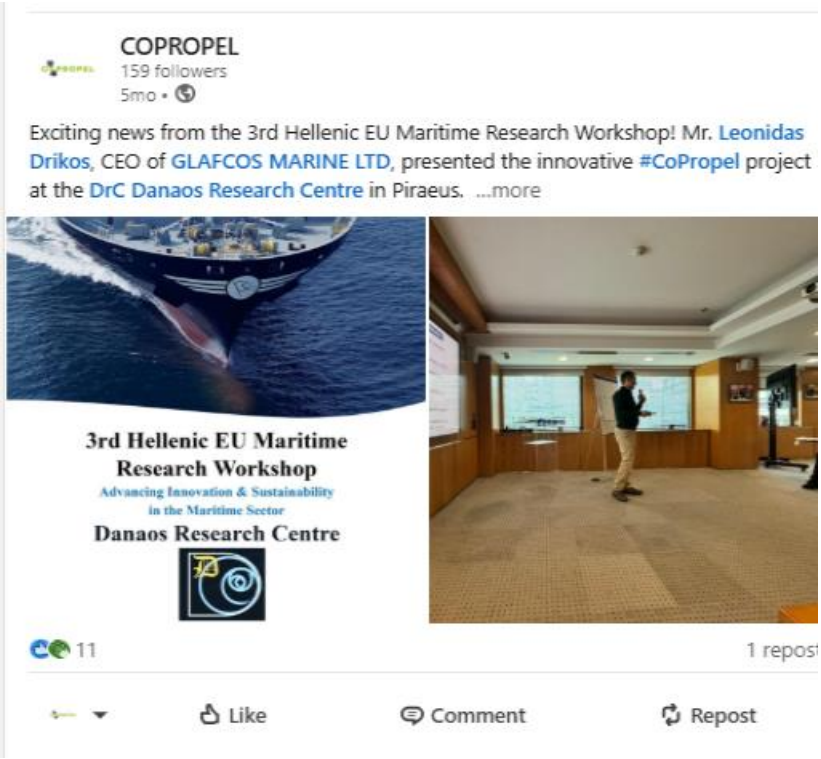


Figure 3: Glafcos marine presenting the Copropel project

4) International Composite Summit (ICS) – 4 -5 September 2024, Milton Keynes, UK

Figure 4: BUL presenting the Copropel update at ICS 2024

5) JEC 2025, 4 - 6 March, 2025, Paris

Figure 5: Loiretech booth: Demonstration of the composite blade and the project progress presentation

6) Waterborne Technology platform V.Z.W has included Copropel into their section of Energy efficiency and zero emissions category and shared a social media post (Figure 6) on the Copropel project.

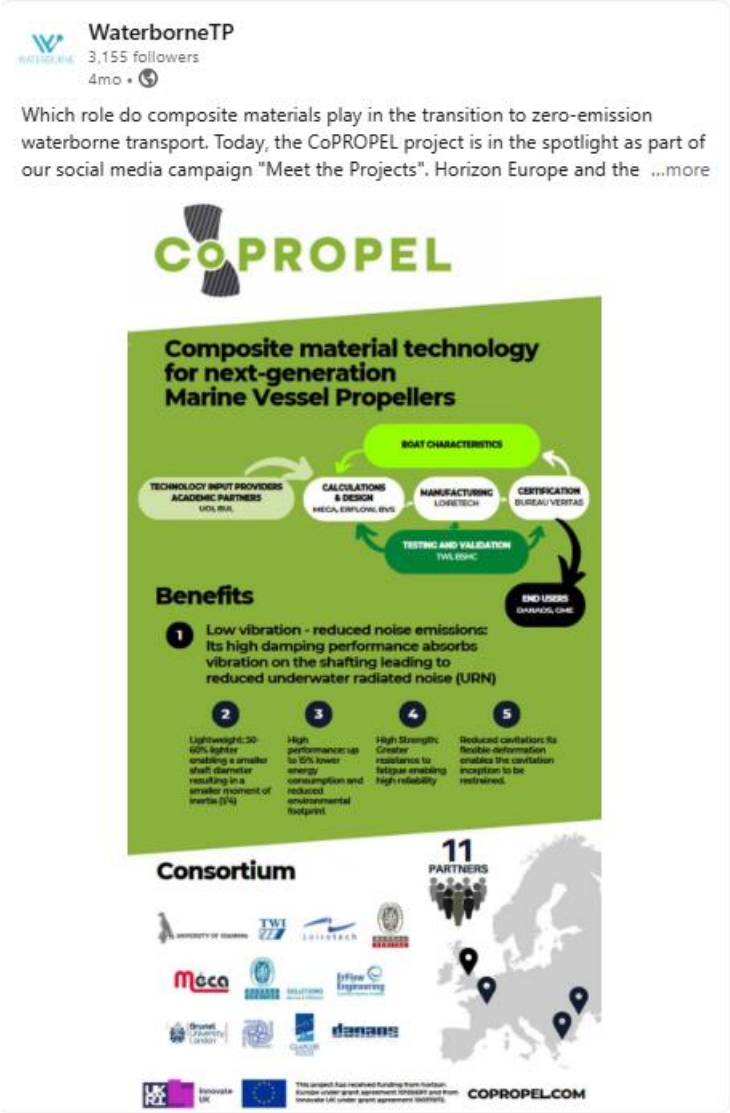


Figure 6: LinkedIn post shared by Waterborne TP

7) CoPropel was invited to the Synergies Kick-off meeting of DT4GS - *The Digital Twin for Green Shipping* project. UOI and LRT participated in the online meeting on 01/03/24 and discussed with members from DT4GS consortium on possible synergies and collaboration between the projects. Partners from ORC4SHIP, ENGIMMONIA, BUGWRIGHT2 and FLEXSHIP projects were also present at this meeting. Main conclusion was that possibly data produced from CoPropel sea trials could be shared with DT4GS project after signing the required non-disclosure agreements. Unfortunately, the CoPropel and DT4GS projects run for the same duration (June 2022 to May 2025) and thus the timeline to implement this synergy was not aligned. The data from CoPropel sea trials became available in the last months of the project, which is too late for the DT4GS project to use in their twin model.

3.2. Multimedia promotional package

3.2.1 Public website

A project website has been created during the first reporting period and is being maintained by TWI (https://www.copropel.com/). This website provides public information to potential stakeholders on project aims and successes. Figure 7 shows the latest image of the composite propeller as the front page of the website.

