Assessment of baseline conditions of each demo site

Implementation planning and KPI

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D4.1

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[1] PU = Public
CO = Confidential, only for members of the consortium (including the Commission Services)
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Technical References

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Abbreviations

Abbreviation / Acronyms	Description
(A)MGA	(Annotated) Model Grant Agreement
CA	Consortium Agreement
CFS	Certificate of Financial Statement
EAB	External Advisory Board
EC	European Commission
EU	European Union
FP	Framework Programme
GA	Grant Agreement
PSB	Project Steering Board
PMT	Project Management Team
PC	Project Consortium
WP	Work Package
WPL	Work Package Leader
DS	Demonstration site
T	Task

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Executive Summary

This deliverable is the first achievement of work package 4 and outcome of Task 4.1.1 Setting the scenes. It describes the detailed steps and activities towards demonstrating 27 innovative technological and non-technological solutions in the seven demo sites of the IMPETUS project. For each of the seven demo sites and solutions demonstrated, pre-requisites, challenges and barriers are identified and the implementation is broken down into the necessary actions and timeline.

This deliverable is further closely linked to WP1 T1.1 Stakeholder Engagement and refers as baseline for the role of partners and steps taken towards the achievement of WP4 Deployment of solutions at demo sites.

Objectives of task and deliverable

The IMPETUS project aims at the development of a multi-scalar cross-sectoral framework for climate change adaptation. Sharing knowledge on climate adaptation solutions and strategies will provide replicability and transferability and will yield innovation packages addressing specific climate change needs. These innovation packages cover all key community systems in the seven European biogeographical regions. As part of their co-design and co-creation, a set of 27 solutions will be demonstrated to build upon and being scaled up to dynamic adaptation pathways. Innovations include technological, governance, behavioural and financial solutions. Basis for their deployment and upscaling is existing knowledge and already demonstrated beneficial innovations, modelling tools and advanced data analytics. WP4 coordinates all demonstration activities.

T4.1.1 sets the basis for progress monitoring within WP4 by defining the initial conditions, role of partners, actions and timeline to fulfilling the WP4 objectives, namely helping decision makers to make better informed decisions by

- providing long-term data on the performance of multi-benefit adaptation R&I solutions under a wide set of scenarios,
- providing data input for WP3-5 to create the innovation packages along adaptation pathways and assess the adaptation measures in risk management, and
- fostering replication and knowledge exchange between regions.

Further to the necessary steps for implementation, barriers and drivers are identified and specific key performance indicators are given to being able to measure the success and quantifying the benefits for each solution and demonstration.

Figure 1 summarizes the IMPETUS solutions and links them to the climate risks addressed and demo sites within IMPETUS. The solutions correspond in general to the tasks of the work package. The work package is further organized in four bundles representing nature-based solutions (bundle 1), innovative technologies (bundle 2), financial and insurance solutions (bundle 3), and governance models, awareness and behavioural change (bundle 4).

This deliverable is structured around the demo sites. For each case study, challenge and technical background are described and the solutions (Figure 1) are linked to the tasks and bundles. Objective of the succeeding task T4.1.2 will be to ensure harmonized bundle management and to draw conclusions on the lessons learned across the demo sites.

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Climate risk addressed	R&I Solution
Flooding risk	**[COASTAL]** Below sea-level multifunctional wetland **[ATLANTIC, ARTIC, BOREAL]** Digital twins and advanced tools for climate adaptation
Water scarcity	**[COASTAL, MEDITERRANEAN]** Decentralized circular-economy inspired water/energy/materials reuse innovations **[MEDITERRANEAN]** Controlled environmental agriculture (CEA) solutions **[MEDITERRANEAN]** Digital twins and advanced tools for climate adaptation **[MEDITERRANEAN]** Water-energy master plan and business plan for autonomous climate proof regions **[CONTINENTAL]** Decision Theatre (DTh) for regional integrated water resource management **[CONTINENTAL, MOUNTAIN MEDITERRANEAN]** Advanced tools for regional water management
Marine storms	**[COASTAL]** Sand dunes restoration techniques and monitoring **[COASTAL]** Sediment transportation through irrigation networks
Fires	**[MEDITERRANEAN]** Forest fires and restoration
Biodiversity loss	**[MEDITERRANEAN]** Supporting reforestation and biodiversity **[COASTAL]** Changes in the spatial distribution of species
Health diseases	**[COASTAL]** Improving bathing water quality after extreme storm events. **[COASTAL]** Increasing resilience of water plants to water-borne pathogens **[ATLANTIC]** Heat awareness system
Temperature increase	**[ARTIC]** Digital twin to co-design a Marine Spatial Planning framework **[MOUNTAIN]** Implemented bio-district to address altitudinal shifts of crops
Avalanche increase	**[ARTIC]** Early-warning and evacuation system for geological and avalanche risk sites
Extreme storms	**[COASTAL]** Assessment of economic impacts of extreme storms in infrastructures
All	**[COASTAL]** Creation of Alliance for a resilient Coast **[COASTAL]** Behavioural change for climate resilient tourism **[MOUNTAIN]** Innovative insurance products for agriculture, forestry and hydropower energy production **[MOUNTAIN]** Activating Cultural heritage to enhance climate resilience **[ATLANTIC]** system monitoring dashboard to support climate change mitigation and adaptation strategies **[BOREAL]** Climate change adaptation governing plan **[ALL]** Assessment of economic impacts of physical climate risk across demo cases

Figure 1: Overview of technological and non-technological IMPETUS solutions

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1 Continental DS: Metropolitan region Berlin/Brandenburg, Germany

1.1 Introduction and background

For more than a hundred years, Berlin's population has been supplied with drinking water from its own urban area and the directly adjacent surrounding countryside. The continuing growth of the population in Berlin and the surrounding area will lead to an increasing demand for drinking water and thus also to an increased volume of wastewater. At the same time, dry periods are expected to increase and last longer due to climate change [Reusswig et al. 2016]. The Berlin Senate Department of the Environment has thus initiated an update of the water supply concept for the metropolitan region. The aim of this "Master Plan Water " is to develop strategies and options for action on the basis of analyses of potential changes in framework conditions relevant to water management and risk assessments based on these analyses, in order to secure the drinking water supply, water protection and an adapted wastewater disposal system for Berlin and the surrounding area. The focus of the master plan is on the challenges posed by the declining inflows of the Spree and Havel rivers due to climate change and mining activities, the trend towards decreasing groundwater recharge, demographic developments and the need for additional water protection requirements [SenUVK 2021].

How the inflow situation to Berlin will ultimately develop after the end of coal mining in the Lausitz region and due to climate change effects cannot yet be conclusively quantified due to a large number of uncertainties (i.e. from climate projections). Relevant questions concerning required surface water inflows, acceptable proportions of treated wastewater in Berlin surface waters and the relevance of urban stormwater runoff will thus be addressed within the IMPETUS project to assess minimal requirements concerning surface water and groundwater quantity and quality and to provide the basis for regional water management.

Main tasks and solutions developed within the Berlin case study to address these questions and challenges are summarized in Table 1 and include an interactive multi-agent regional water balance model (T4.7.1) and the development and application of a decision theatre for regional integrated water management (T4.18) for the metropolitan region of Berlin/Brandenburg, in which the developed model will be applied and discussed with stakeholders, scientists and policy makers.

Table 1 Solutions and related tasks in the continental DS

Solution	Task No	Task title	Bundle No	Bundle
Advanced tools for regional water management	T4.7.1	Interactive multi-agent regional water balance model	2	Innovative technologies
Decision theatre for regional integrated water management	T4.18	Decision theatre for regional integrated water management	4	Governance Models, Awareness and behavioural change

1.2 Pre-requisites, design and concept for implementation

1.2.1 Advanced tools for regional water management

Objective and challenge

The state of Berlin is required to map and justify the water demand from the catchment areas of the Spree and Havel rivers from considerations of the Berlin water cycle through resilience studies. The investigations within IMPETUS case study 1 (Berlin/Brandenburg) are intended to serve this purpose by integrating sectoral data and analytical tools. The main focus is on the following questions:

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- Which surface water inflows to Berlin are absolutely necessary in order to cover the current and future raw water requirements while complying with the requirements of the Drinking Water Regulation?
- What are the maximum permissible proportions of treated wastewater in the respective catchment areas in order to ensure compliance with the drinking water limit values for drinking water abstraction from groundwater replenished with riverbank filtrate?
- What are the minimum surface water inflows to Berlin that are needed to ensure that the minimum ecological and chemical requirements for water bodies can be met in accordance with legal requirements and other usage demands?
- What is the relevance of stormwater runoff (including combined sewer overflows) and the potential of stormwater management measures in regard to the required surface water qualities?
- What are the current and future shares of groundwater recharge, riverbank filtrate and (old) groundwater in Berlin's drinking water supply and what qualitative changes are to be expected?

Usage scenarios will include drinking water supply from groundwater, partially augmented by river water via managed aquifer recharge and bank filtration schemes; usage of rivers as receiving water bodies for treated wastewater; increasing water demand for agriculture; water demand for cooling; large industrial users; and other scenarios identified in co-designing and co-development workshops with local stakeholders.

Technical description

Fulfilling task T4.7.1 requires a modelling cascade capable of representing surface water hydraulic conditions, discharge of treated wastewater and other impacts to surface water, mixing as well as surface water-groundwater interaction with all its in- and outflows and representative boundary conditions.

Figure 2: Main elements of the Berlin water cycle and IMPETUS analysis [Picture from BWB]

Climate change will be accounted for by simulating stepwise impacts from

- reduced surface water inflow to the Berlin water cycle
- increase in wastewater volumes and treated wastewater share in Berlin's surface water bodies
- decrease in natural groundwater recharge

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Surface water balance and tipping points in drinking water quality abstracted from groundwater as a mixture of natural groundwater, riverbank filtrate and potentially artificial groundwater recharge are the two end members considered in system analysis. The results will feed into T4.18 decision theatre. The single elements of the model cascade and required data are summarized in Table 2 below.

