

ReNEW

D4.9 - LL2 Douro River Waterway v1



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5

TABLE OF CONTENTS

1	EXECUTIVE SUMMARY	7
2	METHODOLOGY	8
2.1	DESCRIPTION OF THE METHODOLOGY	8
2.2	MAPPING THE RENEW OUTPUT	9
3	USE CASE 1: EXTREME WEATHER	11
3.1	PURPOSE.....	11
3.2	MAIN FEATURES	14
3.3	FUNCTIONALITIES.....	14
3.4	EXPECTED OUTCOMES	16
3.5	IMPLEMENTATION STEPS.....	16
3.6	MILESTONES	17
3.7	REQUIRED RESOURCES.....	18
3.8	KEY PERFORMANCE INDICATORS (KPIs)	18
3.9	ENGAGING STAKEHOLDERS.....	19
3.10	CONCLUSION.....	20
4	USE CASE 2: ILLEGAL WASTEWATER DUMP	21
4.1	PURPOSE.....	21
4.2	MAIN FEATURES	21
4.3	FUNCTIONALITIES.....	21
4.4	EXPECTED OUTCOMES	23
4.5	IMPLEMENTATION STEPS.....	24
4.6	MILESTONES	25
4.7	REQUIRED RESOURCES.....	25
4.8	KEY PERFORMANCE INDICATORS (KPIs)	26
4.9	ENGAGING STAKEHOLDERS	26
4.10	CONCLUSION.....	27

1 Executive Summary

The Douro Living Lab is an innovative project focused on addressing challenges posed by extreme weather events and illegal wastewater dumping in the Douro region. Through two distinct use cases, the project aims to enhance the resilience, safety, and environmental sustainability of inland waterways.

Use Case 1 focuses on developing a digital twin that simulates and predicts the behavior of the Douro River during extreme weather events. By leveraging real-time data from meteorological and hydrological sensors, the aim is to enhance emergency planning, navigation efficiency, and passenger safety.

Use Case 2 aims to prevent illegal wastewater dumping in the Douro River by utilizing smart contracts and blockchain technology. The focus is on promoting ecological responsibility among vessel operators and safeguarding the water quality and ecosystem.

The Douro Living Lab's use cases represent groundbreaking efforts to enhance inland waterway resilience and sustainability. By combining real-time data analysis, digital twin technology, predictive models, smart contracts, and blockchain, the project offers practical solutions for safer navigation and environmental protection.

Successful implementation of these use cases will contribute significantly to the overall objectives of the Douro Living Lab and the ReNEW project for creating smart, green, and resilient inland waterways. These advancements will set new standards for waterway management and environmental conservation, benefiting the Douro region and beyond.

2 Methodology

2.1 Description of the methodology

The methodology used for the Living Lab in the Douro region follows a structured and iterative approach, aimed at achieving the objectives of Use Case 1: Extreme Weather and Use Case 2: Illegal Wastewater Dump. The methodology encompasses the following key elements:

Stakeholder Engagement: The Living Lab initiates with active involvement from relevant stakeholders, including boat owners, operators, port authorities, regulatory bodies (APA and DGRM), technology experts, and local communities. Stakeholder engagement allows for a comprehensive understanding of their requirements, concerns, and insights, ensuring that the Living Lab addresses real-world challenges effectively.

Data-Driven Approach: The methodology is centered around data collection, integration, and analysis. Real-time data from meteorological and hydrological sensors, AIS, RIS, water level gauges, weather forecasts, vessel positions, speeds, and wastewater tank capacities is collected and utilized for predictive modeling, simulation, and decision-making.

Technology Integration: Advanced technologies, such as smart contracts and blockchain, are integrated into the Living Lab to enhance data transparency, immutability, and traceability. The use of smart contracts enables real-time data collection and validation, while blockchain ensures data security and integrity. **Digital Twin Development:** For Use Case 1, the methodology focuses on the development of a digital twin to simulate the behavior of the Douro River during extreme weather events. This predictive model allows stakeholders to anticipate and respond proactively to adverse conditions, optimizing emergency planning and resource allocation. **Rule-Based Logic and Enforcement:** In Use Case 2, rule-based logic is implemented within the smart contracts to detect illegal wastewater dumping incidents. The system automatically triggers the issuance of illegal dump notices and calculates fines based on the severity of violations, promoting compliance and accountability.

Continuous Improvement: The Living Lab follows an iterative process, continuously monitoring performance and evaluating outcomes. Insights from data analysis and stakeholder feedback are used to identify areas for improvement, leading to continuous refinements and enhanced solutions.

LL timeframe: the methodology sets specific milestones and timeframes for each stage of the Living Lab's implementation. These deliverables ensure that progress is made within a structured timeline, enabling timely evaluations and achieving the Living Lab's objectives within the specified timeframe.

Overall, the methodology adopted for the Living Lab in the Douro region fosters collaboration, data-driven decision-making, and technology integration to enhance resilience, sustainability, and

navigability in the inland waterways. It enables stakeholders to make informed decisions, respond effectively to extreme weather events, and mitigate environmental challenges, ultimately contributing to a more efficient and sustainable water transportation system.