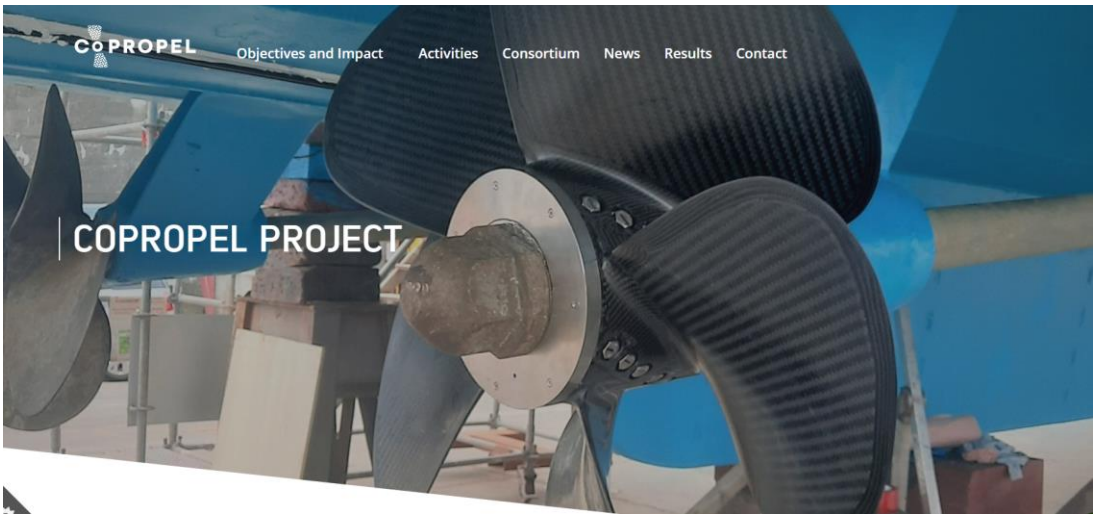


Figure 7 Front page for the CoPropel Project

Below Figure 8, Figure 9 and Figure 10 represent the website statistics during the project period.

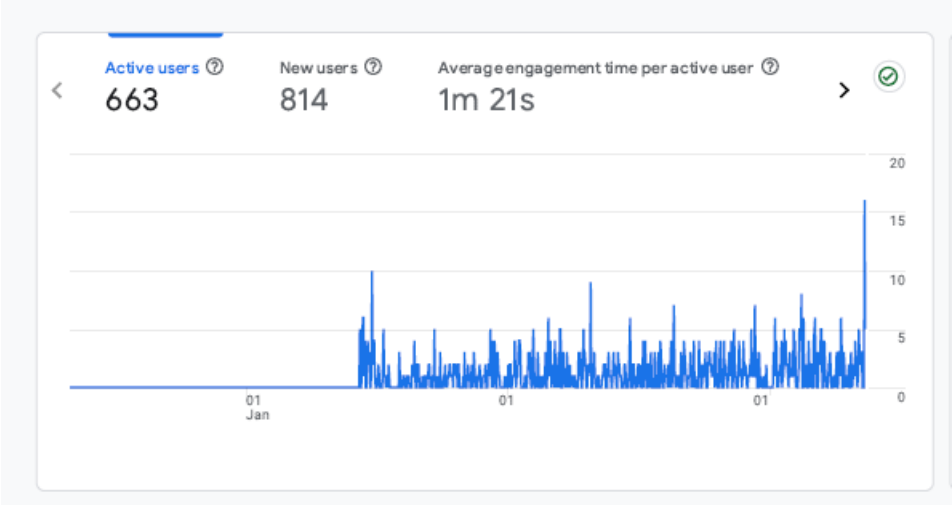


Figure 8: Website user interaction over the project period

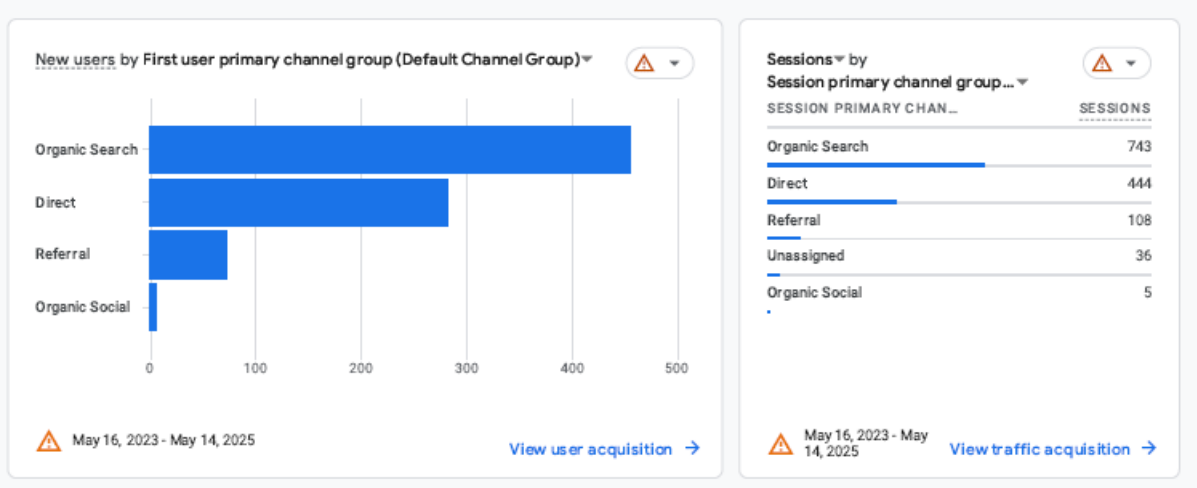


Figure 9: Website search statistics

In Figure 9, the user engagement on the website showed a steady increase throughout the period, with a final spike in visitors indicating growing interest driven by the project's upcoming final dissemination activities.

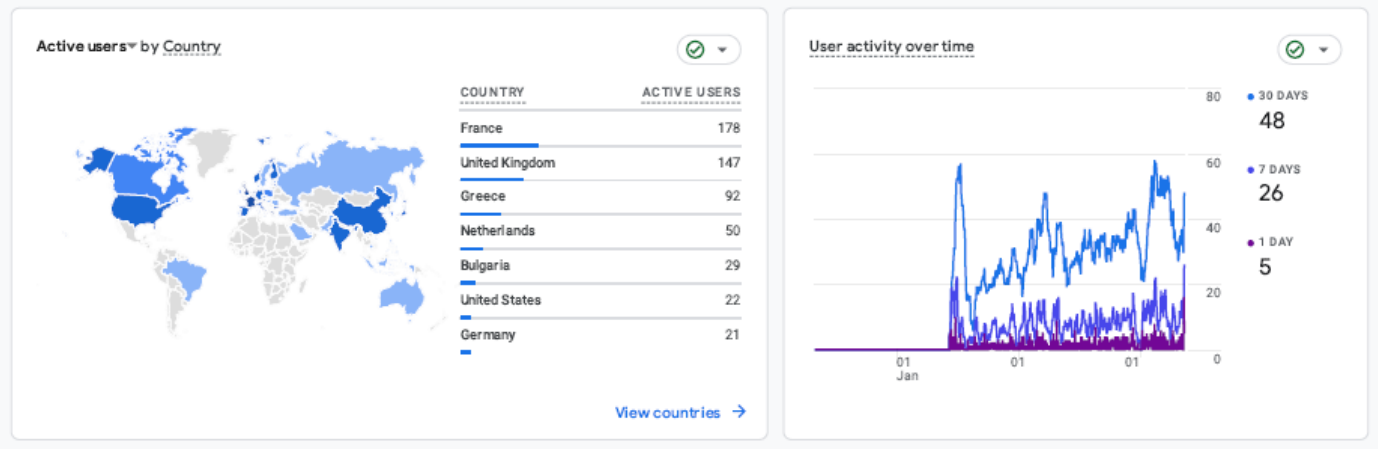


Figure 10: Website usage based on country

Figure 10 illustrates user engagement by country, showing that the website attracted visitors from all major continents, with the highest user share coming from Europe and North America.