Table 2 Data requirements and model availability

Element	Models & tools	Data requirements	
Surface water (Spree, Havel) bodies	HYDRAX model: Hydrological balance model for surface water including inflow/outflow and resulting water levels	Input:	Water level (selected locations) River discharge (selected locations) Water users (water works, sewage treatment plants, thermal power plants) Precipitation Lake Evaporation
		Output:	Water level; River discharge; Flow velocity; Cross-sectional area of the stream; Volume
Climate change scenarios	References from literature and analysis of historic data to be used, e.g. percentual reduction or historic minima/maxima	Input:	precipitation, evapotranspiration, natural groundwater recharge
		Output:	surface water volume; infiltration/exfiltration volume in surface water-groundwater interaction; mixing/ shares of water by source
Wastewater management	BWB-model: Simplified, static, mixing model to assess impacts of wastewater treatment plant operation on freshwater bodies	Input:	flow rates of surface waters and sewage effluents as averages, manual data input initial pollutant concentrations in sewage effluents, surface water and groundwater
		Output:	Shares of treated wastewater and pollutant concentrations in receiving water bodies
Stormwater management	Berlin Load-Model to evaluate impacts from (i) treated wastewater; (ii) CSO; (iii) stormwater discharge regarding volumes and loads of most relevant pollutants into Berlin surface waters (all or individual) on yearly and monthly time scale	Input:	connected area (separate and combined sewers); volumes for combined sewer overflow (CSO) and treated wastewater; concentrations in WWTP effluent and stormwater runoff of different catchment types
		Output:	runoff volumes and loads of most relevant substances in stormwater runoff discharged to surface waters
Groundwater management	FEFLOW model (operational catchment models of BWB per waterworks)	Input:	groundwater recharge; monthly abstraction rates, surface water levels
		Output:	determination of shares of riverbank filtrate per well gallery

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Technical implementation is further expected to be facilitated/ hindered by the following drivers and barriers (Table 3).

Table 3 Potential drivers and barriers

Drivers	Demand (for water and transregional water management): 2018 and 2019 were the driest years in data records for the entire region with severe decrease in surface water availability and groundwater levels. Drinking water abstraction reached maximum values. Although drinking water supply was secured, technical limits were reached. → Knowing the overall quantitative and qualitative water availability and tipping points in quantity and quality is of utmost importance to water utilities, water authorities and other water users. New industry developments and structural change further increase pressure on water bodies and stakeholders that have thus a high interest in getting reliable data and reducing uncertainty about future conditions. Presence of usage conflicts: Berlin relies on secured inflows via Spree and Havel river. IMPETUS is expected to deliver a scientific basis for minimum surface water inflows securing drinking water supply. Demand for risk management (following the new drinking water ordinance, but also the regional and national climate change adaptation strategies): Understanding quantitative and qualitative tipping points is one of the most important steps in risk management by water utilities and water authorities in securing drinking water supply. Risk identification and assessment yields the determination of critical control points, but also mitigation measures to ensure a stable water management under future changed boundary conditions.
Barriers	Federalism: The federal state of Brandenburg is the most important stakeholder in regional water management, but not part of the IMPETUS project. Many parallel projects and ongoing initiatives may hamper willingness to contribute to "yet another project". The survey (WP1) is considered to establish relation to Brandenburg's water authority and to increase willingness in participation to decision theatres and other IMPETUS initiatives. Uncertainty about future scenarios (i.e. coal mining) and climate data: Trust in data and results is crucial for reaching acceptance among stakeholders. The decision theatre format (see section 1.2.2) is expected to increase stakeholders' acceptance from open discussion and identification of so far unanswered questions from decision makers to scientists.

Key Performance indicators, added value and replication potential

Key performance indicators for the advanced tools for regional water management are the quantification of minimum inflows to the Berlin region and resulting quantitative and qualitative changes in groundwater composition and implications for drinking water supply. So far, no threshold values exist. IMPETUS KPIs specific for subtask 4.7.1 are thus:

(1) quantification of surface water in- and outflow to Berlin for at least 3 scenarios

(2) quantification of share of riverbank filtrate in groundwater abstracted for drinking water supply for 45 well galleries in 9 waterworks for at least 3 scenarios

(3) quantification of treated wastewater / stormwater impacts to drinking water supply via riverbank filtration for at least 3 scenarios

The added value lies in the cascading approach linking the assessment of single effects of changing boundary conditions to the different water bodies and water usage scenarios. Target end users are water authorities (such as SenUMVK) and water utilities (such as BWB).

Replication potential is seen (i) for any current and future regional research initiatives and (ii) in the promotion of the IMPETUS approach as a reference within the national water strategy developed by the German Federal Ministry of the Environment. Therefore, the overall participatory approach will be assessed and especially the Resilience Knowledge Booster (RKB, WP2 & WP5) as information and negotiation platform will be disseminated.

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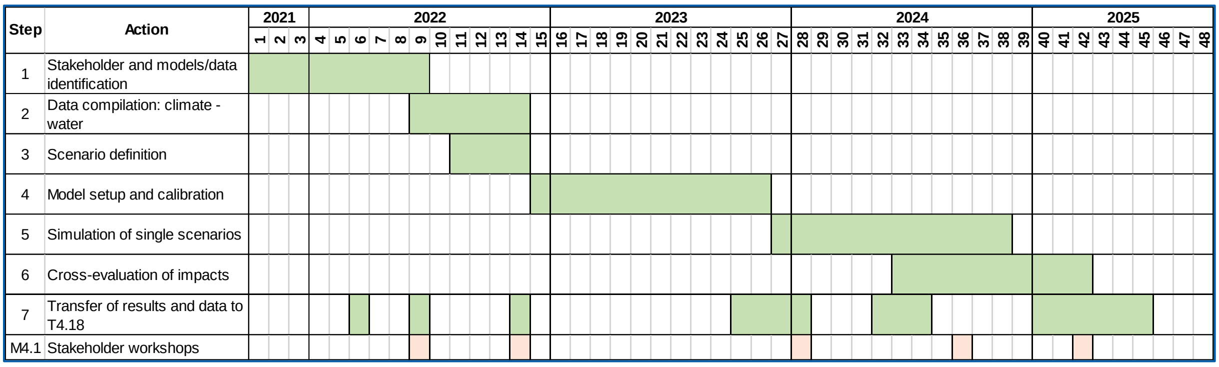
Role of partners and relevant stakeholders

All partners are involved in the model cascade and discussion of scenarios and adaptation measures in the scope of this task and T4.18 Decision theatre. Specifically

- KWB will perform task lead; evaluation of extreme values in previous data to identify climate change scenarios; assessment of impacts from CSO; impacts from stormwater management; coupling of surface water-groundwater by MODFLOW
- SENUMVK will perform scenario analyses in HYDRAX to determine surface water volumes and hydraulics; contribute data on surface water, precipitation, natural groundwater recharge, groundwater levels etc.
- BWB will run the wastewater management model to determine sewage effluent shares in surface waters
- Global Climate Forum (GCF) will lead discussion of worst-case and best-case scenarios and identification of adaptation measures to be included in (i) modelling and (ii) IT-supported discussion in the frame of T4.18
- MobyGIS will assist (i) data compilation and recommend additional data sets from remote sensing and earth observation and (ii) GIS implementation

Actions and timeline



References

Reusswig, F., Lüdeke, M., Lass, W., Walther, C., Becker, C., Neuhaus, A., Weyer, G., Haag, L., Knorr, A., Pankoke, C., Hirschfeld, J., Rupp, J., Walz, S. & Wiesemann, E. (2016) Anpassung an die Folgen des Kilmawandels in Berlin - AFOK, Teil 1: Hauptbericht. 317 p. AFOK.

SenUVK (2021) Zwischenbericht zum Stand der Erarbeitung. 47 p.

1.2.2 Decision theatre for regional integrated water resources management

Objective and challenge

The approach of Decision Theatre is an IT-supported discussion with interactive visualization environments enabling results-driven discussions with relevant stakeholders. A Decision Theatre will be applied in the Continental demo site in order to exemplarily discuss possible futures of regions threatened by water scarcity and parallel demographic and economic growth (e.g. new industries).

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Technical description

Built on the models developed by KWB, SENUVK, BWB and MOBYGIS in T4.7.1 a series of different policy options e.g. investments, regulations and possible events will be developed and their possible effects will be modelled. Relevant stakeholders for the region as public authorities, NGOs, companies, farms, industry, energy supply, households etc. will be invited to discuss the different measures in groups in order to make a joint decision on a limited number of choices. Afterwards in a plenary discussion the model simulations based on their decisions will be compared and evaluated. The visualisation will represent especially the hydrological dimension accompanied by surrounding effects. Finally, feedback by the stakeholders on both the model and the content will ensure the ongoing improvement of the decision theatre.

The decision theatre workshops will be recorded and transcribed for the following evaluation.

Key Performance indicators, added value and replication potential

This transdisciplinary method will enhance decision making in complex challenges such as water scarcity or climate change in general. With some adjustments the developed decision theatre can be applied to different regions and/or related topics. The impact will be demonstrated for instance by a bilateral exchange between Berlin and Arizona, where actors are working on the enormous water management challenges in the greater Phoenix region, also by using decision theatres developed by the Arizona State University. Moreover, analogous cross-connections are possible with further regions.

Role of partners and relevant stakeholders

All partners are involved in the model cascade and discussion of scenarios and adaptation measures in the scope of this task and T4.18 Decision theatre. Specifically

- Global Climate Forum (GCF) will lead lead task and develop a decision theatre based on the models provided by KWB, SENUVK, BWB and MOBYGIS, as well as (ii) implement several DT workshops with relevant regional stakeholders.
- SENUMVK will contribute to scenario definition and analyse (i) climate change data and (ii) resulting surface water quantity for their visualization in the decision theatre events
- BWB will contribute to scenario definition and analyse (i) climate change data and (ii) resulting quantity and distribution schemes of treated wastewater and mixing for their visualization in the decision theatre events. BWB will further assist in validating surface water-groundwater interaction with existing data from their operative models.
- KWB will contribute to scenario definition and analyse (i) climate change data; (ii) resulting surface water quality per scenario from quantitative balance and mixing of water per source; (iii) resulting groundwater quality from quantitative balance and mixing of water per source. KWB will further provide backend data and contribute to frontend design and implementation for a GIS environment visualizing the Berlin water cycle with all its impacts
- MobyGIS will assist in GIS implementation

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Actions and timeline

Step	Action	2021			2022												2023												2024												2025								
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48
1	Literature acquisition	■	■	■	■	■	■																																										
2	Elaboration of possible questions about the water supply						■	■	■	■																																							
3	Definition of water management issues									■	■	■	■																																				
4	Preparation for the demonstration of a DT, first using the example of mobility				■	■																																											
5	Implementation of the DT demonstration for the SenUVK, BWB, KWB				■	■																																											
6	Conflict evaluation what are the conflictual issues in Berlin Brandenburg regarding water supply.					■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■						
7	Option and effects questioning, refinement and modelling												■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■						
8	Decision Theatre for water supply Berlin												■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■						
9	Integration RKB															■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■						

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2 Coastal DS: Coast of Catalonia, Spain

2.1 Introduction and background

The Catalan coast on the North-East of Spain has a length of 600 km on the Mediterranean Sea. It is a temperate area with a large variety of geo and biodiversity systems providing ecosystem services. The hotspot condition of the demo site comes from the combination natural and societal factors, with economic activities and interests. In other words, the coexistence of critical infrastructure (e.g., Barcelona airport and harbour); industries (e.g., Zona Franca in Barcelona and the Petrochemical Industrial Area in Tarragona); tourism (e.g., Costa brava and Costa Daurada); high urbanisation density (more than 10,000 inhabitants per km on the coast); and agricultural production compete severely for the natural resources availability.