2.2 Mapping the ReNEW Output

The following table (Table 1) maps the ReNEW project's Grant Agreement (GA) commitments, both within the formal Deliverable and Task description, against the project's respective outputs and work to perform.

Table 1: Adherence to ReNEW's GA Deliverable & Tasks Descriptions

Deliverable D4.9 LL2 Douro River Waterway v1
Initial Design and Implementation Plan
Task T4.4: LL2 DOURO River Waterway
Description of work: Douro has an extensive hydrological and meteorological network, that consists of: (a) water level gauges and surface water velocity meters; (b) meteorological stations; (c) a near real time system for receiving and storing data and making it available in the DIW Portal. The use of the inland waterway is concentrated between the months of May and September, becoming residual in the remaining months of the year. Currently, APDL has a subscription service that runs hydrological and meteorological models for emitting reports for short-, medium- and long-term weather and hydrological predictions. Although fed with data from multiple sensors and other international weather models, there is a wide space for improvement and even for the development of real time digital twin technology for drought or flood analysis and real time prediction. The Living Lab will implement Digital Spaces and Digital Twins solutions for data sharing and access, and the related analytics and predictions tools developed in WP3. It will apply infrastructure resilience improvement and sustainability scenarios using the multimodal options of combined modes approaches to address disasters using unexplored potential of the innovative mesh communication systems to be shared by both infrastructures (railway, waterway) and the means of transport (train, boat/ships) over the 208 km of extension, where the waterway is in many times in very close proximity with the railway. To improve resilience, solutions will be sought, and combined configurations will be tested in cases for speed measurement and vessel identification in situations where this information cannot be obtained by AIS. Further, there is a potential of using modular inter-modality platforms, for easily transferring passengers from the river to the railway and vice-versa, allowing for alternative solutions to interconnect the five distinct reservoirs in Douro, in case of prolonged damage to locks or excessive low or high-water levels. Perform the LL2 subtasks as described in Table 9.

ReNEW GA Element Title	ReNEW GA Element Outline	Respective Document Chapter (s) and Description
ST4.9.1 LLn Detailed Design	Perform detailed LL design and planning, stakeholder's engagement, licensing and permitting for buildings and operation of the technologies, and iterative detailed LL solutions deployment.	(please give a short description in which chapter the relevant objectives of the subtask are covered)
ST4.9.2 LLn Construction	Execute LL construction plan in a progressive and iterative mode Customise and configure technology, Resilience and Sustainability use cases, Data Spaces and Digital Twin, simulation and monitoring solutions	
ST4.9.3 LLn Operational Monitoring	Perform monitoring, Risks management and mitigation, corrective actions, Data Collection for KPIs and reporting.	

3 Use Case 1: Extreme Weather

3.1 Purpose

The purpose of Use Case 1 in the Douro Living Lab is to address the challenges posed by extreme weather events, such as major floods/flash floods and droughts, in the Douro region. By leveraging real-time data flows from meteorological and hydrological sensors, this use case aims to develop a digital twin to simulate and predict river behavior under extreme weather conditions. The primary goal is to enhance the resilience and efficiency of inland navigation while ensuring passenger safety and minimizing environmental impacts.

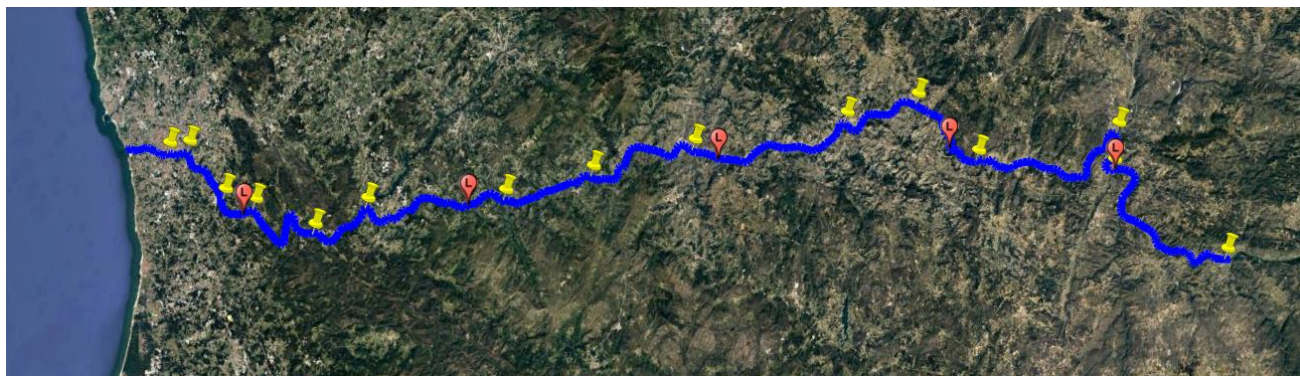


Figure 1 - DIW sensor locations at the five locks/hidrologic dams in the Douro Crestuma-Lever, Carrapatelo, Bagaúste, Valeira, Pocinho ordered from the estuary area towards the border with Spain.