3.2.2 Social media accounts

The LinkedIn account which was created during the beginning of the project is kept up to date and mirrors information shared on the website to increase visibility and reach a larger audience. The LinkedIn URL along with the relevant updates about the project is: https://www.linkedin.com/showcase/88277875/admin/page-posts/published/ Screenshots from the LinkedIn account are provided in Figure 11. The Figure 12 shows the social engagement over the past 1 year.

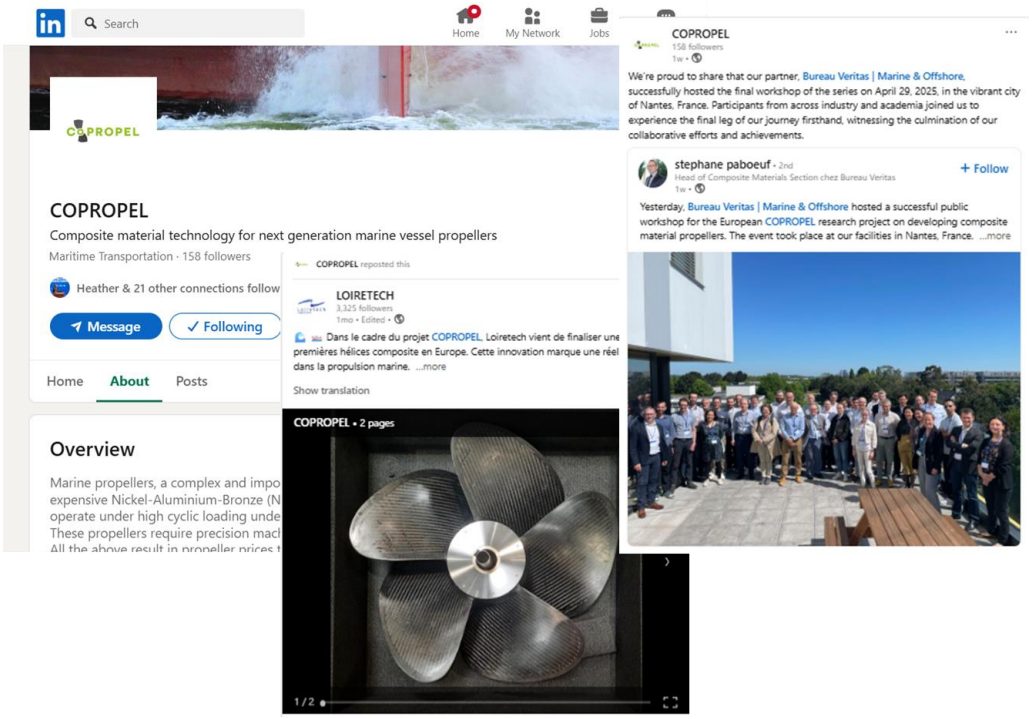


Figure 11 LinkedIn Screenshots

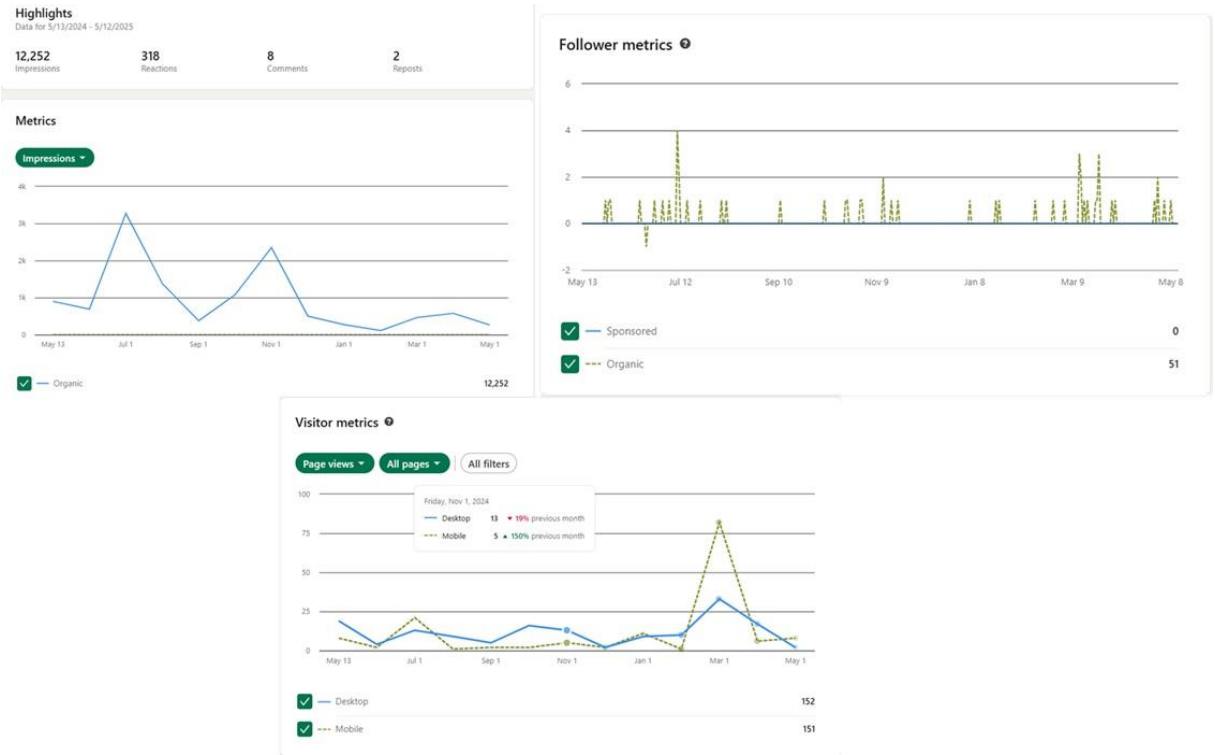


Figure 12: Last 1 year analytics

3.2.3 Project video

CGI Video: A dedicated video was updated to reflect the changes in the propeller design, and the boat intended for promoting the project activities was also developed. Figure *13* presents screenshots from the CoPropel video.