Being a vulnerable area due to climate change, the protection of the environment and the conservation of the natural resources is key today and in the near future, it will be crucial given the climate change impacts, trends and challenges. The most relevant impacts that are being observed or expected are:

- Sea level rise is threatening low-lying coasts (specifically deltas and estuaries) with increasing flooding risks and salt intrusion among other impacts
- The increasing frequency and intensity of marine storms and its impacts on coastal assets impacts the species and biodiversity
- Water scarcity is a chronic problem aggravated by climate change, increased tourism, water supply dependencies on river transfers, desalination plants and reclaimed water
- The increasing irregularity in rainfall is exacerbating flash floods and related damages, which is particularly problematic in densely populated areas where often occurs jointly with marine floods

Considering the similarities and the representativeness of other coastal regions and for the Mediterranean, the objectives behind the activities that will be carried out in the Catalan coast demo site are:

- Increase water availability and quality by the use of hybrid decentralized systems for water management
- Adapt to sea-level rise and marine storms by enhancing river sediment transport to the coast, multifunctional wetlands and novel dune restoration and monitoring methods
- Predict trends of extreme events and related economic impact
- Assess the resilience of drinking water plants with respect the increase of pathogens

The impact expected to be generated beyond the project is the adoption of the:

- Regional innovation package by the Government of Catalonia (the knowledge will be transferred by the Catalan Office for Climate Change of the Ministry of Territory and Sustainability as partner of the project) as part of the Work Programme on Climate Change Adaptation
- Large scale citizen engagement and enhanced behavioural change
- Demonstrations available for replication and transferability in KCS (including tourism)
- Interest to transfer and replicate such approach to similar coastal regions, especially in the Mediterranean for the adaptation of R&I Solutions but also RKB approach

The activities that will be performed on the Catalan coast demo site englobing technical, social, and economic aspects, are presented on Table 1.

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Table 4 Solutions and related tasks

Solution	Task No	Task title	Bundle No	Bundle
Below sea-level multifunctional wetlands	T4.2	Below sea-level multifunctional wetland to adapt to sea-level rise	1	Nature-based solutions
Sand dunes restoration techniques and monitoring	T4.3	Sand dune restoration and monitoring to prevent coastal erosion	1	Nature-based solutions
Decentralized circular-economy inspired water/energy/materials reuse innovations	T4.5.1	Decentralized hybrid fit-for-use water reclamation system for increasing water availability	2	Innovative technologies
Sediment transportation through irrigation networks	T4.6	Sediment transport in deltas	2	Innovative technologies
Improving bathing water quality after extreme storms events	T4.8.1	Improving bathing water quality in extreme storms events	2	Innovative technologies
Increasing resilience of water plants to water-borne pathogens	T4.8.2	Increasing resilience of water plants to water-borne pathogens	2	Innovative technologies
Changes in the spatial distribution of species	T4.9	Changes in the spatial distribution of species	2	Innovative technologies
Assessment of economic impacts of extreme storms in infrastructures	T4.13	Development of a satellite-based coastal monitoring system	3	Financing and Insurance
Behavioural change for climate-resilient tourism	T4.22	Pursuing behavioural change for climate-resilient tourism	4	Governance Models, Awareness and behavioural change

In an integrative way, an Alliance for a resilient coast will be created, which will involve part of the stakeholders of the different sub-tasks. This alliance will address 1) the pre-project baseline of global and climate change adaptation measures, 2) the generated outcomes during the Impetus project, and 3) determine the next steps after the end of the project.

2.2 Pre-requisites, design and concept for implementation

2.2.1 Below sea-level multifunctional wetlands

Objective and challenge

Pilot multifunctional wetland, including novel active layers, will be constructed as a decentralised treatment system in flood risk areas in the Ebro Delta, rice fields located below sea level presently used for agriculture will be used. It will be operated with different management strategies (wet/dry periods) and it will be feed with wastewater from the agricultural uses of the area (using solar pumping) to remove nutrients, pesticides, and organic pollutants before discharge.

Our objective is to demonstrate the feasibility of the technology into wetlands in decentralized systems near to sea areas.

The ecosystem services of the wetland will be evaluated considering water quality improvement, coastal protection, biodiversity and climate regulation (carbon sequestration) and will be compared to the current centralized systems in place. A comparison of the efficiency of the two schemes (centralized vs decentralized) of constructed wetlands will be carried out and a plan for upscaling will be elaborated. IUCN will test the solution to align with internationally accepted NBS principles.

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Technical description

Urban, industrial, and agricultural development in river basins has resulted in the pollution of estuarine and coastal ecosystems (Vikas and Dwarakish, 2015). Discharge from rivers and estuaries contributes to the presence of high amounts of organic microcontaminants (OMCs) in coastal areas, including pesticides from the agricultural runoff of both farmlands located upstream and areas in the estuary itself (e.g., rice fields) (Bansal, 2011). Additionally, wastewater treatment plants (WWTPs) release contaminants of emerging concern (CECs) into rivers (Gogoi et al., 2018). The use of pesticides during the rice-growing season has been reported to be one of the most important sources of OMCs in estuarine areas (Añasco et al., 2010; Kuster et al., 2008), whereas CECs, mainly consisting of pharmaceuticals and household products, are released by WWTPs due to their inefficient treatment (Dulio et al., 2018).

The presence of OMCs in coastal areas can have adverse effects for aquatic biota. For instance, the presence of certain pesticides has been shown to produce changes in the macroinvertebrate community structure and ecosystem functions (Schäfer et al., 2007), whereas certain CECs have been shown to reduce macroinvertebrate diversity in rivers (Ginebreda et al., 2010).

The Ebro River is 910 km long and has a drainage area spanning 85,362 km2. It is the largest river in Spain and feeds the Ebro Delta, one of the largest wetland areas (320 km2) in the western Mediterranean region (Ibáñez and Caiola, 2016). The lower Ebro River, including the delta, suffers from an historical pollution due to the presence of a chloralkali plant located about 115 km upstream from the mouth, as well as the use of chlorinated pesticides in agriculture (Alcaraz et al., 2011). This has resulted in a background contamination of PCBs and DDTs, among other persistent organic pollutants (Huertas et al., 2016).

Constructed wetlands have been used to polish and treat urban wastewater but rarely it is applied to agricultural wastewater. Nutrients, metals, pesticides and organics removal in these systems have achieved successful removal rates (30-99%) given the different processes in their degradation (local conditions, adsorption, precipitation, filtration, sedimentation, microbial degradation, and plant uptake).

Currently, there are two main constructed wetlands in the Ebro Delta, which contribute to reduce by 67% the concentration of organic microcontaminants (V. Matamoros, et al, 2020).

IMPETUS is going to develop an alternative to centralised wetlands and will offer a solution for below sea-level unproductive rice fields promoting nature-based solutions (NBS) to reduce the amount of nutrient, metals, pesticides, and organic pollutants before its discharge to the marine ecosystem.

Different absorbent materials are going to be tested in laboratory conditions in order to identify those with a higher pollution reduction potential. Afterwards, the selected materials are going to be tested in a pilot constructed in a rice field in the Ebro Delta. Once tested and validated on the field, the project aims to implement this NBS to as many fields as possible.

We propose that small but efficient wetlands constructed with bed materials with a high absorbent capacity deployed at the low end of the rice fields will add up more pollutant removal than the current centralised once. Furthermore, below sea level rice fields with very low production rates can have a better use by providing an ecosystem service on the scheme suggested here.

Key Performance indicators, added value and replication potential

Demo sites are going to be implemented during the rice growing season of 2023 after laboratory mesocosms are being conducted during 2022 to test different bed materials.

Key performance indicators such as analytical data on removal of pesticides, organic contaminants, nutrients, metals and other pollutants are going to be collected and analysed during the demonstration.

Stakeholders are going to be invited to demonstration on the demo sites and technical sessions are going to be held in order to add value and replicate the experiment. The potential of this methodology is enormous as any rice field could host a wetland at the low end.

Role of partners and relevant stakeholders

Eurecat is leading this demonstration with both the laboratory tests and the field demonstration. Relevant stakeholders have been identified and are going to be contacted on the right time before the demonstrations are started. Contact information has been already collected in the project Stakeholder list.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 101037084.

Actions and timeline

1. Experiment design and state of the art.
2. Stakeholder identification.
3. Baseline of pollutants characterized in laboratory.
4. Bed materials tested under laboratory conditions.
5. Rice fields identified to conduct demonstration.
6. Implementation of the demo sites.
7. Stakeholder engagement and technical demonstration.
8. Data collection, key performance indicators set.

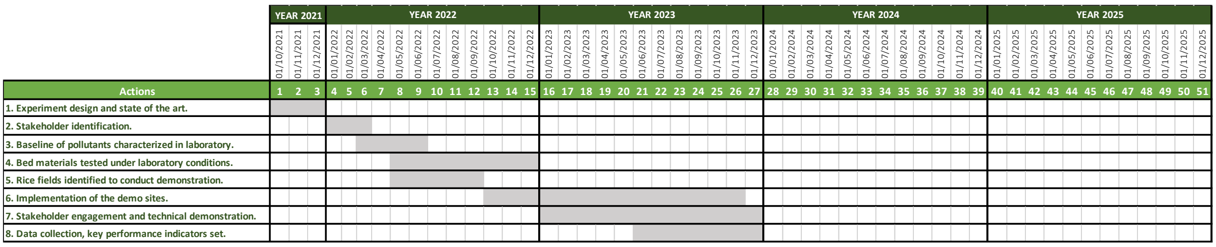

Figure 3: Chronogram of the actions of subtask 4.2

References

Alcaraz, C., Caiola, N., Ibáñez, C., 2011. Bioaccumulation of pollutants in the zebra mussel from hazardous industrial waste and evaluation of spatial distribution using GAMs. Sci. Total Environ. https://doi.org/10.1016/j.scitotenv.2010.11.015.

