DELIVERABLE 4.6
Updated version of MARENDATA

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WP 4

Deliverable 4.6 Updated version of MARENDATA

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SAFE WAVE project synopsis

The European Atlantic Ocean offers a high potential for marine renewable energy (MRE), which is targeted to be at least 32% of the EU's gross final consumption by 2030 (European Commission, 2020). The European Commission is supporting the development of the ocean energy sector through an array of activities and policies: the Green Deal, the Energy Union, the Strategic Energy Technology Plan (SET-Plan) and the Sustainable Blue Economy Strategy. As part of the Green Deal, the Commission adopted the EU Offshore Renewable Energy Strategy (European Commission, 2020) which estimates to have an installed capacity of at least 60 GW of offshore wind and at least 1 GW of ocean energy by 2030, reaching 300 GW and 40 GW of installed capacity, respectively, moving the EU towards climate neutrality by 2050.

Another important policy initiative is the REPowerEU plan (European Commission, 2022) which the European Commission launched in response to Russia's invasion of Ukraine. REPowerEU plan aims to reduce the European dependence amongst Member States on Russian energy sources, substituting fossil fuels by accelerating Europe's clean energy transition to a more resilient energy system and a true Energy Union. In this context, higher renewable energy targets and additional investment, as well as introducing mechanisms to shorten and simplify the consenting processes (i.e., 'go-to' areas or suitable areas designated by a Member State for renewable energy production) will enable the EU to fully meet the REPowerEU objectives.

The nascent status of the Marine Renewable Energy (MRE) sector and Wave Energy (WE) in particular, yields many unknowns about its potential environmental pressures and impacts, some of them still far from being completely understood. Wave Energy Converters' (WECs) operation in the marine environment is still perceived by regulators and stakeholders as a risky activity, particularly for some groups of species and habitats.

The complexity of MRE licensing processes is also indicated as one of the main barriers to the sector development. The lack of clarity of procedures (arising from the lack of specific laws for this type of projects), the varied number of authorities to be consulted and the early stage of Marine Spatial Planning (MSP) implementation are examples of the issues identified to delay projects' permitting.

Finally, there is also a need to provide more information on the sector not only to regulators, developers and other stakeholders but also to the general public. Information should be provided focusing on the ocean energy sector technical aspects, effects on the marine environment, role on local and regional socio-economic aspects and effects in a global scale as a sector producing clean energy and thus having a role in contributing to decarbonise human activities. Only with an informed society would be possible to carry out fruitful public debates on MRE implementation at the local level.

These non-technological barriers that could hinder the future development of WE in EU, are being addressed by the WESE project funded by European Maritime and Fisheries Fund (EMFF) in 2018. The present project builds on the results of the WESE project and aims to move forward through the following specific objectives:

1. Development of an **Environmental Research Demonstration Strategy** based on the collection, processing, modelling, analysis and sharing of environmental data collected in WE sites from different European countries where WECs are currently operating (Mutriku power plant and BIMEP in Spain, Aguçadoura in Portugal and SEMREV in France); the SafeWAVE project aims to enhance the understanding of the negative, positive and negligible effects of WE projects. The SafeWAVE project will continue previous work, carried out under the WESE project, to increase the knowledge on priority research areas, enlarging the analysis to other types of sites, technologies and countries. This will increase information robustness to better inform decision-makers and managers on real environmental risks, broad the engagement with relevant stakeholders, related sectors and the public at large and reduce environmental uncertainties in consenting of WE deployments across Europe.

2. Development of a **Consenting and Planning Strategy** through providing guidance to ocean energy developers and to public authorities tasked with consenting and licensing of WE projects in France and Ireland; this strategy will build on country-specific licensing guidance and on the application of the MSP decision support tools (i.e. WEC-ERA[1] by Galparsoro et al., 2021[2] and VAPEM[3] tools) developed for Spain and Portugal in the framework of the WESE project; the results will complete guidance to ocean energy developers and public authorities for most of the EU countries in the Atlantic Arch.
3. Development of a **Public Education and Engagement Strategy** to work collaboratively with coastal communities in France, Ireland, Portugal and Spain, to co-develop and demonstrate a framework for education and public engagement (EPE) of MRE enhancing ocean literacy and improving the quality of public debates.