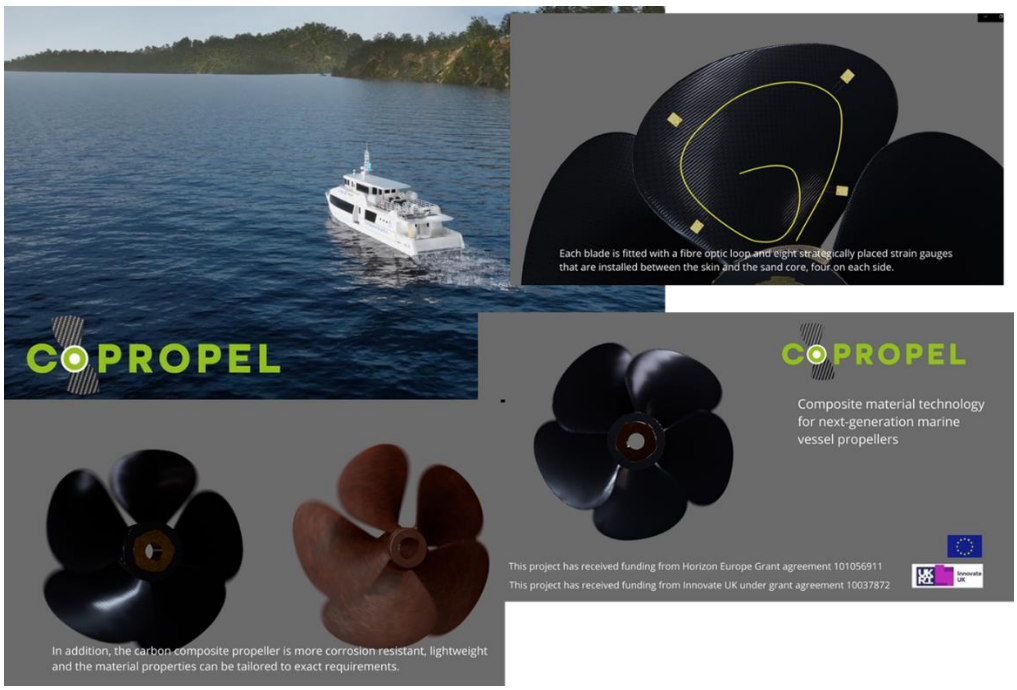


Figure 13 Screenshots from CGI project video

Progress video #1 and #2: Two milestone events—blade manufacturing and sea trials—were documented and condensed into a short video lasting 60 to 90 seconds. This video was shared on both the project website and social media platforms. The Figure 14 shows the screenshots of videos prepared for communicating the project results and thus achieving the milestones.

Figure 14: Screenshots from video#1 and video#2

3.2.4 Other promotional material

Apart from the logo, website, LinkedIn account, brochure and video, an infographic has been developed as shown in Figure 15. As part of the dissemination strategy, infographics played a key role in effectively communicating the

core messages and outcomes of the CoPropel project. Printed infographics were used at conferences and events attended by consortium members to provide concise, accessible overviews of the project's objectives.

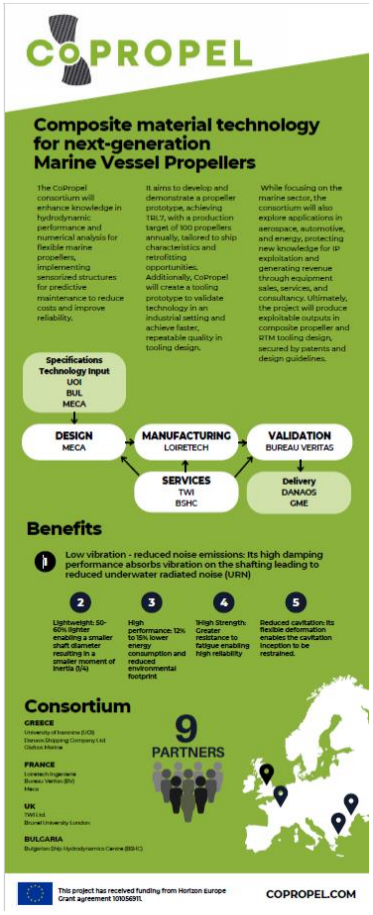


Figure 15 CoPropel infographic

4. Dissemination and exploitation strategy

Dissemination is a significant tool that is used to inform people (i.e. consortium members, the general public and specific target groups of stakeholders in the related scientific fields) of the achievements and activities performed within this project. Exploitation activities involve all actions related to the use of the knowledge generated within the project. Consequently, by effectively and strategically disseminating and exploiting the project's results, greater public awareness is created, as well as knowledge sharing, transparency and education being promoted.

The dedicated plan for the dissemination and exploitation of CoPropel results has been prepared and is detailed below.

- The inclusion of project results in the Partners web sites.
- The publication of project results in technical papers, trade journals and conferences.
- Disclosure of information through a project brochure to relevant associations and organizations.

This plan summarizes the consortium's strategy and concrete foreseen actions to disseminate, exploit, and protect the new knowledge produced within CoPropel. The dissemination leader LRT played an essential role both in the definition and implementation of this dissemination plan using their own network towards factory partners in fabrication and OEMs. The scientific knowledge developed was disseminated to the target end-users through established links fostered by large beneficiary partners within the consortium. The target audiences and dissemination activities are listed in ***Table 4***.

Table 4 CoPropel Dissemination Strategy- Target audience and means of engagement

Target audience	Format	Activity	Distribution	Deliverable	Short name[2]
Scientific community	Research publication, Conferences, workshops, emails, website	Technical information review	Six monthly to Project participants, scientific community	Technical design package	CoPropel-Dis1.X
Educators	Training documents, workshops	Training reviews	As required to Project Team and Stakeholders	Training material and report	CoPropel-Dis2.X
Marine and manufacturers Professionals	Emails, website, interactive forums, workshops, implementation of the methods and the tools into commercially available software	Project results reviews, updates	Quarterly to Professionals	Project outcomes: Website, interactive forums, workshops	CoPropel-Dis3.X

4.1. Objectives

The primary objective of the CoPropel Dissemination and Exploitation Plan is to strategically identify and organize activities to be executed in a timely manner, maximizing the project's overall impact. It also considered the dissemination needs at each stage of the project lifecycle, along with the specific technical, market, and organizational interests of the defined CoPropel target groups and end users. The main aims of this approach can be summarized as follows:

8) **Inform** about the CoPropel activities to stimulate the participation of SMEs, Academia, Industry, Research Establishments, civil society and their networks. Organise (participate in) events, workshops and seminars;

9) **Raise Awareness**: Present the project, its main objectives and expected impact (e.g. CoPropel public website, social media pages, project leaflet, poster and newsletter, etc.);

[2] The dissemination activities mentioned in Table 4 are broad categories of the activities performed in CoPropel. Therefore a serial number has been included in the short name to take into account the different activities within each category when reporting on the EU portal.

10) **Networking**: Exchange experiences with other projects relevant to CoPropel in order to combine efforts, minimize duplication and maximize its exploitation potential;

11) **Disseminate Knowledge and make the toolset commercially available to industry**: Regularly provide information about CoPropel results through several channels (e.g. Horizon Europe, the EU Research and Innovation Magazine);

12) **Support CoPropel Exploitation**: Pave the way for a successful exploitation of the project's results by addressing the full range of potential users and uses, including research, commercial, and investment, social, environmental, policy making, setting standards, skills and educational training.