Añasco, N.C., Koyama, J., Uno, S., 2010. Pesticide residues in coastal waters affected by rice paddy effluents temporarily stored in a wastewater reservoir in southern Japan. Arch. Environ. Contam. Toxicol. https://doi.org/10.1007/s00244-009-9364-1.

Bansal, O.P., 2011. Fate of pesticides in the environment. J. Indian Chem. Soc. 88 (10), 1525–1532.

Dulio, V., van Bavel, B., Brorström-Lundén, E., Harmsen, J., Hollender, J., Schlabach, M., Slobodnik, J., Thomas, K., Koschorreck, J., 2018. Emerging pollutants in the EU: 10 years of NORMAN in support of environmental policies and regulations. Environ. Sci. Eur. https://doi.org/10.1186/s12302-018-0135-3.

Ginebreda, A., Muñoz, I., de Alda, M.L., Brix, R., López-Doval, J., Barceló, D., 2010. Environmental risk assessment of pharmaceuticals in rivers: relationships between hazard indexes and aquatic macroinvertebrate diversity indexes in the Llobregat River (NE Spain). Environ. Int. https://doi.org/10.1016/j.envint.2009.10.003.

Gogoi, A., Mazumder, P., Tyagi, V.K., Tushara Chaminda, G.G., An, A.K., Kumar, M., 2018. Occurrence and fate of emerging contaminants in water environment: a review. Groundw. Sustain. Dev. https://doi.org/10.1016/j.gsd.2017.12.009.

Huertas, D., Grimalt, J.O., Benito, J., Benejam, L., García-Berthou, E., 2016. Organochlorine compounds in European catfish (Silurus glanis) living in river areas under the influence of a chlor-alkali plant (Ebro River basin). Sci. Total Environ. https://doi.org/10.1016/j.scitotenv.2015.06.103.

Ibáñez, C., Caiola, N., 2016. Ebro Delta (Spain). In: The Wetland Book, https://doi.org/10.1007/978-94-007-6173-5_145-1.

Kuster, M., López de Alda, M.J., Barata, C., Raldúa, D., Barceló, D., 2008. Analysis of 17 polar to semi-polar pesticides in the Ebro river delta during the main growing season of rice by automated on-line solid-phase extraction-liquid chromatography-tandem mass spectrometry. Talanta. https://doi.org/10.1016/j.talanta.2007.11.027.

Matamoros, V., Caiola, N., Rosales, V., Hernández, O., & Ibáñez, C. (2020). The role of rice fields and constructed wetlands as a source and a sink of pesticides and contaminants of emerging concern: Full-scale evaluation. Ecological Engineering, 156, 105971. doi:10.1016/j.ecoleng.2020.105971

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Schäfer, R.B., Caquet, T., Siimes, K., Mueller, R., Lagadic, L., Liess, M., 2007. Effects of pesticides on community structure and ecosystem functions in agricultural streams of three biogeographical regions in Europe. Sci. Total Environ. https://doi.org/10.1016/j.scitotenv.2007.04.040.

Vikas, M., Dwarakish, G.S., 2015. Coastal pollution: a review. Aquat. Proc. https://doi.org/10.1016/j.aqpro.2015.02.051.

2.2.2 Sand dunes restoration techniques and monitoring

Objective and challenge

The overall objective of the task 4.3 is to assess the suitability of dune restoration along the beaches of the Catalan coast to act as NBS to coastal hazards. This includes the following specific objectives:

- Analysis of the present status of dune systems in the Catalan coast by on-site and remote sensing surveys.
- Application of multiscale indicators to assess the impacts of climate change (e.g., frequency and intensity of marine storms) and other human impacts (e.g., tourism).
- Test, monitor and assess by means of indicators the ongoing dune restoration actions on the Catalan coast in terms their resilience against marine storms, biodiversity enhancement and promotion of citizens' behavioural change along the Catalan coastline.
- Monitoring of the actions carried out in Calafell (Costa Daurada, South coast of Catalonia) and Sant Pere Pescador (Costa Brava, North coast of Catalonia) as cases of demonstration of good practices in adaptation to climate change on the coast by restoring the dune system.
- Propose guidelines to improve the effectivity of restoration actions and elaborate a plan for upscaling dune restoration in the coast of Catalonia.

The challenge addressed is to perform a series of field experiments in the previously mentioned demonstration cases to determine efficient management strategies for dune restoration under typical conditions of the Catalan coast to determinate the most efficient measures for dune restoration.

Technical description

Coastal dunes are natural buffers between land and sea which reduce the exposure of the hinterland and thereby protect people and infrastructure from the impact of natural hazards (e.g. Barone et al. 2014). Their protection capabilities depend on different parameters such as their geometry (e.g. volume, crest elevation), continuity and ecological status (e.g. vegetation) (e.g. Debaine and Robin, 2012; Sigren et al. 2018).

Despite the important protection service by these natural systems, throughout the 20th century almost 70% of the European coastal dunes have disappeared, especially those located on the Mediterranean coast, as a consequence of the transformation and urbanization of the coastal zone, mainly related to the development of coastal tourism (Martinez et al. 2004; Ruocco et al., 2014). A clear example of this process is the Spanish Mediterranean coast, where, for example, it has been estimated that dune degradation has affected more than 90% of the systems along the Catalan coast in the last half-century (Garcia-Lozano et al., 2018; 2020).

Prioritising tourist and recreational use above the natural and protective functions of beach-dune systems is indicative of a lack of integrated management, leading to the accelerated degradation of these fragile, vulnerable systems (Alonso et al., 2002; Nordstrom, 2008; Pilkey et al., 2011; Sardá et al., 2013; Taylor et al., 2015).

Apart from human degradation, climate change is also a potential threat to coastal dunes, as SLR

becomes a major disturbance, especially in those areas where there is a lack of accommodation space that can result in coastal squeeze (e.g. Martinez et al. 2014). Consequently, the use of coastal dunes in the framework of an adaptation strategy based on the use of NBS requires adequate conditions for their development and for the maintenance of their ecological integrity. In this context, this task addresses the restoration and conservation of coastal dunes as NBS to increase the resilience of low-lying coasts to the risks associated with climate change, such as flooding and erosion.

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Dune restoration on developed coasts is therefore a well-validated practice requiring the correct implementation of management measures. To this effect, sand fences to trap aeolian sediment and prevent dune trampling is a crucial technique for dune development. Managers have enough information on using fence techniques to create dune morphologies in dune degraded areas since there has been substantial trial-and-error research based on sand fence installations for controlling sand deposition. However, other methods such as restricting or rerouting pedestrian traffic, altering beach cleaning procedures, and eliminating exotic species are also necessary to environmentally recover dune morphologies.

Despite the abundance of dune restoration guidelines whose effectiveness is supported by various studies, managers tend not to adapt these measures to each specific geo-environmental situation, leading to unsatisfactory and even counter-productive results. Gomez-Pina et al. (2002) and Roig-Munar et al. (2018) discuss the dune restoration techniques adopted along the Spanish coastline, concluding that they are not adapted to the situation of each beach. These management measures therefore fail to achieve the desired results and sometimes even create deflation zones or lead to blowouts caused by the sand fences.

Dune restoration is a complex process which involves interaction and feedbacks between a large number of variables from different domains (i.e. geomorphological, ecological, socio-economic). Although the techniques for dune restoration are well known and they are well described in the literature (e.g. Ley et al. 2007¸ Martínez et al. 2013), their applicability and degree of success will vary depending on the conditions of the site (Martínez et al. 2013). Thus, in this task we shall test some of these techniques (such as different types of sand traps and roped dunes) to identify the most suitable ones to be applied in beaches with different management objectives (dune conservation, dune restoration, dune recovery or renaturation of the upper beach).

Based on previous results obtained by the members of this task and the knowledge of socio-environmental conditions along the Catalan coast (e.g. Garcia-Lozano and Pintó, 2018), a set of indicators will be applied to determine the potential for dune restoration, and a series of management techniques will be implemented in a survey area of the Sant Pere Pescador and Calafell beaches. Different kinds of sand traps and roped dunes will be installed in the selected sites to assess their performance to achieve management goals (conservation, restoration, recovery). Although, this is a long-term process and should require monitoring beyond the duration of this task, this field experiment will allow to evaluate the initial response of the dune system to the techniques tested and, it will serve as a field test to verify the validity of the index developed. The sites will be monitored throughout the project duration and, the evolution of each system against the management objectives will be used to identify the best technique according to the socio-environmental characteristics of each site.

Key Performance indicators, added value and replication potential

Demo sites to implement dune management measures will be identified based on existing information from previous analysis. Due to this, no delay is expected to start field experiments. They are going to be implemented during the spring of 2022 and are being controlled during 2023 and 2024. The group responsible for this task has the required knowledge and experience (on methods and on the area of study) to efficiently implement them and to monitor dune evolution.

Key performance indicators are going to be collected and analysed. As the final goal of the task is to assess and apply the most efficient strategies to develop coastal dunes as NBS against climate change in the study cases, Sant Pere Pescador and Calafell. These will be a set of different typologies of representative beaches in the Catalan coast, as the entire Mediterranean coastline, in terms of their intensity of use and degree of naturalization (e.g. urban, semi-urban and natural), and different dune management strategies (dune conservation, dune restoration and dune recovery).

Role of partners and relevant stakeholders

The involved stakeholders will be asked to know if they are aware of the environmental problems of coastal areas and, in particular, of the sandy strips. It is very important to identify their role and responsibilities in an adaptation strategy based on managed retreat and dune restoration in the Catalan coast context (as representative of the Mediterranean coastal zone conditions).

Many relevant stakeholders have already been contacted (Contact information has been already collected in the project Stakeholder list). Contact with the rest of stakeholders will be established from the beginning of the project, with partners having extensive experience and having interacting with them in previous projects. Project partial results will be shared as soon as they are available to facilitate/maintain their engagement.