[1] https://aztidata.es/wec-era/;
[2] Galparsoro, I., M. Korta, I. Subirana, Á. Borja, I. Menchaca, O. Solaun, I. Muxika, G. Iglesias, J. Bald, 2021. A new framework and tool for ecological risk assessment of wave energy converters projects. Renewable and Sustainable Energy Reviews, 151: 111539
[3] https://aztidata.es/vapem/

Executive summary

The present document describes the updated version of MARENDATA Data Platform (https://marendata.eu/), within the SafeWAVE project. MARENDATA is designed to present marine renewable energy industry with resource and impact assessment related information instantaneously in a format suitable for technical and non-technical audiences. It integrates datasets from the different sites, providing scientifically robust data on the potential environmental effects of marine energy devices to support consenting and licensing processes.

The SafeWAVE project enabled a continued improvement of the software supporting data organization and dissemination. Several new features were developed, and the goal of this Deliverable is to describe the underlying software and how the platform is maintained.

1. MARENDATA Data Platform

1.1 History

The first data were collected during the SOWFIA project[4]. This project ended in October 2013 and back then the name was SOWFIA's Data Management Platform (Leitão et al., 2013 and Magagna et al., 2012). In 2018 it got funds from projects WESE (https://marendata.eu/wese) and SeaWAVE (https://marendata.eu/seawave). After a poll proposed to all partners of both consortia, the name MARENDATA was chosen for the Data Platform.

The latest project that started using this platform is SafeWAVE (https://www.safewave-project.eu/).

Data from SOWFIA were integrated into the MARENDATA platform (https://marendata.eu/) and complemented with new data collected in the WESE and SeaWAVE project. Environmental data are collected in sites where devices are operating in Spanish, Portuguese, French and Scottish coastal waters, representing different types of marine environment (onshore, nearshore and offshore) that can potentially be affected by wave energy projects.

1.2 Present context

The data collection around wave energy harnessing devices currently operating at sea will increase the knowledge on positive, negative, and negligible environmental impacts of the following priority research areas:

1. risk to marine animals from sound generated by wave devices.
2. changes in physical systems (energy removal).
3. effects of Electromagnetic Fields (EMF).

[4] Further information on this project can be seen at https://ec.europa.eu/energy/intelligent/projects/en/projects/sowfia and https://www.plymouth.ac.uk/research/coast-engineering-research-group/sowfia-project

MARENDATA is where project generated primary raw data is organized along with validated metadata information (compliant with Spatial Information in the European Community INSPIRE Directive) and secondary data (post-processed data, if any). In addition, numerical results from wave hindcast models are also included in the platform.

Data measured by SafeWAVE partners was structured for dissemination purposes. This means that each data set needs to be adequate for storing and sharing. For example, some raw data is of the order of Terabytes. The concept used in the project was that each partner decides how its own data should be shared. The platform is organized to ensure that the data is findable, accessible, interoperable, and reusable.

1.3 Framework

The Vision and the Mission put forward for MARENDATA frames the long-term goals and helps establish partnerships with new financing projects and organizations.

Vision:

- The renewable energy industry requires complex environmental information in order to overcome the challenges of harnessing energy from the marine environment.
- This will be delivered through an established open platform aggregating multiple sources of raw and secondary data to ensure access to meaningful information for the user.

Mission:

- Establish an adequate IT platform that links with existing and new data repositories;
- Enable access to raw and secondary data;
- Disseminate data and knowledge previously reviewed by experts;
- Survive individual projects' financing constraints;
- Reach a significant audience in the industry.

2. Updates to the Platform

This report aims to provide a description of Marendata, focused on the updates developed during SafeWAVE. Those updates were designed to enhance the platform's functionality and user experience, but also aimed at speeding up the process of making data available in the platform:

- Third party identity providers: Users now have the option to log in to Marendata using their existing Microsoft, Google, or Facebook accounts. This integration simplifies the login process, facilitating a smoother onboarding experience for new users (described in D4.5).
- Database Triggers for Automatic Data Creation: To streamline data management, database triggers have been implemented to automatically synchronize data between the legacy SOWFIA database and the MARENDATA database. These triggers ensure that whenever new data is added or changed to the legacy database, it is promptly reflected in the MARENDATA database, eliminating the need for manual data entry and keeping information up-to-date across both systems.
- Integration of Marendata into the PRIMRE Portal: Marendata, has been seamlessly integrated into the Portal and Repository for Information on Marine Renewable Energy (PRIMRE) available at https://primre.org/. A deep link was made available from the primary endpoint, directing users to a specific dataset (described in D4.5).
- Interactive Visualization Tool Update: The interactive visualization tool aims to facilitate data treatment, visualization, and sharing. This tool empowers users to visualize graphs, compare variables, access PDF documents through an integrated viewer, and view videos all without needing to leave the platform. In SafeWAVE, the PDF viewer was added.
- Operational Forecast Models: The platform also includes the daily downloading of Global Ocean Waves Analysis and Forecast data, providing users with 3 days of hindcast data and 7 days of forecast

information. This functionality demonstrates the platform's versatile capacity to aggregate diverse information, including operationally executed models, thus enriching the analytical capabilities available to users.