Figure 2 - Limnimeter and water velocity sensor at Regua bridge



Figure 3- Carrapatelo lock limnimeter

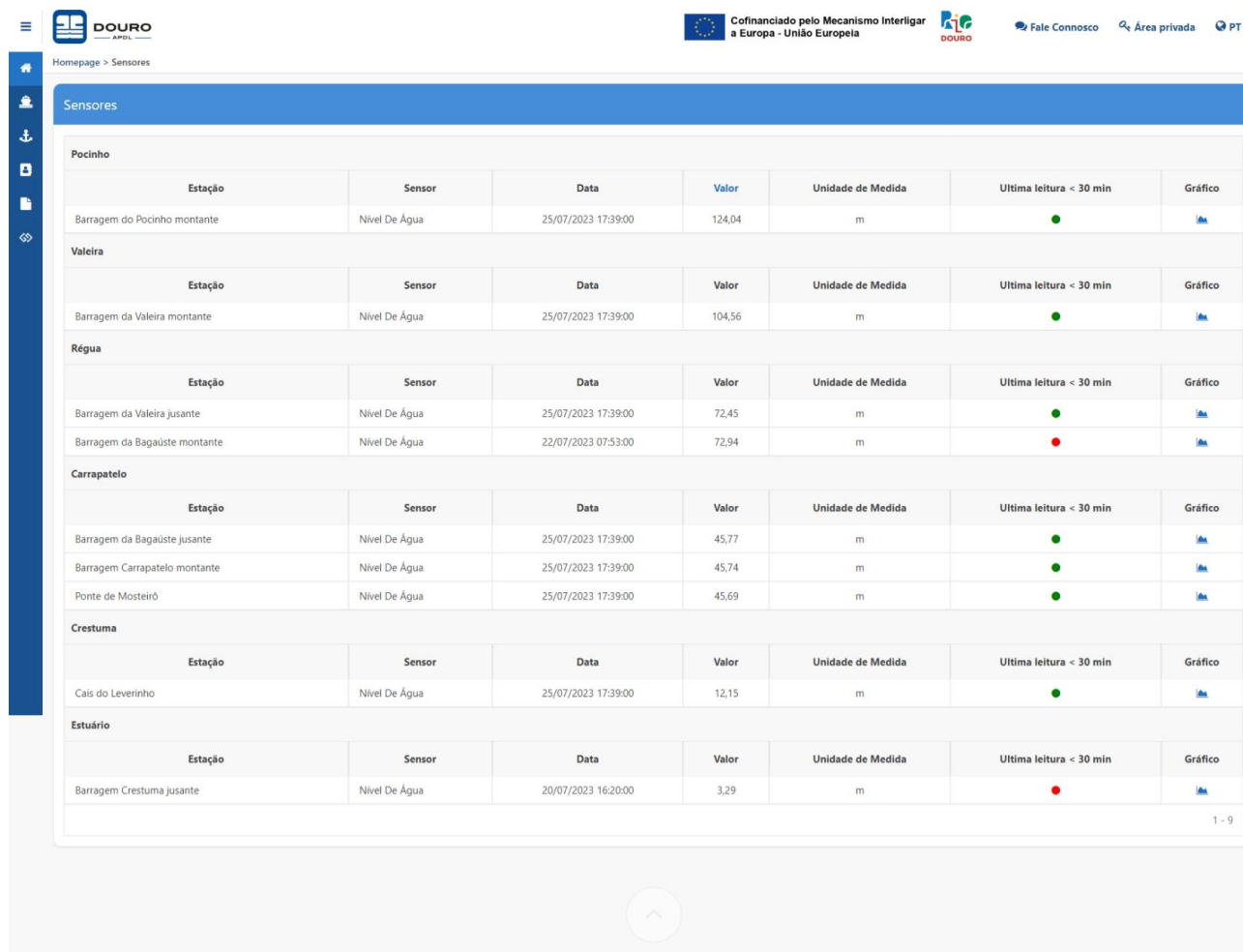


Figure 4 - RIS Douro - real time hydrological data indicating the locations, number of sensors and functions (water level measurement unit of measure (metters, real time last measurement (> 30 minutes), evolution chart).

DOURO

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Homepage > Sensores de Meteorologia

Sensores de Meteorologia

Sensor : Direção Vento

Estação	Albufeira	Data	Valor	Unidade de Medida	Ultima leitura < 30 min	Gráfico
Barragem Valeira	Valeira	25/07/2023 17:42:58	333,14 NNO	°		Gráfico
Centro Controlo Régua	Carrapatelo	25/07/2023 17:43:00		°		Gráfico
Barragem Carrapatelo	Carrapatelo	25/07/2023 17:42:59	333,13 NNO	°		Gráfico
Cais do Leverinho	Crestuma	25/07/2023 17:42:57	284,1 ONO	°		Gráfico

Sensor : Humidade Relativa

Estação	Albufeira	Data	Valor	Unidade de Medida	Ultima leitura < 30 min	Gráfico
Barragem Valeira	Valeira	25/07/2023 17:42:58	74,87	%		Gráfico
Centro Controlo Régua	Carrapatelo	25/07/2023 17:43:00	25,44	%		Gráfico
Barragem Carrapatelo	Carrapatelo	25/07/2023 17:42:59	74,87	%		Gráfico