4.2. Publication of articles and participation in scientific conferences

As part of the project's dissemination activities, a range of project-related texts were made available for unrestricted distribution by the beneficiaries across Europe and beyond. The consortium aimed to publish papers in high-impact peer-reviewed journals and industry-specific magazines to promote advancements in composite materials, manufacturing and automation, as well as processing simulation and modelling. Articles are written once the project results have been identified and validated, and enough evidence has been gathered to meet the requirements of the peer review process. It should be noted that, due to the nature of the project, the majority of publications were expected to be produced during the final year of the project and after its official conclusion. The scientific publications—including conference papers and articles in peer-reviewed journals—produced during the 36-month duration of the Copropel project are listed in ***Table 5***.

Short name	Type of activity	Description
CoPropel-Dis1.1	Conference	Clement Retiere, Maël Moret, Aldyandra Hami Seno, Nithin Amirth Jayasree, Mihalis Kazilas, 'Introduction to CoPropel: **Composite materials for marine propellers to reduce fuel consumption and underwater radiated noise'**, ECCM21 – 21st European Conference on Composite Materials 02-05 July 2024, Nantes, France
CoPropel-Dis1.2	Conference	Stéphane Paboeuf, Maxime Deydier, Pierre Berthelot and Sébastien Loubeyre, '**Certification approach for composite propeller with design assessment based on new tool application'**, ECCM21 – 21st European Conference on Composite Materials 02-05 July 2024, Nantes, France
CoPropel-Dis1.3	Conference	Marion Larreur , Thibaut Alleau, Gabriel Héguy, Daniel Pierrat, Elamine Gheffari, '**Design methodology for flexible composite propeller by coupling structural and hydrodynamic simulations'**, ECCM21 – 21st European Conference on Composite Materials 02-05 July 2024, Nantes, France
CoPropel-Dis1.4	Conference	Aldyandra Hami Seno, Swaroop Narayanan Nair, Sofia Sampethai, Stuart Lewis, Dimitrios Fakis, Akram Zitoun, Nithin Amirth Jayasree, Mihalis Kazilas, '**Validation of a novel underwater wireless strain monitoring system for a smart composite propeller under static and fatigue testing'**, ECCM21 – 21st

		European Conference on Composite Materials 02-05 July 2024, Nantes, France
CoPropel-Dis1.5	Conference	Maria Xenidou, Kyriaki Tsirka, Andreas Kalogirou, Alkiviadis Paipetis, '**Integration of fiber optic sensors into CFRP for structural health monitoring of a marine composite propeller'**, ECCM21 – 21st European Conference on Composite Materials 02-05 July 2024, Nantes, France
CoPropel-Dis1.6	Conference	Aldyandra Hami Senoa, Dimitrios Fakis, Akram Zitoun, Mihalis Kazilas, Maria Xenidou, Andreas Kalogirou, Kyriaki Tsirka, Alkiviadis Paipetis, Marion Larreur, '**Smart Self-sensing Composite Marine Propeller: Increased maintenance efficiency through integrated structural health monitoring systems'**, 10th Transport Research Arena, TRA 2024, Dublin, Ireland.
CoPropel-Dis1.7	Journal publication	Maria Xenidou, Kyriaki Tsirka, Andreas Kalogirou, Nick Markov, Valeriy Dimitrov, Clement Retiere, Gabriel Heguy, Thibaut Alleau, Alkiviadis Paipetis, '**Design, Manufacturing, Hydrodynamic Testing & Structural Health Monitoring of a Composite Marine Propeller with Embedded Fiber Optic Sensors'**, Journal of Composite Part B: Engineering (Manuscript submitted: Under review)
CoPropel-Dis1.8	Conference/ Proceedings	Kashan Ali, Maxime Deydier, Stephane Paboeuf, Pauline Regnier, Gabriel Heguy, Thibaut Alleau, '**Numerical validation of a composite propeller design by using different hydro-structural coupling methods'**, Proceedings of the ASME 2025 44th International Conference on Ocean, Offshore and Arctic Engineering OMAE2025, June 22-27, Vancouver, British Columbia, Canada (future event)

Table 5: The scientific publications, both conference papers and publications at peer reviewed scientific journals

Short name	Type of activity	Description
CoPropel-Dis1.1	Conference	Clement Retiere, Maël Moret, Aldyandra Hami Seno, Nithin Amirth Jayasree, Mihalis Kazilas, 'Introduction to CoPropel: **Composite materials for marine propellers to reduce fuel consumption and underwater radiated noise'**, ECCM21 – 21st European Conference on Composite Materials 02-05 July 2024, Nantes, France
CoPropel-Dis1.2	Conference	Stéphane Paboeuf, Maxime Deydier, Pierre Berthelot and Sébastien Loubeyre, '**Certification approach for composite propeller with design assessment based on new tool application**', ECCM21 – 21st European Conference on Composite Materials 02-05 July 2024, Nantes, France
CoPropel-Dis1.3	Conference	Marion Larreur , Thibaut Alleau, Gabriel Héguy, Daniel Pierrat, Elamine Gheffari, '**Design methodology for flexible composite propeller by coupling structural and hydrodynamic simulations**', ECCM21 – 21st European Conference on Composite Materials 02-05 July 2024, Nantes, France

CoPropel-Dis1.4	Conference	Aldyandra Hami Seno, Swaroop Narayanan Nair, Sofia Sampethai, Stuart Lewis, Dimitrios Fakis, Akram Zitoun, Nithin Amirth Jayasree, Mihalis Kazilas, '**Validation of a novel underwater wireless strain monitoring system for a smart composite propeller under static and fatigue testing**', ECCM21 – 21st European Conference on Composite Materials 02-05 July 2024, Nantes, France
CoPropel-Dis1.5	Conference	Maria Xenidou, Kyriaki Tsirka, Andreas Kalogirou, Alkiviadis Paipetis, '**Integration of fiber optic sensors into CFRP for structural health monitoring of a marine composite propeller**', ECCM21 – 21st European Conference on Composite Materials 02-05 July 2024, Nantes, France
CoPropel-Dis1.6	Conference	Aldyandra Hami Senoa, Dimitrios Fakis, Akram Zitoun, Mihalis Kazilas, Maria Xenidou, Andreas Kalogirou, Kyriaki Tsirka, Alkiviadis Paipetis, Marion Larreur, '**Smart Self-sensing Composite Marine Propeller: Increased maintenance efficiency through integrated structural health monitoring systems**', 10th Transport Research Arena, TRA 2024, Dublin, Ireland.
CoPropel-Dis1.7	Journal publication	Maria Xenidou, Kyriaki Tsirka, Andreas Kalogirou, Nick Markov, Valeriy Dimitrov, Clement Retiere, Gabriel Heguy, Thibaut Alleau, Alkiviadis Paipetis, '**Design, Manufacturing, Hydrodynamic Testing & Structural Health Monitoring of a Composite Marine Propeller with Embedded Fiber Optic Sensors**', Journal of Composite Part B: Engineering (Manuscript submitted: Under review)
CoPropel-Dis1.8	Conference/ Proceedings	Kashan Ali, Maxime Deydier, Stephane Paboeuf, Pauline Regnier, Gabriel Heguy, Thibaut Alleau, '**Numerical validation of a composite propeller design by using different hydro-structural coupling methods'**, Proceedings of the ASME 2025 44th International Conference on Ocean, Offshore and Arctic Engineering OMAE2025, June 22-27, Vancouver, British Columbia, Canada (future event)

4.3. CoPropel workshop

Three dedicated workshops to promote the activities of CoPropel project were conducted during Q2-2024, Q4-2024 and Q2-2025. The workshops aimed to let the rest of the marine and composite materials community know that this project is working on proving the efficiency of a composite propeller which leads to lower fuel consumption, reduced underwater radiated noise and that have an appropriate structural health monitoring (SHM) system. Each workshop was organised as a day event where the CoPropel partners have dedicated time slots to present their progress and activities as part of the project. Photos of the consortium and participants to the workshop are presented in Figure 16.