3. Software design

3.1 Overall Architecture

The MARENDATA platform's architecture is modular and interoperable, designed to facilitate seamless data sharing, analysis, and regulatory compliance across diverse marine test sites. Developed using Angular, the platform benefits from this technology's responsiveness, efficiency, and modular structure, which supports easy customization and enhances user experience.

Key components include (Figure 1):

- **GeoNetwork** for metadata management.
- **Backend Database** (Legacy and New) for data storage and structured management.
- **Processing and Analytics Modules** to automate data processing.
- **User Interface** for data visualization, built with interactive maps and data displays. Additionally, **THREDDS** is used to serve spatial data layers via WMS, allowing users to render geospatial layers dynamically on the map within the UI, providing a powerful tool for marine data visualization and analysis.
- **API and Authentication** through Azure B2C, providing secure access and supporting HTTP requests for data extraction.

This architecture provides both flexibility and robust data management, making MARENDATA suitable for a wide array of stakeholders in marine energy research.

3.2 Data Ingestion Layer

The Data Ingestion Layer utilizes GeoNetwork for managing metadata linked to data submissions, allowing data providers to either create a new XML metadata file or upload an existing one. Data itself is uploaded separately by partners via an FTP server.

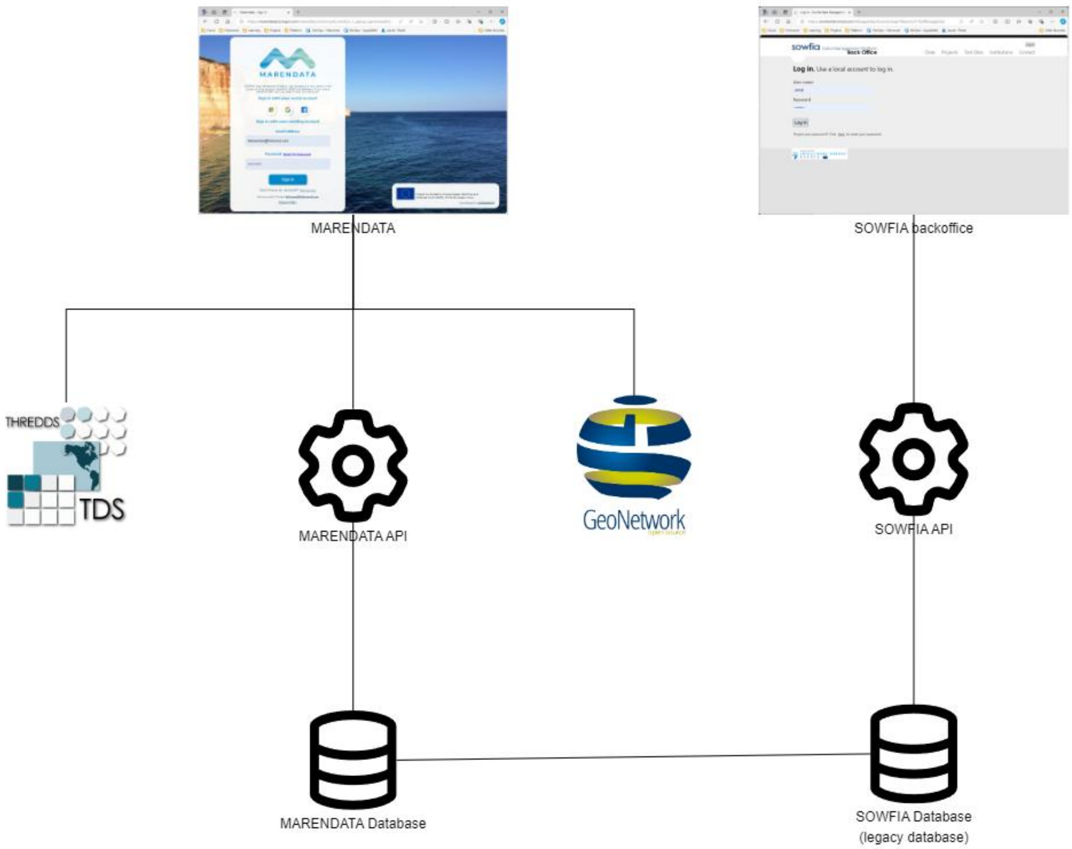

Figure 1. MARENDATA Architecture.