Sensor : Precipitação

Estação	Albufeira	Data	Valor	Unidade de Medida	Ultima leitura < 30 min	Gráfico
Barragem Valeira	Valeira	25/07/2023 17:42:58	0	mm		Gráfico
Centro Controlo Régua	Carrapatelo	25/07/2023 17:43:00	-	mm		Gráfico
Barragem Carrapatelo	Carrapatelo	25/07/2023 17:42:59	0	mm		Gráfico

Sensor : Pressão Atmosférica

Estação	Albufeira	Data	Valor	Unidade de Medida	Ultima leitura < 30 min	Gráfico
Barragem Valeira	Valeira	25/07/2023 17:42:58	1015,82	mBar		Gráfico
Centro Controlo Régua	Carrapatelo	25/07/2023 17:43:00	1008,13	mBar		Gráfico
Barragem Carrapatelo	Carrapatelo	25/07/2023 17:42:59	1015,82	mBar		Gráfico

Sensor : Rajada Vento

Estação	Albufeira	Data	Valor	Unidade de Medida	Ultima leitura < 30 min	Gráfico
Barragem Valeira	Valeira	25/07/2023 17:42:58	11,3	m/s		Gráfico
Centro Controlo Régua	Carrapatelo	25/07/2023 17:43:00	-	m/s		Gráfico
Barragem Carrapatelo	Carrapatelo	25/07/2023 17:42:59	11,3	m/s		Gráfico
Cais do Leverinho	Crestuma	25/07/2023 17:42:57	8,2	m/s		Gráfico

Sensor : Temperatura Ar

Estação	Albufeira	Data	Valor	Unidade de Medida	Ultima leitura < 30 min	Gráfico
Barragem Valeira	Valeira	25/07/2023 17:42:58	18,67	°C		Gráfico
Centro Controlo Régua	Carrapatelo	25/07/2023 17:43:00	33,99	°C		Gráfico
Barragem Carrapatelo	Carrapatelo	25/07/2023 17:42:59	18,67	°C		Gráfico

Sensor : Velocidade Vento

Estação	Albufeira	Data	Valor	Unidade de Medida	Ultima leitura < 30 min	Gráfico
Barragem Valeira	Valeira	25/07/2023 17:42:58	7,81	m/s		Gráfico
Centro Controlo Régua	Carrapatelo	25/07/2023 17:43:00	-	m/s		Gráfico
Barragem Carrapatelo	Carrapatelo	25/07/2023 17:42:59	7,81	m/s		Gráfico
Cais do Leverinho	Crestuma	25/07/2023 17:42:57	3,76	m/s		Gráfico

Sensor : Visibilidade

Estação	Albufeira	Data	Valor	Unidade de Medida	Ultima leitura < 30 min	Gráfico
Centro Controlo Régua	Carrapatelo	25/07/2023 17:43:00	-	m		Gráfico
Cais do Leverinho	Crestuma	25/07/2023 17:42:57	-	m		Gráfico

1 - 26

Figure 5 - RIS Douro real time meteorological data indicating the locations, number of sensors and functions (wind direction, rain, humidity, gust of wind, air temperature, wind velocity, atmospheric pressure and visibility conditions, measurement units

of measure (metters, percentage, milliliters, meters per second, mBAr,), real time last measurement (> 30 minutes), evolution charts).

3.2 Main Features

- a. Real-time Data Analysis: Collect and analyze data from meteorological and hydrological sensors to monitor weather patterns, water levels, and velocities in real-time.
- b. Digital Twin Simulation: Develop a digital twin that replicates the behavior of the Douro River during extreme weather events, enabling what-if scenario analysis.
- c. Predictive Models: Create predictive models that forecast potential flood or drought situations and their impact on navigability and logistics networks.
- d. Emergency Planning: Integrate the digital twin's predictions into the existing Emergency Plan to facilitate quick decision-making and response during extreme weather events.
- e. Safety Measures: Implement safety protocols and guidelines for vessel navigation during extreme weather conditions to prevent congestion and delays.

3.3 Functionalities

- a. Data Integration: Integrate data from various sources, including sensors, AIS, RIS, and weather forecasts, into a centralized information system.
- b. Data Validation: Ensure the accuracy and reliability of collected data through validation mechanisms.
- c. Simulation and Analysis: Develop algorithms to simulate river behavior and analyze the impact of extreme weather events on the navigability of the Douro River.
- d. Real-time Monitoring: Enable real-time monitoring of water levels, velocities, and weather conditions to identify potential risks promptly.
- e. Decision Support: Provide decision-makers with actionable insights and recommendations based on the digital twin's predictions.

The decision support system based on the digital twin provides decision-makers with timely, accurate, and actionable information to navigate the Douro River safely during extreme weather events. It optimizes emergency planning, infrastructure resilience, and navigation protocols, ensuring a more sustainable and efficient inland waterway system in the Douro region.