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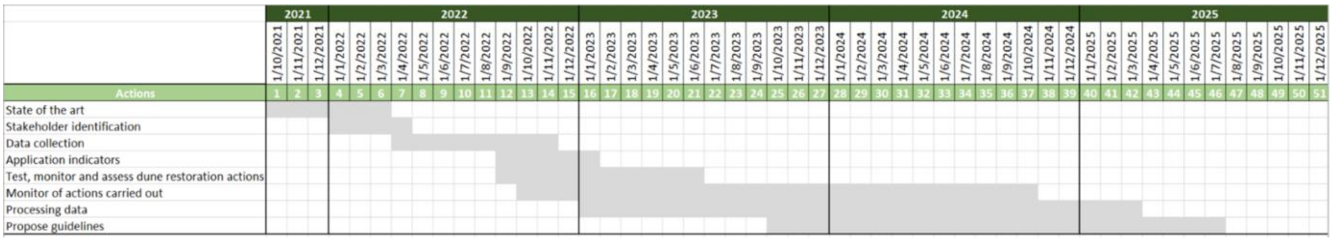
Actions and timeline

The subtask 4.3 is divided in 8 main actions:

- October 2021 – March 2022: State of the art.
- January – April 2022: Stakeholder identification.
- April - November 2022: Analysis of the present status of dune systems in the Catalan coast by on-site and remote sensing surveys (RGB, E=1/1000 (resolution 10x10 cm).
- September 2022 - January 2023: Application of multiscale indicators to assess the impacts of climate change and other human impacts.
- September 2022 - June 2023: Test, monitor and assess ongoing dune restoration actions in touristic beaches in terms their resilience against marine storms, biodiversity enhancement and promotion of citizens' behavioural change.
- October 2022 – October 2024: Monitoring of the actions carried out in Calafell (Costa Daurada, South coast of Catalonia) and Sant Pere Pescador (Costa Brava, North coast of Catalonia) as cases of demonstration of good practices in adaptation to climate change on the coast by restoring the dune system.
- January 2023 – March 2025: Processing data.
- October 2023 – July 2025: Propose guidelines to improve the effectivity of restoration actions and elaborate a plan for upscaling dune restoration in the coast of Catalonia.



References

Alonso, Alcantara-Carrio, J., Cabrera, L., 2002. Tourist resorts and their impact on beach erosion at sotavento beaches, Fuerteventura, Spain. *Journal of Coastal Research,* 7, 1–7.

Barone DA, McKenna KK, Farrell SC. 2014. Hurricane sandy: beach-dune performance at New Jersey beach profile network sites. *Shore & Beach,* 82(4), 13-23.

Debaine F, Robin M. 2012. A new GIS modelling of coastal dune protection services against physical coastal hazards. Ocean & Coastal Management, 63, 43-54.

Garcia-Lozano C, Pintó J, Roig F. 2020. Set of indices to assess dune development and dune restoration potential in beach-dune systems on Mediterranean developed coasts. *J. Env. Manag.*, 259, 109754.

Garcia-Lozano C, Pintó J. 2018. Current status and future restoration of coastal dune systems on the Catalan shoreline (Spain, NW Mediterranean Sea). *Journal of Coastal Conservation*, 22, 519-532.

Gómez-Pina, G., Munoz-Pérez, J.J., Ramírez, J.L., Ley, C., 2002. Sand dune management problems and techniques, Spain. *Journal of Coastal Research,* 332, 325–332.

Ley, C., Gallego-Fernández, J.B., Vidal, C., Gallego-Fernández, J.B., Vidal-Pascual, C., 2007. *Manual de Restauración de Dunas Costeras.* Ministerio de Medio Ambiente. Dirección General de Costas, Madrid.

Martínez ML, Mendoza G, Silva R, Mendoza E. 2014. Land use changes and sea level rise may induce a "coastal squeeze" on the coasts of Veracruz, Mexico. *Global Env. Change*, 29, 180-188.

Martínez ML, Psuty NP. 2004. *Coastal dunes.* Springer Verlag.

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Martínez, M.L., Gallego-Fernández, J.B., Hesp, P.A., 2013. *Restoration of Coastal Dunes.* Springer, London & New York.

Nordstrom, K.F., 2008. *Beach and Dune Restoration.* Cambridge University Press, Cambridge.

Pilkey, O.H., Neal, W.J., Kelley, J.T., Cooper, J.A.G., 2011. *The World's Beaches*. University of California Press, Singapore.

Roig-Munar, F.X., Martín-Prieto, J.A., Rodríguez-Perea, A., Blázquez Salom, M., 2018. Restauración de sistemas dunares en las islas Baleares (2000-2017): una visión crítica. *Investigaciones Geográficas* 119–136.

Ruocco M, Bertoni D, Sarti G, Ciccarelli D. 2014. Mediterranean coastal dune systems: Which abiotic factors have the most influence on plant communities? *Estuarine, Coastal and Shelf Science*, 149, 213-222.

Sardá, R., Pintó, J., Valls, J.F., 2013. *Hacia un nuevo modelo integral de gestión de playas*. Documenta Universitaria, Girona.

Sigren, J. M., Figlus, J., Highfield, W., Feagin, R. A., & Armitage, A. R. 2018. The effects of coastal dune volume and vegetation on storm-induced property damage: Analysis from Hurricane Ike. *Journal of Coastal Research,* 34(1), 164-173.

Taylor, E.B., Gibeaut, J.C., Yoskowitz, D.W., Starek, M.J., 2015. Assessment and monetary valuation of the storm protection function of beaches and foredunes on the Texas coast. *Journal of Coastal Research,* 315, 1205–1216.

2.2.3 Decentralized circular-economy inspired water/ energy/ materials reuse innovations

Objective and challenge

The **challenge addressed** is to develop decentralised hybrid water reclamation systems to increase water availability. The specific context is greywater reuse in campsites on the Catalan coast. This challenge has been chosen because: 1) campsite owners already show significant motivation to reduce the impact on water resources; 2) water reuse is a practice increasingly accepted by the population and with scope for technological development and future uses; and 3) there is a high seasonality in the quantity and quality of greywater in camping resorts. The **objective of the demonstration** is to prove the economic, social and environmental benefits of greywater reuse in the context of campsites on the Catalan coast.

Spain has the **highest risk for water shortage** and aridification among European countries. Catalunya and its coastline in particular is a region that struggles with the supply of high-quality water. However, since the early 2000's the Catalonian government has made significant progression in the **implementation of water management strategies**. Since the first example of **greywater reuse** in 2008 (Domènech & Saurí, 2010), the public perception of greywater reuse has been of high satisfaction at the beginning. Then, the public perception has worsened at the point of turn problems start to appear in maintenance, especially in the disinfection stage, as failure leads to odour emissions and turbidity or even color changes. In some scenarios, a few municipalities decided ''not to include greywater reuse systems in the regulation due to health risks involved when the maintenance of the system is not satisfactory'' (Domènech et al., 2015). Nevertheless, **public perception improved due to the adoption of more advanced technologies**.

The most common water source for camping resorts in the Catalan coast is the public network, although some of them used other sources, such as their own wells or rainwater tanks. From 2000 till now, camping resorts applied water-saving measures (WSMs) motivated by competitiveness, legitimation and ecological responsibility (Llausàs et al., 2020). The most frequent WSMs in the campsites are delivering information to customers to increase awareness; awareness-raising among employees; the installation of aerators, sensors or timers on taps and showers; the installation of double-flush flow cisterns and the use of more efficient filtration systems to clean the water in swimming pools (Llausàs et al., 2020). Other measures, such as grey-water reuse or the collection and reuse of rainwater, had been scarcely implemented.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 101037084.

Technical description

Greywater segregation and reuse is one of the emerging approaches to cope up with sustainable and integral water management in different parts of the world where the population faces acute water shortage (Vuppaladadiyam et al., 2018). On the other hand, the increase in water supply costs can be suppressed by opting for a greywater recycle approach. However, some risks and problems may arise when greywater is reused. Among them, major constraints are associated with **microbiological risks** when greywater is used for irrigation and toilet flushing (Teh et al., 2015) and the **impact of detergents** and xenobiotic organic compounds at elevated concentrations is not completely understood (Eriksson et al., 2002).

The quality of greywater mainly depends on the water supply source, the type of water distribution system (e.g. leaks or biofilm formation on the walls of pipes) and the household activities (Eriksson et al., 2002). Depending on the source, greywater can be divided into (1) light greywater, which includes the wastewater from the bath, shower, and hand washing, and (2) dark greywater, which included the effluent from the kitchen sink, dishwasher, laundry, and washing machines (Shaikh & Ahammed, 2020). The main differences between greywater and blackwater are that it contains only one-tenth of the total nitrogen in wastewater, fewer fecal pathogenic organisms and higher concentrations of surfactants. Among the organic pollutants in greywater, surfactants (surface active agents) have gained special interest due to their high concentrations in greywater compared to domestic wastewater, their widespread use, and their toxic effects on the environment, on humans, and wildlife.

The type of greywater treatment to be considered depends on the reuse applications and their specific requirements. The reuse of greywater is legal only after it has been treated according to the water quality standards and guidelines of the locale (WHO and UNEP, 2006; USEPA, 2012). To meet such guidelines, greywater may be processed using one or several primary, secondary and tertiary treatments. Primary treatments separate suspended and settleable solids before the degradation of organic matter and removal of nutrients in secondary and tertiary processes. The **biological treatment** of greywater involves the biodegradation of soluble, colloidal, and particulate organic materials and nutrients using various treatment technologies. Previously studied aerobic and anaerobic biological greywater treatment technologies include the sequencing batch reactor (SBR), the membrane bioreactor (MBR), rotating biological contactors (RBCs), the moving bed biofilm reactor (MBBR), and the upflow anaerobic sludge blanket (UASB) (Khalil & Liu, 2021).

The lower cost of anaerobic treatment compared to aerobic treatment, in addition to the nitrogen deficiency of greywater for aerobic treatment, were the reasons for choosing an anaerobic reactor. However, there are limitations of using anaerobic technologies for greywater treatment. Although studies have reported up to 76% biodegradability using anaerobic treatments (Khalil & Liu, 2021), the high surfactant concentration in greywater might inhibit the anaerobic biodegradation as they require molecular oxygen to complete.

The proposed treatment approach will be adapted to the high season production peaks and weekend peaks during the mid-season. In addition, greywater treatment will be adapted to the strict legislation for water reuse and the foreseen use for green zones and other cleaning purposes. Figure 4 shows a first scheme for the treatment, which will be validated and modified if necessary, during the bench scale operation. Three steps are foreseen: 1) dissolved organic carbon by an anaerobic MBR or UASB with ultrafiltration, 2) nutrients removal by a biofilter and 3) polishing step, with a disinfection if necessary.