Once metadata and data is submitted in GeoNetwork portal (Figure 2), available at https://nautilus.hidromod.com:8443/geonetwork, Hidromod's team performs a thorough review to ensure that metadata aligns with the platform's structure and standards. Following this verification, metadata is integrated into a legacy database via the backend. Data files are copied from the FTP server and organized into an optimized structure, facilitating efficient and rapid loading into the platform, ensuring users have quick and reliable access to the information.

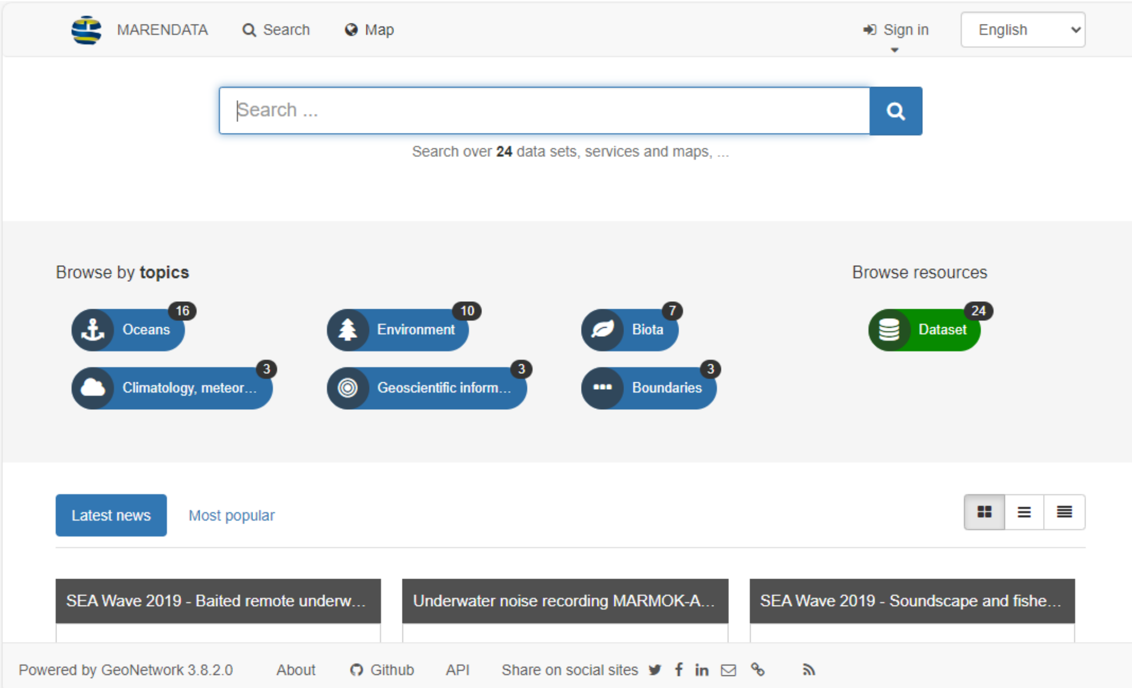

Figure 2. GeoNetwork portal.

3.3 Data storage

MARENDATA utilizes a dual-database system:

- **Legacy Database** (SOWFIA project): A repository for metadata and data managed under the SOWFIA back-office system, this database serves as a bridge between legacy data structures and MARENDATA.
- **MARENDATA Database**: This new database was designed to accommodate modern data demands and facilitate faster data access for visualization and reporting within MARENDATA.

A dedicated data synchronization protocol between the legacy and new databases includes triggers that automatically update the MARENDATA database whenever new information is added to the legacy database. This process ensures that data within MARENDATA is current, reducing manual entry and expediting data availability.

3.4 Processing and Analytics Layer

This layer supports automatic data processing, including report generation with environmental datasets like ERA5[5] model. Automated workflows manage data analysis and report visualization, allowing for efficient processing without manual intervention. These processes enable up-to-date, reliable analytics, which are critical for understanding marine site conditions and supporting regulatory compliance.

3.5 Presentation and Interaction Layer

The user-facing component of MARENDATA enables data access and interaction, supporting the visualization of datasets, including 2D graphics, geospatial map, PDF viewer, and videos stored on YouTube. The platform offers interactive data displays through maps, reports, and charts, making complex environmental data accessible and comprehensible.

The MARENDATA platform is structured to deliver an intuitive and visually rich experience for users, allowing seamless access to environmental data through interactive maps, charts, and geospatial data. Built with Angular, the platform benefits from high-performance rendering, component-based architecture, and responsive design. Angular's modular framework also supports streamlined updates and consistent user experience, enhancing maintainability and scalability.