Here is an example of how the decision support system can be used:

1. **Real-Time Monitoring and Early Warning:** The decision support system continuously monitors real-time data from meteorological and hydrological sensors, AIS, RIS, water level gauges, and weather forecasts. It compares this data with the pre-approved navigation plan and locking schedules. If extreme weather conditions are detected, the system provides early warnings to relevant stakeholders, such as boat operators, port authorities, and emergency response teams. These warnings help them prepare for potential disruptions and take proactive measures to ensure safety and avoid congestion.
2. **Simulation and Scenario Analysis:** The digital twin is the core of the decision support system. It models the behavior of the Douro River during extreme weather scenarios, simulating the effects of major floods, flash floods, or droughts. Decision-makers can use the digital twin to run scenario analyses and assess the potential impacts of different extreme weather events on navigability and infrastructure. This information enables them to plan and allocate resources more effectively, ensuring the smooth operation of passenger mobility and logistics networks.
3. **Emergency Response Planning:** The digital twin predictions are integrated into the Emergency Plan for the Douro River. During extreme weather events, the decision support system updates the Emergency Plan in real-time, incorporating the latest digital twin simulations. This ensures that emergency response teams have the most up-to-date information on the river's conditions, enabling them to implement efficient and targeted measures to mitigate damages and disruptions.
4. **Adaptive Navigation and Locking Schedules:** The decision support system assists in formulating adaptive navigation plans and locking schedules based on the digital twin's predictions. Vessel operators receive optimized routes and schedules, considering the real-time river conditions and potential weather-related constraints. This adaptive approach minimizes delays, reduces congestion, and enhances overall navigability during extreme weather events.
5. **Performance Evaluation and Continuous Improvement:** The decision support system allows stakeholders to evaluate the performance of the river's infrastructure and emergency response mechanisms during extreme disruptions. After each event, stakeholders can analyze the system's effectiveness and identify areas for improvement. This iterative process of continuous improvement enhances the resilience of the Douro River over time.

3.4 Expected Outcomes

- Upgraded data collection systems with integrated real-time data from meteorological and hydrological sensors.
- Developed digital twin algorithms and simulation model for extreme weather scenarios.
- Predictive models for flood and drought situations, facilitating better decision-making.
- Integration of the digital twin's predictions into the existing Emergency Plan for improved emergency response.
- Established safety protocols and guidelines for vessel navigation during extreme weather events.

3.5 Implementation Steps

Step 1: Data Collection and Integration

Implement data collection systems and integrate additional sensor data (4 months)

Step 2: Digital Twin Development

Develop algorithms for digital twin simulation (6 months)

Step 3: Predictive Modeling and Analysis

Create predictive models for extreme weather scenarios (8 months)

Step 4: Emergency Planning Integration

Incorporate digital twin predictions into the Emergency Plan (10 months)

Step 5: Safety Measures and Guidelines

Establish safety protocols and navigation guidelines (12 months)

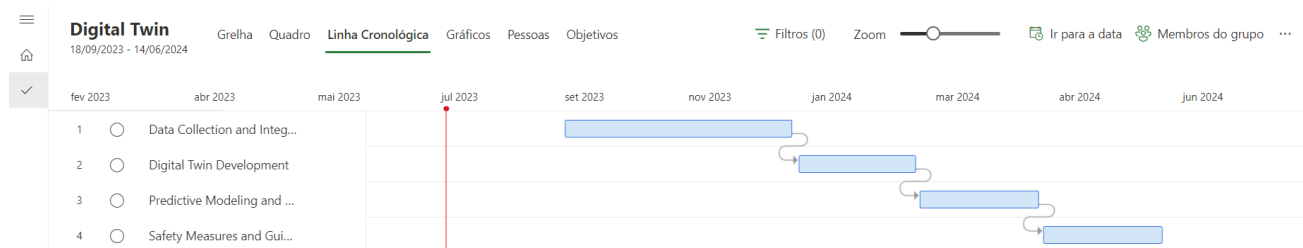


Figure 6 - Digital Twin Gantt chart

Timeframe:

The complete implementation of Use Case 1 is expected to take 12 months

3.6 Milestones

1. **Milestone: Data Collection and Integration** This milestone involves the successful implementation of data collection systems and the integration of sensor data from various sources, including meteorological and hydrological sensors, AIS, RIS, water level gauges, and weather forecasts. The collected data will be used for the development of algorithms for digital twin simulation.

Timeframe: Achieve data collection and integration within 4 months.

2. **Milestone: Digital Twin Development and Predictive Modeling** The second milestone focuses on the development of algorithms for digital twin simulation, which will model the behavior of the Douro River during extreme weather scenarios, such as major floods/flash floods or droughts. These predictive models will utilize the integrated sensor data to provide real-time predictions.

Timeframe: Complete digital twin development and predictive modeling within 8 months.

3. **Milestone: Emergency Planning Integration and Safety Measures** The third milestone involves incorporating the digital twin predictions into the Emergency Plan, ensuring that the plan takes into account the real-time simulations for extreme weather events. Additionally, safety protocols and navigation guidelines will be established based on the predictive models to enhance navigability and safety during adverse conditions.

Timeframe: Integrate emergency planning and establish safety measures and guidelines within 12 months.

Achieving these milestones within the specified timeframe will demonstrate the successful implementation of Use Case 1 in the Douro Living Lab. The integration of data collection systems and sensor data will provide a foundation for the development of the digital twin, enabling real-time predictions of the river's behavior during extreme weather scenarios. By incorporating the digital twin predictions into the Emergency Plan and establishing safety protocols, the Douro River can enhance its resilience and navigability during adverse weather conditions, contributing to a more sustainable and efficient inland waterway system in the region.