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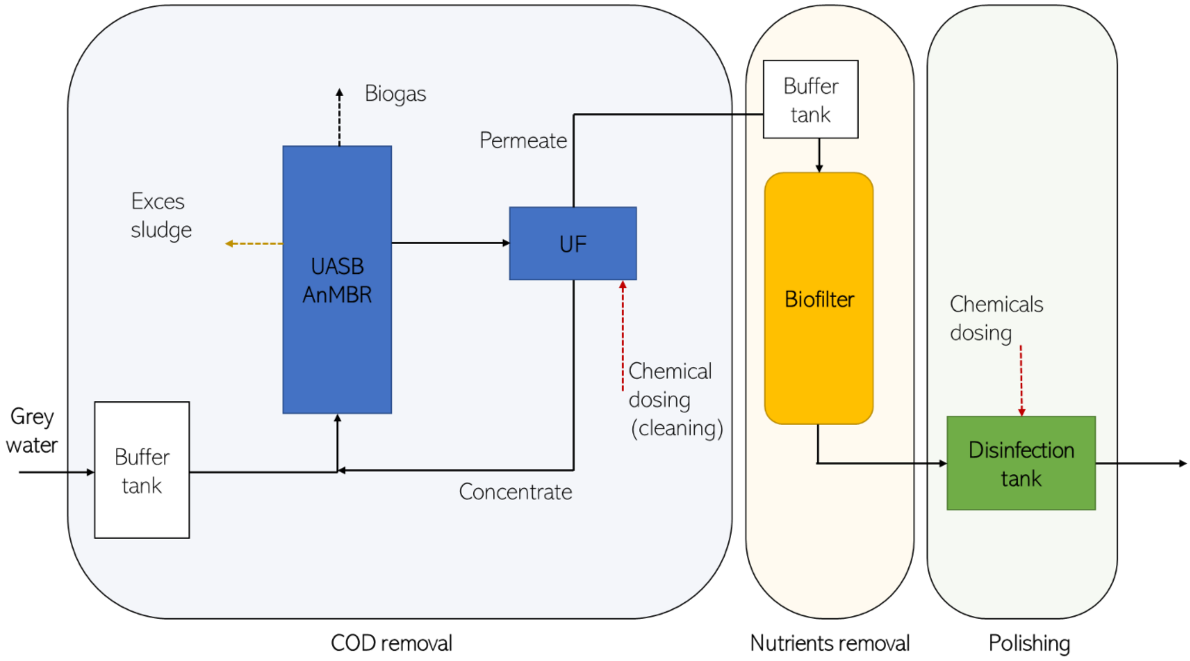
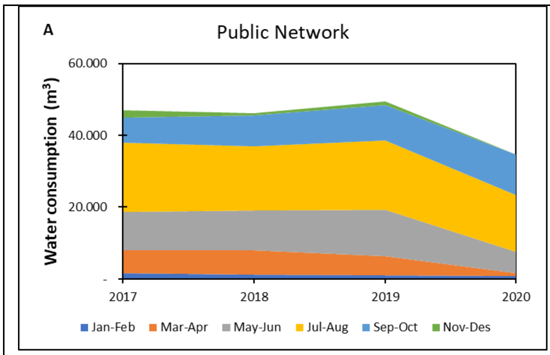
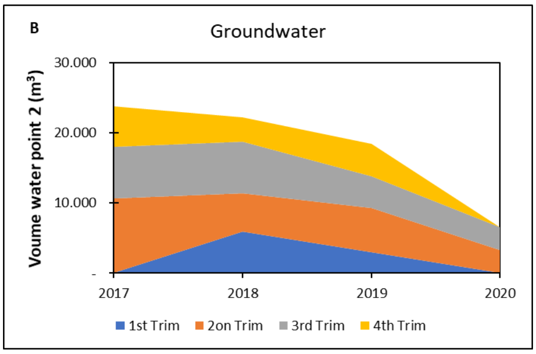


Figure 4: Proposed scheme for greywater treatment

The current data available is the total water consumption from the public network and groundwater source (Figure 5) and the water quality after the water treatment in the wastewater plant of the camping.

Water consumption is heavily dependent on the drinking water network, with a percentage that has been increasing steadily (Figure 5.C). First of all, the impact of the covid pandemic can be clearly observed, which has led to a general decrease in water consumption in 2020 (Figure 5.A and B). Groundwater consumption is fairly stable over time, except in the first three months of each year when it decreases substantially (Figure 5.B). On the other hand, the consumption of water from the public network clearly shows the seasonality of consumption and how it is highest in the summer season and lowest in the winter season (Figure 5.A).





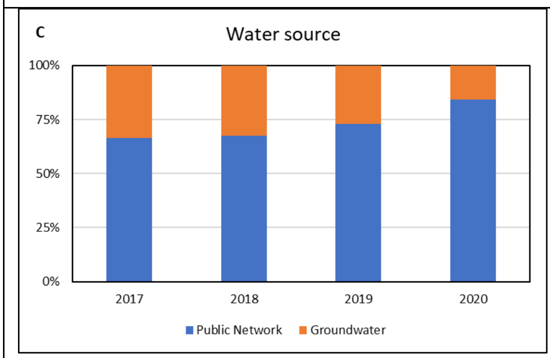


Figure 5 A) water consumption from the public network; B) Water consumption from groundwater source; and C) percentage of water source per year.

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The campsite also has a small wastewater treatment plant (black and grey water together) which makes a first treatment before discharging the wastewater to the municipal wastewater treatment plant. In this treatment plant, the following parameters are monitored on a non-regular basis (between 1 to 5 times per year): suspended matter, COD, pH, electrical conductivity, inhibiting substances, organic and ammoniacal nitrogen, total phosphorus, ammonium, oils and fats, anionic detergents, decantable matter and chlorides.

When greywater is segregated from wastewater, it will be necessary to know on a more regular basis: the volume of incoming and outgoing water and the quality of the indicators mentioned above. In addition, and not exclusively, microbial indicators (faecal coliforms and E. coli) and a wider range of detergents and surfactants will have to be analysed.

UASB and anaerobic MBR are novel technologies, which few bibliography referring to greywater. Of great importance is also to know the degradation potential of detergents and surfactants under anaerobic conditions in the reactors.

Another added value is the adaptability of the reclamation system for variable loading while achieving the desired levels for the reuse.

The potential barriers and drivers are:

- Seasonal loads combined with low temperatures, which will impact on biological processes.
- Surfactants and detergents which, could inhibit the biological processes and could not be removed.
- Delay on the construction of the pilot plant due to problems with stocks
- Start-up issues demonstration: the biological processes should start during warm months.
- Acceptance of the stakeholders for water reuse.

Key Performance indicators, added value and replication potential

The proposed key performance indicators (KPIs) of the developed model are the following:

- Quality of the treated water and achievement of the standards of the guides
- Percentage of removal of the different indicators
- Amount of reclaimed water

Role of partners and relevant stakeholders

Relevant stakeholders have been identified and are going to be contacted to involve them into the project. They will be involved on the implementation of the system and the monitoring tasks. Specifically for the local stakeholders, a monitoring plan will be detailed and a formation will be carried out to teach how to run the pilot plant.

Actions and timeline

The subtask 4.5.1 is divided in four main actions:

1. Planification and preparation
    1. State of the art and planification
    2. Experimental design, set-up bench scale
2. Bench scale testing to obtain parameters for the pilot plant design and operation
    1. Start up of the bioreactor
    2. decrease of temperature to 15ºC
    3. Simulation of real fluctuations
    4. Biofilter start up and disinfection
3. Pilot demonstration construction and operation
    1. design and construction of the pilot plan
    2. pilot plant installation and start up
    3. operation of the pilot plant and water reuse
4. Results analysis
    1. Technical, economic and environmental impact analysis

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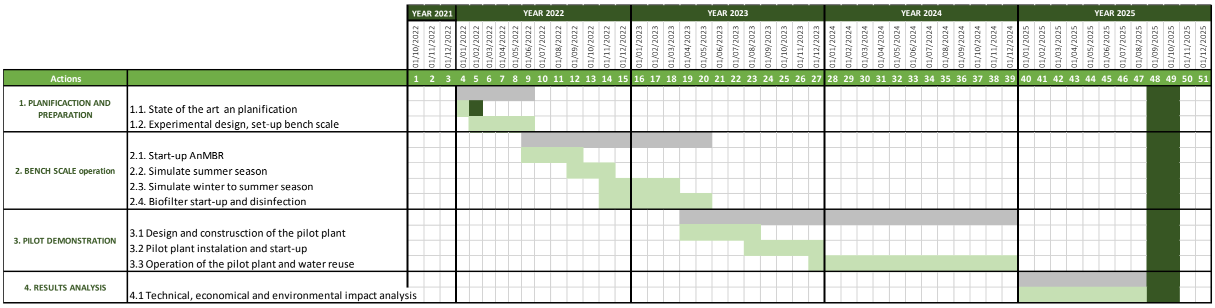

Figure 6 Chronogram of the actions and subactions of subtask 4.5.1.

References

Domènech, L., March, H., Vallès, M., & Saurí, D. (2015). Learning processes during regime shifts: Empirical evidence from the diffusion of greywater recycling in Spain. Environmental Innovation and Societal Transitions, 15, 26–41. https://doi.org/10.1016/J.EIST.2014.01.001

Domènech, L., & Saurí, D. (2010). Socio-technical transitions in water scarcity contexts: Public acceptance of greywater reuse technologies in the Metropolitan Area of Barcelona. Resources, Conservation and Recycling, 55(1), 53–62. https://doi.org/10.1016/J.RESCONREC.2010.07.001

Eriksson, E., Auffarth, K., Henze, M., & Ledin, A. (2002). Characteristics of grey wastewater. Urban Water, 4(1), 85–104. https://doi.org/10.1016/S1462-0758(01)00064-4

Khalil, M., & Liu, Y. (2021). Greywater biodegradability and biological treatment technologies: A critical review. International Biodeterioration & Biodegradation, 161, 105211. https://doi.org/10.1016/J.IBIOD.2021.105211

Llausàs, A., Padullés Cubino, J., Ribas Palom, A., Padullés, J., Anna, C., & Palom, R. (2020). Small and medium sized accommodation managers and opportunities for water conservation. PASOS. Revista de Turismo y Patrimonio Cultural, 18(1), 129–142. https://doi.org/10.25145/J.PASOS.2020.18.008

Shaikh, I. N., & Ahammed, M. M. (2020). Quantity and quality characteristics of greywater: A review. Journal of Environmental Management, 261, 110266. https://doi.org/10.1016/J.JENVMAN.2020.110266

Teh, X. Y., Poh, P. E., Gouwanda, D., & Chong, M. N. (2015). Decentralized light greywater treatment using aerobic digestion and hydrogen peroxide disinfection for non-potable reuse. Journal of Cleaner Production, 99, 305–311. https://doi.org/10.1016/J.JCLEPRO.2015.03.015

USEPA, 2012. Guidelines for Water Reuse. Environmental Protection Agency, Office of Wastewater Management, Office of Water, Washington, D.C.