The platform's visualization and interaction capabilities are powered by an array of libraries that bring advanced features to the user interface:

3.5.1 Map and Geospatial Visualization:

- **Leaflet**: This open-source library, integrated via the @asymmetrik/ngx-leaflet Angular wrapper, provides highly customizable map visualizations. Additional plugins like leaflet.markercluster and leaflet.awesome-markers enable

[5] ERA5 is the fifth generation European Centre for Medium-Range Weather Forecasts (ECMWF) atmospheric reanalysis of the global climate covering the period from January 1940 to present. ERA5 is produced by the Copernicus Climate Change Service (C3S) at ECMWF: https://www.ecmwf.int/en/forecasts/dataset/ecmwf-reanalysis-v5

sophisticated marker clustering and visual marker customization, ideal for presenting marine test site data on a large scale.

- **leaflet- time dimension**: This plugin supports time-based data visualizations, allowing dynamic rendering of data over time to track changes in environmental conditions.

3.5.2 Data Visualization and Reporting:

- **Highcharts**: The platform uses Highcharts for creating detailed charts and graphs. These visualizations allow users to analyze trends, perform comparative analyses, and gain insights into data collected from test sites. Highcharts supports multiple chart types and has responsive design capabilities, making it ideal for various data displays.
- **Kendo UI components**: Used for implementing date pickers, popup elements, and tree views, the Kendo Angular suite enhances the platform's interactivity, ensuring smooth and professional user experience.

3.5.3 User Authentication:

- **Azure B2C and OAuth Integration**: User authentication is secured via Azure B2C, which manages access permissions and enhances security through OAuth 2.0, allowing login with popular accounts like Microsoft, Google, or Facebook (described in detail in Deliverable 4.5). The system also supports custom tokens with one-year validity via the "x-api-key" field, enabling users to securely extract data through HTTP requests.

Detailed information on this feature can be found in Deliverable 4.5.

3.6 Interoperability and Standards

MARENDATA adheres to Open Geospatial Consortium (OGC) standards and is Inspire-compliant, ensuring interoperability with international data-sharing frameworks. This compliance allows seamless data exchange, facilitating integration with other platforms and broadening the reach and accessibility of MARENDATA's data offerings. The platform's data is accessible in standard formats, including JSON, XML, and CSV, allowing users from diverse backgrounds to retrieve data effectively.

3.7 Monitoring and Maintenance

To maintain high performance and ensure data accuracy, the platform undergoes routine monitoring and maintenance. Continuous monitoring includes data integrity checks, performance optimization. Scheduled maintenance cycles are designed to keep the system secure, efficient, and up-to-date, incorporating updates for both security and functionality. This ongoing process ensures that MARENDATA meets user expectations and operates at peak capacity, supporting the diverse needs of its stakeholders.

4. Concluding Remarks

The MARENDATA platform has achieved significant strides in software development, particularly in terms of optimizing data accessibility and storage management for marine renewable energy research. The platform's modular architecture and use of technologies like Angular and GeoNetwork enable it to respond flexibly to new data requirements and diverse user needs. By leveraging standardized data protocols and third-party identity providers, MARENDATA offers a streamlined, secure user experience while promoting accessibility through scalable data ingestion and dynamic visualization tools. The integration of various components, such as Highcharts for data analysis and leaflet-based mapping for spatial data visualization, illustrates how MARENDATA effectively bridges raw data with actionable insights, supporting stakeholders' decision-making in environmental impact assessments.

However, maintaining and evolving MARENDATA presents ongoing challenges within a continuously changing software paradigm. As data storage requirements grow, so does the need to address complexities associated with database synchronization, real-time updates, and the efficient management of legacy data. The adoption of triggers and automated processes to sync the SOWFIA and MARENDATA databases has reduced manual tasks, yet ensuring data consistency across databases requires regular adjustments and can be resource-intensive. Maintaining this synchronization in line with evolving web access requirements calls for rigorous monitoring and the potential integration of new data storage solutions that are capable of supporting the platform’s expanding scale without compromising speed or reliability.

Future work on MARENDATA will need to emphasize adaptability within its data infrastructure. As data volumes increase and new data sources emerge, refining the platform’s storage strategies and exploring advanced data structures may become essential to sustain performance. Enhancements to API functionalities and integration with more third-party platforms will support MARENDATA’s interoperability and extend its reach within the global marine research community. In addition, balancing innovation with system stability will be crucial to ensure that updates to the platform's user-facing features and backend functions do not disrupt ongoing operations or data availability. A dedicated maintenance strategy, involving continuous software refactoring, database optimization, and regular security updates, will help MARENDATA remain a reliable resource in the dynamic field of marine energy research.