The ***Table 6*** represents the list of three workshops organized by the partners to disseminate the project results to external organizations. The attendees comprise researchers specializing in composite manufacturing technologies, as well as industrial end users—including those from the marine, automotive, and aerospace sectors, along with maintenance industries—who were interested in novel, high-throughput composite manufacturing solutions.

Table 6: List of workshop organized by the consortium

Short Names	Type of activity	Organizing partner	Number of external participant organization
CoPropel-Dis3.1	Workshop	Loiretech Engineering, Nantes, France: 11th April 2024	9
CoPropel-Dis3.2	Workshop	Bulgarian Ship and Hydrodynamic Centre (BSHC), Varna, Bulgaria: 24th October 2024	8
CoPropel-Dis3.3	Workshop	Bureau Veritas (BV), Nantes, France: 29th April 2025	27

The Figure 16 shows the participants who attended the workshops and able to witness the project journey, collaborative efforts and achievements.

Figure 16: Workshops event

4.4. Exploitation content

Exploitation activities involved all actions related to the use of the knowledge generated within the project. Through effective and strategic dissemination and exploitation of the project results, greater public awareness was created, along with increased knowledge sharing, transparency, and education. The exploitation of results achieved during the CoPropel project enhanced the relationships among consortium partners and increased business opportunities for future applications with Tier 1 end users. The results achieved during the project contributed to innovation in marine propeller product design and marine composite manufacturing processes, and supported the development

of competences and capabilities within the European marine industry. Below are the potential exploitation results from the project.

4.4.1 Composite propeller manufacturing

The CoPropel project's consortium partners have helped generate knowledge to pave the way for the commercialization of composite propellers for boats. LOIRETECH, the manufacturer of tooling and composite propellers, was able to optimize its manufacturing process in preparation for industrial-scale production.

To begin with, LOIRETECH designed, manufactured and tested the operation of injection tooling for the RTM process, taking into account the integration of sensors inside the composite, i.e. an SHM system. Several of the manufacturer's customers have shown an interest in this type of technology, which could enable it to develop a new market.

At the same time, the development of the PMOC system for injection tooling has brought to light a new type of sensor, piezoelectric sensors, which can monitor the degree of curing of the resin as well as its progress through the mold. The manufacturer will then be able to design tooling with this type of monitoring, which was not previously available. However, further development of such a system is still required before it can be put to industrial use.

Then, with CoPropel, LOIRETECH was able to confirm its expertise in the manufacture of fabric shaping and injection tooling for the RTM process. LOIRETECH had already mastered this commercial activity prior to the CoPropel project. However, the CoPropel project can help LOIRETECH to convince customers to work with them by presenting the demonstrators (tooling and composite parts) produced during the project. At least one major commercial project has been won by LOIRETECH, thanks to the activities carried out during CoPropel, for the serial production of composite parts.

During the CoPropel project, when manufacturing the small-scale propeller, LOIRETECH designed and manufactured a new type of injection mold using a material they had patented in a previous project. The SILAXY material is obtained by infusing resin into a sand-based mineral 3D print. The CoPropel project enabled LOIRETECH to test this new type of injection mold under industrial conditions. This new tooling concept is less expensive than metal tooling, and requires less manufacturing time. The CoPropel project has enabled LOIRETECH to showcase the SILAXY material for a new application that could be commercialized in the future.

Finally, the CoPropel project has enabled LOIRETECH to strengthen its market position in the manufacture of RTM tooling and composite parts for boat propellers. This manufacturer has made a name for itself in propeller manufacturing, with research organizations, designers, boat builders and shipyards in Lorient. Various communication activities such as trade fairs (JEC, ECCM), workshops and press articles have helped to give LOIRETECH visibility in the manufacture of composite propellers. The results obtained during the project, and more particularly during the sea trials, provide strong arguments for LOIRETECH to convince boat builders to switch to composite rather than metallic propellers. Following the CoPropel project, LOIRETECH was consulted several times for other research projects involving composite propeller manufacturing.

4.4.2 Wired and wireless SHM system for composites in marine application

The development of the wired and wireless SHM systems for composite propellers in CoPropel was performed by UOI and BUL, respectively. LRT successfully integrated both systems in the manufactured propellers both at small and large scale.

The wired system consisted of Fiber Optic sensors embedded in the composite propeller, which can provide distributed strain measurements from the blade during operation as well as off-line. Application of the system was fully demonstrated during the hydrodynamic testing of the small-scale propeller at BSHC facilities and was also demonstrated for off-line measurements of the propeller before and after sea trials.

Development of a complete solution for application of integrated fiber optic sensors in a rotating propeller was expected to reach TRL 5-6 during CoPropel and this goal was achieved. The complete solution required efforts at lab scale coupon level to select the less intrusive method for fiber placement and evaluate sensor integration against mechanical properties of the composite specimens, design efforts by MECA to integrate the fiber optic sensor into the blade design, selection of the most appropriate technology (Rotary Joint) to couple and transfer the optical signal from the rotating part to the acquisition system, design of a protective cap hosting the rotary joint and selection of a support structure for application of the complete solution.

All these activities generated knowledge and practical experience for UOI and the other involved partners (LRT, BSHC, MECA) which is already being used for further development of the technology, led to the preparation and submission of a publication, and last but not least led to increased interest by stakeholders outside the consortium to form new collaborations in order to further exploit the technology. Further exploitation of the results from UOI includes development efforts to mature the wired technology to a higher TRL level and development of possible solutions for a wireless SHM system based on fiber optics for large diameter propeller applications.

The wireless strain gauge system developed by BUL is an ambitious solution for structural health monitoring of rotating structures, achieving TRL 4 through successful laboratory demonstration on coupons and partial field deployment. The system utilises an innovative approach for both data transmission (433MHz) and wireless power transfer (110kHz) through coaxial coil coupling, which is suitable for seawater, eliminating the need for slip rings between the rotating propeller and stationary vessel systems. Developing this solution generated valuable intellectual property for BUL in the areas of electromagnetic interface design, signal processing algorithms for noisy marine environments, and power management strategies for autonomous sensor operation.