Vuppaladadiyam, A. K., Merayo, N., Prinsen, P., Luque, R., Blanco, A., & Zhao, M. (2018). A review on greywater reuse: quality, risks, barriers and global scenarios. Reviews in Environmental Science and Bio/Technology 2018 18:1, 18(1), 77–99. https://doi.org/10.1007/S11157-018-9487-9

WHO, U.N.E.P., 2006. Guidelines for the Safe Use of Wastewater, Excreta and Greywater, WHO Policy and Regulatory Aspects 1.

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2.2.4 Sediment transport through irrigation networks

Objective and challenge

With this task, Eurecat aims to model the sediments transport in an estuary and the irrigation system of the area to preserve the delta in front of climate change impacts. The action will allow to reproduce the current sediment behaviour in the channels and the river and to propose an efficient management and adaptation measures. The study will be applied at the delta of the Ebro's River.

Technical description

Climate change can increase the frequency and the intensity of rain events, and also extending the drought periods. High variations on river levels and stream velocities can affect the erosion, and thus, the suspended sediments in water bodies and the sediments' distribution along the river, lakes, and estuaries. Particularly, increasing the erosion, suspended sediments load and resuspension during stronger storms, and decreasing the erosion and suspended sediments load and increasing sedimentation during droughts. Due to climate change impacts, maintain the river water quality though an effective erosion and a sediment control management is challenging.

Previous studies have shown that numerical models are powerful tools to simulate the hydromorphological processes that are occurring in water streams such as sediment erosion, transport, resuspension, and sedimentation (Huggins, Piedrahita, y Rumsey 2004; Huybrechts, Villaret, y Hervouet 2010). For decades, one-dimensional (1D) and two-dimensional (2D) models have been largely used considering assumptions and simplifications due to computing limitations (Zhang et al. 2021). Thus, under complex phenomenon, such as the interactions between flow, sediment and geomorphic evolution, have shown to be less reliable. Despite the computational progress during last years and the implementation of three-dimensional (3D) to improve the reliability and representativity of the simulation results, the models have been implemented in a small rivers or river's sections (Lepesqueur et al. 2019). In addition, particle heterogeneity, in terms of particle size and density distributions, is barely considered. For example, Castillo, Carrillo, y García 2013; García Alba et al. 2014 consider one unique median sediment class, and Bi y Toorman 2015; Hostache et al. 2014, consider two sediment grain-size classes assuming a uniform density.

As start, the study will be based on the works carried out during the project LIFE EBRO ADMICLIM on sediments transport along the irrigation system at the delta in Ebro River. A three-dimensional (3D) model will be developed using computational fluid dynamics (CFD) to describe the water flow within the river and the irrigation channels and the sediments behaviour through the system. For the model development, a free opensource CFD software will be used named OpenFOAM which offers a broad range of applications, including the movement of sediment particles transported by water flows, and flexibility to adapt or implement new mathematical equations to describe the desired phenomena (Xu et al. 2018). The model complexity and detail will be adjusted during its development to offer an efficient computational/simulation time while ensuring its representativity and reliability.

Public data, such as river water quality and flows, meteorological data or river cartography information, and data obtained during LIFE EBRO ADMICLIM project, will be used to develop, and implement the 3D model. Apart of the public data and the data set from LIFE EBRO ADMICLIM, if data are still missing, published data from the existing literature will be considered.

Key Performance indicators, added value and replication potential

The proposed key performance indicators (KPIs) of the developed model are the following:

- Quantity of sediments accumulated at the delta (3D images)
- Quantity of sediments accumulated at the irrigation systems (3D images)
- Quantity of sediments carried by the water flow (river)

The model will allow to evaluate different scenarios and conditions, like climate change scenarios, and identify several adaptation strategies based on the presented KPIs.

In addition, the presented model will consider general mathematical equations to describe common phenomena occurring in estuaries and irrigation systems in the same area with the objective to ensure its replicability to other locations experiencing similar conditions and climate change effects.

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Role of partners and relevant stakeholders

The task, led by Eurecat, also counts on the participation of the Catalan Office of Climate change (OCCC from the Catalan name “Oficina Catalana del Canvi Climàtic) of the Government of Catalonia. Public data, knowledge and global interests will be shared by the OCCC. Also, general questions related to this task and to current and future climate change impacts will be specified by the OCCC and Eurecat to in order to develop a useful tool.

Relevant stakeholders have been identified and are going to be contacted to involve them into the project. Partners and the selected stakeholders will be involved on the discussion of the needs of the natural park and the inhabitants of the region, and interests on protecting the estuary.

Actions and timeline

The task has been divided in different actions:

1. Data collection
    1. Bathymetry data of the Ebro River
    2. Design of the irrigation system
    3. Water flows and quality data
2. Model definition
    1. Model objectives
    2. Model limits
    3. Boundary conditions
    4. Process identification
3. Model development
    1. Selection of the process equations
    2. Integration of the equations
4. Model calibration
    1. Model parameters adjustment
5. Model validation
    1. Test the model under different historic scenarios
    2. Test climate change scenarios

The timeline proposed to achieve the objective of the task is presented in Figure 1.

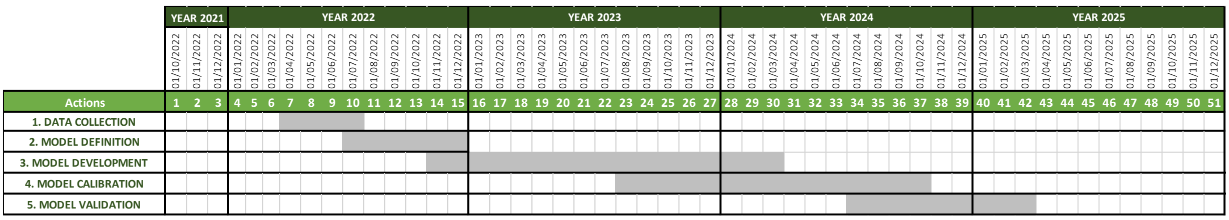

Figure 7. Timeline of the actions included in Task 4.6

References

Huggins, Dania L., Raul H. Piedrahita, y Tom Rumsey. 2004. «Analysis of Sediment Transport Bi, Qilong, y Erik A. Toorman. 2015. «Mixed-Sediment Transport Modelling in Scheldt Estuary with a Physics-Based Bottom Friction Law». *Ocean Dynamics* 65 (4): 555-87. https://doi.org/10.1007/s10236-015-0816-z.

Castillo, Luis Gerardo, José María Carrillo, y Juan Tomás García. 2013. «Flow and Sediment Transport Through Bottom Racks. CFD Application and Verification with Experimental Measurements.» En . Beijing.

García Alba, J., A. G. Gómez, R. O. Tinoco López, M. L. Sámano Celorio, A. García Gómez, y J. A. Juanes. 2014. «A 3-D Model to Analyze Environmental Effects of Dredging Operations –

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Application to the Port of Marin, Spain». *Advances in Geosciences* 39 (abril): 95-99. https://doi.org/10.5194/adgeo-39-95-2014.

Hostache, R., C. Hissler, P. Matgen, C. Guignard, y P. Bates. 2014. «Modelling Suspended-Sediment Propagation and Related Heavy Metal Contamination in Floodplains: A Parameter Sensitivity Analysis». *Hydrology and Earth System Sciences* 18 (9): 3539-51. https://doi.org/10.5194/hess-18-3539-2014.

Huggins, Dania L., Raul H. Piedrahita, y Tom Rumsey. 2004. «Analysis of Sediment Transport Modeling Using Computational Fluid Dynamics (CFD) for Aquaculture Raceways». *Aquacultural Engineering* 31 (3-4): 277-93. https://doi.org/10.1016/j.aquaeng.2004.05.007.

Huybrechts, N., C. Villaret, y J. M. Hervouet. 2010. «Comparison between 2D and 3D modelling of sediment transport: application to the dune evolution». En . Braunschweig, Germany.

Lepesqueur, Jérémy, Renaud Hostache, Núria Martínez-Carreras, Emmanuelle Montargès-Pelletier, y Christophe Hissler. 2019. «Sediment Transport Modelling in Riverine Environments: On the Importance of Grain-Size Distribution, Sediment Density, and Suspended Sediment Concentrations at the Upstream Boundary». *Hydrology and Earth System Sciences* 23 (9): 3901-15. https://doi.org/10.5194/hess-23-3901-2019.

Xu, Shan-lin, Rui Sun, Yuan-qiang Cai, y Hong-lei Sun. 2018. «Study of Sedimentation of Non-Cohesive Particles via CFD–DEM Simulations». *Granular Matter* 20 (1): 4. https://doi.org/10.1007/s10035-017-0769-7.

Zhang, Bangwen, Baosheng Wu, Shi Ren, Ruoyin Zhang, Wei Zhang, Jinqiu Ren, y Yi Chen. 2021. «Large-Scale 3D Numerical Modelling of Flood Propagation and Sediment Transport and Operational Strategy in the Three Gorges Reservoir, China». *Journal of Hydro-Environment Research* 36 (mayo): 33-49. https://doi.org/10.1016/j.jher.2021.03.003.

2.2.5 Improving bathing water quality after extreme storms events

Objective and challenge

In this subtask a Quantitative Microbiological Risk Assessment (QMRA) will be developed to determine the risk due to the presence of pathogens in seawater. The objective is to develop and implement tools for risk prediction, monitoring and management of water-borne disease in Barcelona demo-site.

Technical description

The Quantitative Microbial Risk Assessment (QMRA) estimates the infectious/illness risk of exposure to microorganisms, on the basis of dose-response relations between the number of pathogens and the health effects. In recent years, the number of studies addressing the application of QMRA to assess the risk for recreational waters, covering inland and marine waters, has increased exponentially (Federigi et al., 2019). In the different QMRA studies, the exposure to various pathogens has been considered. The selection of reference pathogens for QMRA is based on previous studies and mainly on the incidence of illnesses in the general population, or in the population of concern. Other criteria for reference pathogens selection are their concentration in wastewaters (Eregno et al., 2016), their survival in different natural waters, the type of contamination sources present and the availability of detection methods. In some studies, the use of Faecal Indicator Bacteria (FIB) (coliforms, *E. Coli* and intestinal enterococci) to estimate pathogens has been reported as FIB can be easily measured and information regarding their concentration can be obtained. In these cases, the application of pathogen to indicators ratios to calculate the concentration of reference pathogens and the associated risk has been reported.