3.7 Required Resources

- a. Skilled Technical Team: Data scientists, hydrological experts, and software developers.
- b. Hardware and Sensors: Procurement and installation of water level gauges, meteorological stations, and other necessary sensors.
- c. Data Infrastructure: IT infrastructure and servers for data storage and processing.
- d. Stakeholder Cooperation: Collaboration with relevant authorities, boat owners, and operators for data sharing and compliance.

3.8 Key Performance Indicators (KPIs)

1. KPI: Navigability During Extreme Weather Events Definition: Navigability during extreme weather events measures the capacity of the Douro River to facilitate safe and efficient inland navigation despite the occurrence of major floods/flash floods or droughts. It quantifies the river's ability to maintain a certain percentage of navigable capacity during such extreme weather conditions.

Required Data: Real-time data from meteorological and hydrological sensors, AIS, RIS, water level gauges, and weather forecasts. This data will provide information on river water levels, velocities, weather conditions, vessel positions, and speeds.

Measurement Method: Calculate the percentage of navigable capacity during extreme weather events by comparing the actual vessel movements to the pre-approved navigation plan and locking schedules. Monitor vessel speeds, congestion, and delays during these events.

Target: Ensure at least 50% navigability capacity during extreme weather events. This means that at least half of the river's navigable capacity should be maintained, minimizing disruptions and facilitating safer navigation during adverse weather conditions.

2. KPI: Infrastructure Resilience During Extreme Disruptions Definition: Infrastructure resilience during extreme disruptions evaluates the effectiveness of the Douro River's infrastructure, including locks, canals, and inter-modality platforms, in maintaining its overall functionality during major floods/flash floods or droughts.

Required Data: Real-time data on the status of locks, canals, inter-modality platforms, and other relevant infrastructure components. This data will include information on water levels, equipment status, and any damages or malfunctions.

Measurement Method: Assess the percentage of infrastructure components functioning as expected during extreme disruptions. Monitor the response time and effectiveness of emergency measures taken to mitigate damages and restore functionality.

Target: Ensure at least 80% of infrastructure resilience at the network level during extreme disruptions. This means that, despite the challenges posed by extreme weather events, at least 80% of the river's infrastructure should continue to operate efficiently.

3.9 Engaging Stakeholders

Identify Key Stakeholders:

Start by identifying the key stakeholders relevant to Use Case 1. This may include representatives from Administração dos Portos do Douro, Leixões e Viana do Castelo, SA (APDL), boat owners and operators, local communities and experts in meteorology and hydrology. Understanding their interests, concerns, and roles is crucial for tailoring engagement efforts.

Hold Workshops and Meetings:

Organize 2 workshops with the identified stakeholders to discuss the objectives, challenges, and expectations of Use Case 1. These sessions provide an opportunity to gather insights, gather feedback, and foster collaboration. Encourage open discussions and ensure that all stakeholders have a platform to voice their opinions and contribute to the decision-making process while involving them in defining the goals and scope of Use Case 1. Collaboratively determining the expected outcomes and benefits will increase stakeholders' sense of ownership and commitment to the project.

Transparent Communication:

Maintain transparent and consistent communication channels with stakeholders throughout the development process. Share updates, progress, challenges, and successes regularly via specific emails or via public website depending the type of information.

Conduct Pilot Tests:

Involving stakeholders in pilot tests and demonstrations allowing them to see the practical application of Use Case 1's outcomes.

By implementing these strategies, the Douro Living Lab can foster a collaborative and inclusive approach to Use Case 1. Engaged stakeholders will play a critical role in shaping and realizing the vision of enhancing resilience and navigability during extreme weather events, leading to a more sustainable and efficient inland waterway system in the Douro region.

3.10 Conclusion

Use Case 1: Extreme Weather in the Douro Living Lab aims to enhance the navigability and resilience of the Douro River during extreme weather events. By developing a digital twin and predictive models, the use case will provide valuable insights for emergency planning and safer navigation. With careful implementation, this use case will contribute to the overall success of the Douro Living Lab and the ReNEW project's objectives for sustainability and resilience in inland waterways.

4 Use Case 2: Illegal Wastewater Dump

4.1 Purpose

The purpose of Use Case 2 in the Douro Living Lab is to address the issue of illegal wastewater dumping in inland waterways, with specific focus on the Douro River and promote ecologically responsible behavior among vessel operators. By leveraging smart contracts and blockchain technology, this use case aims to monitor wastewater tank levels and vessel positions in real-time to prevent illegal dumping. The primary goal is to enforce compliance with Douro inland navigation regulations, protect the environment, and reduce pollution caused by unauthorized wastewater discharge.

4.2 Main Features

- a. Smart Contract Implementation: Deploy smart contracts on the blockchain to monitor and track wastewater tank levels and vessel positions in real-time.
- b. Real-time Data Collection: Gather and timestamp vessel data, including vessel names, positions, speeds, and wastewater tank capacities, in an immutable manner.
- c. Rule-Based Enforcement: Establish rules within smart contracts to trigger an illegal dump notice and issue fines if wastewater tank levels decrease outside designated wastewater collection areas.
- d. Accountability and Transparency: Ensure data immutability and transparency through blockchain technology, preventing tampering and providing non-repudiation of actions.
- e. Environmental Protection: Encourage vessels to comply with wastewater regulations, leading to a reduction in water pollution and an improvement in environmental sustainability.