The development efforts produced a complete hardware and software solution, including custom Arduino firmware for multi-channel strain acquisition, Python-based real-time visualization tools, and automated data logging capabilities. Despite challenges with sensor survivability (40% retention rate) and connection reliability during sea trials, the demonstrated technologies have attracted interest from marine propulsion manufacturers and classification societies. BUL will actively pursue further development opportunities, including transitioning to integrated PCB designs, implementing machine learning algorithms for automated damage detection, and exploring applications in wind turbine monitoring where similar rotating interface challenges exist. The knowledge gained regarding microcoaxial cable integration, electrical isolation strategies, and wireless communication protocols in conductive media positions BUL as a key partner for future marine SHM implementations.

5. Market outlook

The CoPropel consortium is constantly updating the post-project exploitation plan that has been created with regards to the technology developed in the project. This high-level analysis of the state of the target market is intended to support the ongoing development of the plan.

The scope of this report is to assess the characteristics and growth forecasts for the project's target market, namely marine propeller manufacturing. It also examines the influence of policy and regulation, and the competitive landscape of the target market.

5.1. Status of target markets:

It provides an overview of the current conditions, trends, and growth potential of the identified target markets, serving as a foundation for assessing the commercial viability of the project outcomes.

5.2. Ocean freight market

The continuing uncertainty over US tariffs is likely to continue to shape and disrupt global markets around the world, increasing the cost of global trade and the potential for a global recession. Retaliatory counter-tariffs will likely affect the volume and cost of freight in the shipping container sector, however the effect of re-routing shipping trade to avoid tariffs is still uncertain until there is more clarity regarding countermeasures. The tanker market is likely to see less impact, as imports of oil, gas, and refined products were exempted from the US tariffs, however the overall economic impact of tariffs will still likely be heavy in this sector (Lloyd's List Intelligence).

Recent changes in port fee structures in the US will significantly impact Chinese carriers and shipyards in particular, although vessels smaller than 4,000 TEU or on voyages shorter than 2,000 nautical miles will be exempt from the new fee structure, and shipping companies may try to circumvent the costs by moving to smaller or exempt vessels. Currently about 20% of containerships calling at US ports will be affected.

Although global container trade experienced an 11.2% increase at the beginning of 2025, the forecast has now been revised to predicting a decline of 1.1% globally. This is due to shipping companies pausing shipments as they wait for the outcome of tariff negotiations and/or counter-tariff measures in retaliation to US-imposed tariffs (DHL).

5.3. Shipbuilding

The ship building market is forecast to grow from US$236.09 billion in 2025 to US$295.63 billion by 2029 (a CAGR of 5.8%). A major focus will be the growing tourism industry - a significant resurgence in global travel post-pandemic is shown in international tourist receipts exceeding US$1 trillion in 2023. This will continue to be a driving force behind the ship building market's growth (Research and Markets, March 2025).

The global market for marine propellers is expected to grow at a CAGR of 5.1% from 2024 to 2030, from US$5.7 billion to US$7.7 billion. The increasing demand for fuel efficiency and environmentally friendly propulsion systems is driving the advancement in propeller design and materials (Research and Markets, May 2025).

5.4. Propellers

The global market for marine propellers is expected to grow at a CAGR of 5.1% from 2024 to 2030, from US$5.7 billion to US$7.7 billion. The increasing demand for fuel efficiency and environmentally friendly propulsion systems is driving the advancement in propeller design and materials (Research and Markets, May 2025).

Overall, the composite propeller market, which includes aviation and aerospace as well as the marine industry, is projected to increase in value from US$1.1 billion in 2023 to US$2.3 billion by 2031, a growth of 8.5% CAGR. In the marine sector, the resistance of composite materials to corrosion and a reduction in maintenance requirements will influence this growth. Growth in both recreational boating and commercial shipping will be the drivers in this sector. Overall, industry will see a growth in composite propellers with their longer lifespan and maintenance cost savings over time, although high initial costs for this technology, regulatory and certification standards, and complex manufacturing processes may act as restraints on the composite propeller market (Verified Market Research).

5.5. The influence of policy and regulation

5.5.1 Noise reduction

The International Maritime Organization released its revised guidelines regarding the reduction of underwater radiated noise (URN) in 2023. Propeller design is acknowledged to be an important factor in reducing URN, by minimising cavitation and optimising energy efficiency (IMO, p7).

"Measures aimed at reducing applied or installed propulsion power and propeller thrust loading, with the appropriate safety caveats,4 are options to improve energy efficiency, reduce emissions, and typically result in URN reduction, e.g. wind assistance, optimized hull design, and regular maintenance and hull cleaning to avoid fouling and reduce hull resistance are all effective measures for reduced emissions and URN." (IMO, p12)

5.5.2 Qualification and certification of composite propellers

A public guidance note, NI663, was issued by Bureau Veritas at the end of Fabheli project and prior to Copropel. This note covers all aspects of composite propeller certification, from design assessment to manufacturing, testing, and sea trials.

During the project, a certification guideline was written as part of deliverable D6.4. It is based on work performed in all work packages, concerning recommendations or requirements for certification, which was not previously described in NI663. It is also illustrated with multiple examples from the project on how to justify the different requirements. While this guideline is a sensitive deliverable, BV will use this work to improve the public guidance note NI663. A new version should be published in 2025 or 2026 and will implement different requirements and recommendations that were described in D6.4, such as intrusivity for SHM (Structural Health Monitoring) sensors, balancing criteria or sea trial procedure.

6. Supply chain and market entry points

In order to understand where the CoPropel technology will be targeted, a theoretical supply chain model is presented below in Figure 17. This model helps understanding of the value-adding stages, activities and actors involved in taking a major component from functional design (TRL 4-6) through to at-scale manufacture (TRL 9).