4.3 Functionalities

- a. Smart Contract Development: Create smart contracts with the ability to collect, store, and validate vessel data.
- b. Real-time Data Collection: Implement mechanisms to collect and timestamp vessel data in real-time for accurate tracking.
- c. Rule Engine: Develop rule-based logic within smart contracts to trigger actions in case of unauthorized wastewater dumping.

d. Data Immutability: Utilize blockchain technology to ensure the security and immutability of collected data.

e. Fine Issuance: Establish a process to issue fines to vessel owners/operators for illegal wastewater dumping.

Use Case 2 ensures effective monitoring of wastewater disposal practices, encourages ecological responsibility among vessel operators, and helps preserve the water quality and ecosystem of the Douro River. Here the details of how Use Case 2 may work.

Smart Contract Integration

The implementation starts by integrating smart contracts into the vessels' onboard systems. These smart contracts are designed to collect and timestamp critical data such as vessel names, GPS positions, speeds, and wastewater tank capacities. The smart contracts are deployed on a blockchain platform, ensuring that the data is secure, transparent, and cannot be altered or tampered with.

Real-Time Data Collection

As vessels navigate the Douro River, the integrated smart contracts continuously collect and record the relevant data, including vessel movements and wastewater tank levels. The data is stored on the blockchain, providing an immutable and transparent record of vessel activities.

Geofencing and Wastewater Collection Areas

The Douro Living Lab establishes designated geofenced areas along the river known as wastewater collection areas. These areas are strategically located and marked using GPS coordinates. When vessels enter these areas, the smart contracts detect their presence and monitor their wastewater tank levels.

Wastewater Dump Monitoring

When a vessel enters a wastewater collection area, the smart contracts automatically check its wastewater tank levels against the allowed capacity for that specific area. If the vessel is within the designated range, no further action is required.

Detection of Illegal Dumping

If the smart contracts detect that a vessel's wastewater tank levels drop significantly outside the permitted range while inside the wastewater collection area, it raises an alert for potential illegal wastewater dumping.

Automatic Issuance of Illegal Dump Notice

Upon detecting a potential illegal dump, the smart contracts trigger the issuance of an illegal dump notice to the vessel's operator. The notice contains details of the violation, including the vessel's position and the timestamp of the incident.

Fine Calculation and Imposition

Based on the severity and frequency of violations, the Douro Living Lab sets a fine structure. The smart contracts calculate the appropriate fine according to the violation's nature and the vessel operator's historical compliance record.

Stakeholder Notifications and Reporting

The relevant stakeholders, such as APA, DGRM, and boat owners, receive real-time notifications of illegal dumping incidents and fine imposition. Additionally, periodic reports on compliance and illegal dumping incidents are generated for monitoring and analysis.

Data Transparency and Accountability

The data recorded in the blockchain remains transparent and immutable, providing stakeholders with a trustworthy source for assessing wastewater disposal compliance and holding violators accountable.

Compliance Monitoring and Improvement

The Douro Living Lab continuously monitors compliance rates and analyzes the data to identify patterns and trends. Based on the insights, stakeholders can implement strategies to improve compliance and reduce illegal wastewater dumping incidents.

4.4 Expected Outcomes

- a. Deployed smart contracts for real-time data collection and monitoring of vessel wastewater tank levels and positions.
- b. Real-time data collection system integrated with vessel GPS devices and wastewater tank sensors.
- c. Rule-based logic within smart contracts to trigger illegal dump notices and fines for offenders.
- d. Blockchain implementation for data immutability and transparency.
- e. A streamlined mechanism for issuing fines to vessel owners/operators for illegal wastewater dumping.

4.5 Implementation Steps

Step 1: Regulatory entities onboarding

- Meetings with national regulatory entities discussing the objectives, overall approach and regulatory baselines (3 months)

Step 2: Smart Contract Development

- Develop smart contracts for real-time data collection and validation (4 months)

Step 3: Real-time Data Collection System

- Implement mechanisms for real-time vessel data collection and timestamping (6 months)

Step 4: Rule Engine Implementation

- Design and integrate rule-based logic within smart contracts (8 months)

Step 5: Blockchain Integration

- Utilize blockchain technology for data immutability and transparency (10 months)

Step 6: Fine Issuance Mechanism

- Establish a process for issuing fines to offenders (12 months)



Figure 7 - Illegal Wastewater Dump Gantt chart

The complete implementation of Use Case 2 is expected to take 12 months, with milestones achieved at different intervals within this timeframe.

4.6 Milestones

1. **Milestone: Regulatory entities onboarding** This milestone involves the successful onboarding of national entities, specifically the Directorate-General for Natural Resources, Safety, and Maritime Services (DGMR) and the Portuguese Environmental Agency (APA) that are the Portuguese entities that are mandated for environment protection and ship certifications, to ensure the legal background that will make the project results viable and useful.

Timeframe: Successful regulatory entities onboarding within 6 months.

2. **Milestone: Smart Contract Development and Real-Time Data Collection System.** This milestone involves the successful development of smart contracts for real-time data collection and validation, along with the implementation of mechanisms for real-time vessel data collection and timestamping. The smart contracts will be designed to capture vessel names, GPS positions, speeds, and wastewater tank capacities, while the data collection system will ensure accurate and timely data retrieval.

Timeframe: Achieve smart contract development and real-time data collection system implementation within 6 months.

2. **Milestone: Rule Engine Implementation and Blockchain Integration.** The third milestone focuses on designing and integrating rule-based logic within the smart contracts to detect illegal wastewater dumping incidents. Additionally, blockchain technology will be integrated to provide data immutability and transparency, ensuring that vessel data cannot be altered or tampered with.

Timeframe: Complete rule engine implementation and blockchain integration within 10 months.

3. **Milestone: Fine Issuance Mechanism and Stakeholder Notifications.** The fourth milestone involves establishing a process for issuing fines to offenders based on the severity and frequency of violations. Once the smart contracts detect an illegal dumping incident, the system will automatically trigger the issuance of an illegal dump notice and calculate the appropriate fine. Relevant stakeholders will receive real-time notifications of illegal dumping incidents and fine imposition.

Timeframe: Implement the fine issuance mechanism and stakeholder notifications within 12 months.

4.7 Required Resources

- a. **Technical Team:** Blockchain developers, data analysts, and software engineers.

- b. Hardware and Sensors: Procurement and installation of GPS devices and wastewater tank sensors for data collection.
- c. Blockchain Infrastructure: Setup and maintenance of the blockchain network for data storage and validation.
- d. Collaboration: Cooperation with Portuguese Environmental Agency (APA), Directorate-General for Natural Resources, Safety, and Maritime Services (DGRM), and boat owners/operators for data sharing and compliance.

4.8 Key Performance Indicators (KPIs)

Compliance with Wastewater Regulations Definition: Compliance with wastewater regulations measures the extent to which vessel operators adhere to the pre-defined rules and guidelines for wastewater disposal. It quantifies the percentage of vessels that comply with designated wastewater collection areas and avoid illegal dumping.

Required Data: Real-time data from smart contracts and GPS devices installed on vessels, including vessel names, positions, speeds, and wastewater tank capacities. Additionally, data on the number of illegal dump notices issued and fines imposed.

Measurement Method: Calculate the percentage of vessels complying with wastewater regulations by analyzing data from smart contracts. Monitor instances of unauthorized wastewater dumping and the effectiveness of the enforcement mechanism.

Target: Achieve at least 95% compliance with wastewater regulations. This means that at least 95% of vessels should adhere to designated wastewater collection areas, demonstrating responsible wastewater disposal practices.

4.9 Engaging stakeholders

Identify Key Stakeholders

Identify the key stakeholders relevant to Use Case 2, including the Portuguese Environmental Agency (APA), Directorate-General for Natural Resources, Safety and Maritime Services (DGRM), boat owners, operators, and other regulatory bodies. Understand their roles, responsibilities, and interests in addressing the issue of illegal wastewater dumping.

Consultative Meetings

Conduct 2 consultative meetings with the identified stakeholders to discuss the objectives and scope of Use Case 2. Seek their input and feedback on the design and implementation of the smart contract-based monitoring system. Involve them in decision-making processes to ensure that the system aligns with their needs and requirements.

Address Regulatory Concerns

Engage with regulatory bodies, such as APA and DGRM, to ensure that the proposed monitoring system complies with existing regulations and policies. Address any concerns or challenges related to data privacy, security, and legal aspects of implementing smart contracts for enforcement.

Collaborative Design

Involve boat owners and operators in the design and development of the system. Understand their perspectives on the challenges they face in complying with wastewater regulations and how the monitoring system can be user-friendly and practical for their operations.

Data Sharing Agreements

Establish data sharing agreements with relevant stakeholders to access vessel data, including wastewater tank levels and GPS positions. Assure stakeholders of data privacy and security measures to build trust and encourage data sharing.

Conduct Pilot Tests

Conduct pilot tests of the monitoring system in collaboration with boat owners and operators. This allows stakeholders to see the system in action, provide real-time feedback, and identify any practical challenges that need to be addressed.

Analysis on possible recognition and incentives

Recognize and incentivize stakeholders, such as boat owners and operators, who actively comply with wastewater regulations and demonstrate responsible behavior. Acknowledge their efforts in protecting the environment and being part of the solution.

4.10 Conclusion

Use Case 2: Illegal Wastewater Dump in the Douro Living Lab aims to curb the issue of illegal wastewater dumping, protect the environment, and promote ecologically responsible behavior among vessel operators. By utilizing smart contracts and blockchain technology, this use case will provide an automated and transparent mechanism for monitoring and enforcing compliance with wastewater regulations. Successful implementation of this use case will contribute to a cleaner and more sustainable inland waters, in particular the Douro River, aligning with the overall goals of the Douro Living Lab and the ReNEW project for resilience-centric, smart, green, and networked inland waterways.