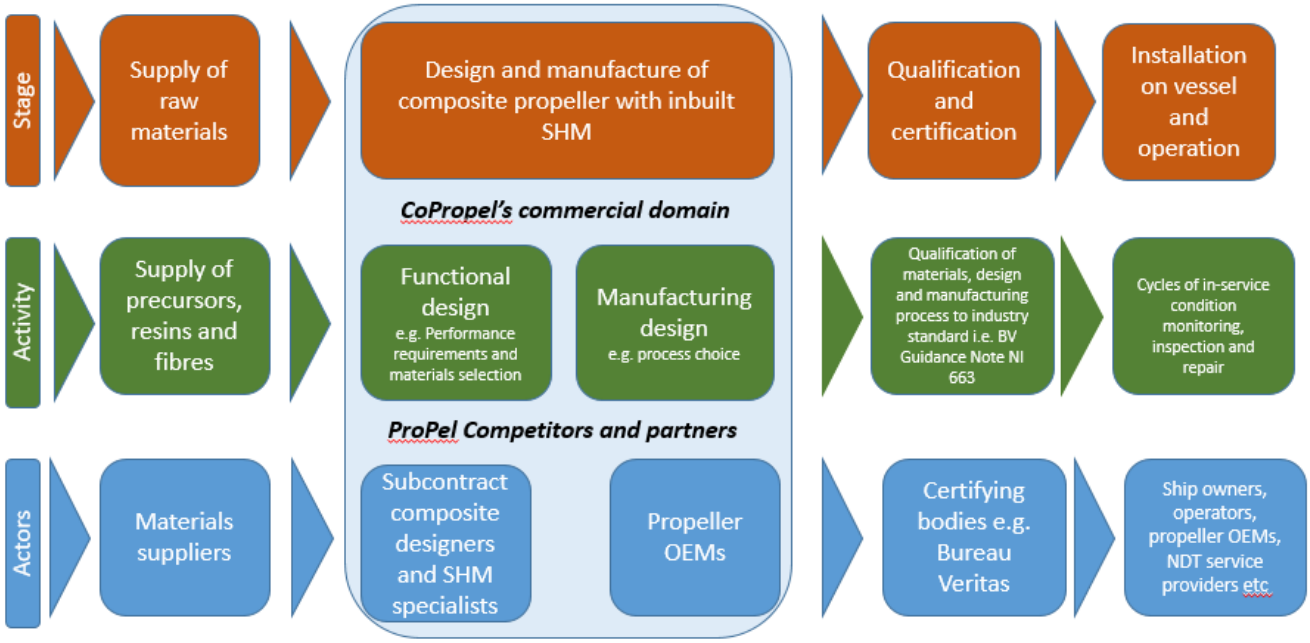


Figure 17: CoPropel theoretical supply chain model

The project CoPropel technology have advanced to TRL 7 (system prototype in an operational environment, via sea trials), but is not fully market ready. On the other hand, the manufacturer is already ready to start producing composite propellers. We now need to analyze all the data before we can convince boat builders. To achieve a commercial application, it would be necessary to show interest in larger propellers, such as 4 meters in diameter. When it is, it will address the central design and manufacture stage of the supply chain. To get to that point in a live commercial/industrial context may need further investment and industrial partnership.

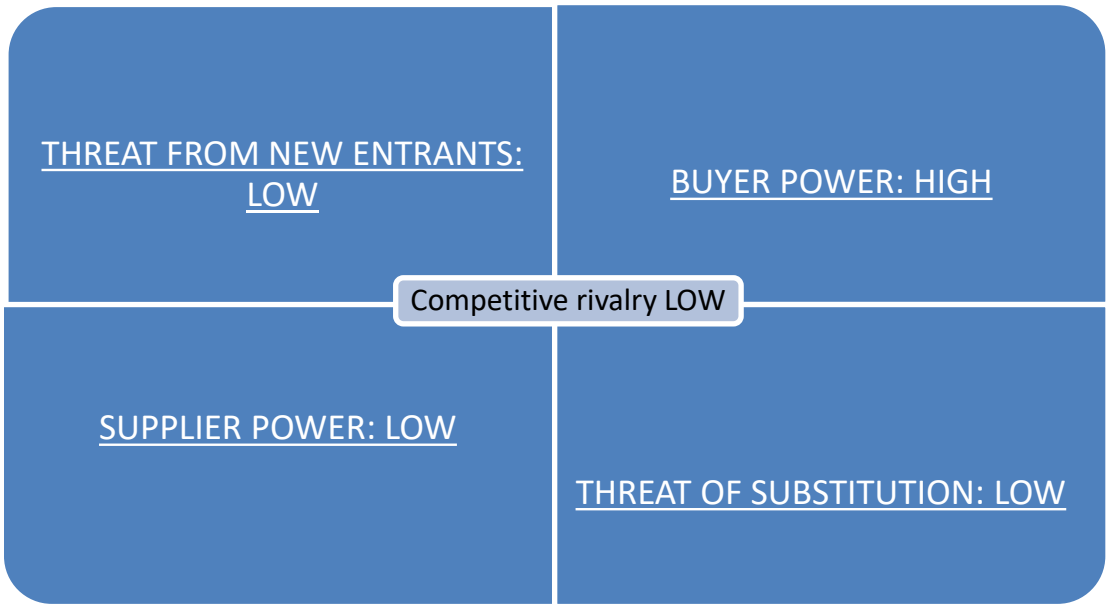
7. Competitive landscape

The principal incumbents in the market for marine propellers are listed in ***Table 7***. Those that use composite materials are highlighted with an asterisk and hyperlinks.

Table 7 Principal propeller manufacturers

AB Volvo
Balti Composite Technology (formerly AIR Fertigung-Technologie GmbH)*
Brunswick Corporation
Hyundai Heavy Industries
Kawasaki Heavy Industries Ltd.
LoireTech*
MAN Energy Solutions SE
Méca*
Mecklenburger Metallguss GmbH
Mercury Marine
Metstrade*
Mitsubishi Heavy Industries Ltd.
MOTH
Nakashima Propeller Co. Ltd.*
Naval Group*
Pirhana*
ProPulse AB* (no website available)
Rolls-Royce Holdings
Schaffran Propeller + Service GmbH
Schottel GmbH
Teignbridge Propellers International Limited
Veem Ltd.
Wartsila

8. Porter – five forces analysis



Supplier power – low

- Competitive due to numerous materials suppliers.
- CoPropel's materials requirements are standard.
- Switching suppliers to get better deals easy.

Threat from new entrants – low

- Few new entrants join market due to high capex costs of metal casting.
- However, threat could escalate rapidly due to the introduction of a disruptive technology e.g. CoPropel

Buyer power - High

- Large ship builders add capacity at the top of the market, creating 'boom and bust' cycles out of step with wider economic cycle.

Threat of substitution – low

- No direct competitor that combines composite propeller with integral SHM capability

Overall degree of competitive rivalry – low

- CoPropel has ‘first mover’ advantage

9. Conclusion

In conclusion, the CoPropel project successfully advanced marine propeller design and composite manufacturing, generating valuable knowledge and fostering strong collaboration among consortium partners. Strategic communication, dissemination, and exploitation activities raised public awareness, supported knowledge sharing, and opened new business opportunities with Tier 1 end users. This deliverable summarises the strategy and tools used to manage these activities, detailing the efforts made to promote the project and maximise its impact within the European marine industry.

A dedicated website and LinkedIn account were strengthen the support to the project's outreach, and a distinctive logo, serving as the visual identity of CoPropel, was consistently used across all marketing materials. A CGI and the milestone promotional video was also developed and showcased at various events to provide an overview of CoPropel's activities. The deliverable presents the target markets and outlines a plan for the exploitation of project results, including key activities and the intended pathways for implementation. Additionally, it includes a description of the multimedia promotional package and provides an update on the events and conferences that partners have attended to date, as well as those planned for the remainder of the project.

As part of the dissemination efforts, three dedicated workshops were organised to share the project outcomes with external organisations that had expressed interest. These workshops targeted both researchers in composite manufacturing technologies and industrial end users—including representatives from the marine industries and academia who were interested in high-throughput, innovative composite manufacturing solutions.

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