The studies show that QMRA can be applied to characterize different exposure scenarios, determine the risks caused by various types of FIB and pathogens, develop alternative recreational water quality criteria and evaluate the impact of control measures on health risk. Another important aspect addressed in recent studies is the role of meteorological conditions on bacterial indicators present in recreational waters and the impact of polluted streams on seawater contamination confirming that meteorological variables are critical for bathing waters quality (Federigi et al., 2017). Thus, QMRA results could be used to develop predictive models of microbial contamination in relation with climatic conditions, in order to protect human health from bathing in polluted seawaters, such as preventive closure of beaches.

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However, there are still some critical issues that need to be addressed in order to improve the reliability of QMRA applied to recreational waters such as the lack of relevant data regarding contamination and its variability and the information about dose-response relationships.

The work to be carried out during IMPETUS project will take into account the results of the previous project IBATHWATER in which Eurecat has participated. A management tool of Combined Sewer Overflows episodes impact into bathing waters will be developed and implemented combining advanced on-line pathogen monitoring (*E.Coli* and total coliforms) and water quality models to prevent water quality decrease in the seacoast. The developed tool will allow to monitor microbiological water quality in order to alert about significant risks for human health in the demo-site.

Data obtained from AquaBio, a measuring equipment developed during iBATHWATER project that continuously and automatically measures *E. coli*, enterococci and total coliforms to provide the alert to a possible risk to human health, will be considered. AquaBio can measure the mentioned microbiological parameters in sea water and wastewater. Reference pathogens which are known to persist on seawater and others causing common human diseases, will be selected to determine QMRA. In the developed QMRA model, pathogens concentrations will be estimated from E.coli and Enterococci indicators by applying the pathogens/indicators ratios determined for Barcelona beaches.

The potential barriers and drivers of this subtask will be mainly the lack of representative data regarding reference pathogens in order to determine pathogens to indicators ratios for Barcelona beaches and subsequently validate the developed QMRA tool.

Key Performance indicators, added value and replication potential

The risk management tool will support municipalities and public organisations on decision making to minimise the human health risk in front of severe storm events. The tool permits to monitor and prevent risks for human health. The main key performance indicators that will be evaluated during this task is:

- Human health risks associated to bathing water quality
- Number of events where the water quality is risky for human health

The tool can be easily implemented in other coastal areas where online measurements of pathogens concentrations are available.

Role of partners and relevant stakeholders

Relevant stakeholders have been identified and are going to be contacted to involve them into the project. They will be involved on the implementation of the tool and teach for its use. Also, they will be part of the discussions on the development to adapt the tool to their needs.

Actions and timeline

Task has been divided in five main actions:

1. Tool definition
    1. Requirement's definition of the Quantitative Microbiological Risk Assessment (QRMA) tool
2. Data collection
    1. Data collection from Barcelona demo-site
3. Tool development
    1. Development of the Quantitative Microbiological Risk Assessment (QMRA) tool
4. Tool validation and optimisation
    - Validation and optimization of the developed QMRA tool with collected data
5. Tool implementation
    1. Implementation of the QMRA tool in Barcelona demo-site to monitor and prevent risks for human health

The timeline proposed for each action to achieve the objective of the task, is presented in Figure 1.

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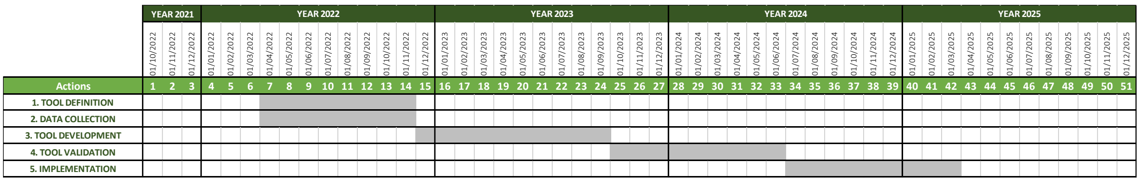

Figure 8. Timeline of the actions included in Task 4.8.1.

References

Eregno, F. E., Tryland, I., Tjomsland, T., Myrmel, M., Robertson, L., & Heistad, A. 2016. *Quantitative microbial risk assessment combined with hydrodynamic modelling to estimate the public health risk associated with bathing after rainfall events.* Science of the Total Environment 548–549 270–279.

Federigi, I., Verani, M., Donzelli, G., Cioni, L., & Carducci, A, 2019. *The application of quantitative microbial risk assessment to natural recreational waters: A review*. Marine Pollution Bulletin 144 (2019) 334 – 350.

Federigi, I., Verani, M., Carducci, A. 2017. *Sources of bathing water pollution in northern Tuscany (Italy): Effects of meteorological variables*. Marine Pollution Bulletin 114 843-848.

2.2.6 Increasing resilience of water plants to water-borne pathogens

Objective and challenge

The presence of cyanotoxins produced by harmful algal blooms (HABs) is a serious threat to drinking water sources and an urgent global challenge (Brooks et al., 2017; Gaget et al., 2017). Continued eutrophication and climate change have led to significant increases in HABs and the associated cyanotoxin contamination of drinking water sources (Brooks et al., 2017; He et al., 2016). The ingestion of potent cyanotoxins poses serious health hazards for humans, including increased cancer risks. The United States Environmental Protection Agency (US EPA) has included a number of cyanotoxins produced during HABs in the Drinking Water Contaminant Candidate List 4 (CCL-4) (US EPA - Agency, 2016). For the common cyanotoxins, microcystins (MCs) and cylindrospermopsin (CYN), the US EPA has issued ten-day health advisory (HA) values for drinking water.

Taking into account this increasing concern, the principal objective of the demonstration in the framework of the IMPETUS Project is to evaluate a low-cost and easy to operate technology able to remove cyanotoxins from drinking water treatment plants. The subtask has three specific objectives: 1) predict HABs events by implementing advanced monitoring tools in water reservoirs, 2) prevent the growth in the reservoirs by implementing technology based on ultrasonic treatment, and 3) evaluate solar disinfection for cyanotoxins removal during drinking water treatment.

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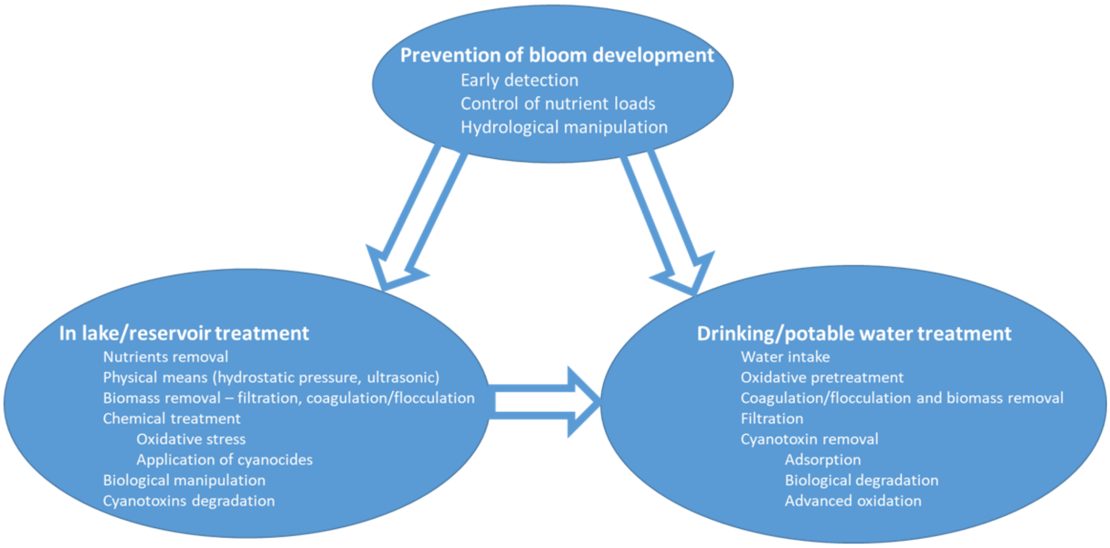

Figure 9: Schematic presentation of strategies and techniques implemented to prevent the development of HAB and to mitigate potential impacts on aquatic ecosystem and potable water (Sukenik & Kaplan, 2021).

Technical description

State of the art

Prediction of HABs

Early warning systems to identify HAB development are considered an important source of information for drinking-water treatment plants (DWTPs) that take raw water from above-ground sources. The information can be acquired from real-time monitoring systems located at the vicinities of pumping stations and from hyperspectral or multispectral devices mounted on satellites or drones (Sukenik & Kaplan, 2021). Additionally, gathered information can be used as an input for forecasting models to predict the development of cyanobacteria and their toxicity in a DWTP inlet (Sukenik & Kaplan, 2021). The prediction of HABs can be used by DWTPs to apply in-lake treatments, which will be most effective when the population density of cyanobacteria and other harmful algae is low.

Beyond the sampling and analysis that can be carried out more or less frequently in the water reservoirs and inlets of DWTPs, the use of sensors that continuously measure parameters related directly (chlorophyll-a, phycocyanin) or indirectly (turbidity, nutrients) are cost-effective tools that are providing valuable information on the dynamics of HABs.

Prevention of HABs

Reducing nutrients is necessary but difficult to achieve, even in the long-term. The majority of nutrient management methods are costly and require frequent dosing with unknown side-effects for the aquatic ecosystem. Besides, the duration and intensity of algal bloom events is strongly depended not only on nutrients but also on a combination of environmental factors, such as climate change, weather patterns, and an unbalanced ecosystem.

A wide variety of technologies exist to prevent and/or remove HABs (

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Table 5). Among these technologies, ultrasound highlights with the advantage of the low impact on ecosystems, but with the drawback of few experiences in up-scaled levels. At present, the main implementation scenarios of ultrasonic technology for HABs control are small landscape water bodies or lakes (Zhan et al., 2021).

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Table 5: Advantages and drawbacks of algal-bloom control methods (Zhan et al., 2021)

Methods	Removal techniques	Advantages	Drawbacks
Physical methods	Mechanical harvesting	Less pollution	High cost
	Aeration and oxygenation	Low impact on ecosystems	High capital cost
	Membrane separation	High separation efficiency	Membrane fouling leads to increased cost
	Air floatation	Short operation time	Addition of flocculants or surfactants
	Ultrasound	Low impact on ecosystems	To be confirmed at up-scaled levels
Chemical methods	Algaecide	High residence time	Toxicity against non-target species
Physicochemical methods	Coagulation-air flotation	Less cell damages	High cost
	Flocculation-sedimentation	Less energy demand	High chemical cost
Biological and ecological methods	Microorganisms	High specificity	High cost
	Aquatic organisms	Low impact on environment	Affect biodiversity
	Aquatic vegetation restoration	Low cost	Unstable and slow implementation effects
	Constructed wetland	Low impact on ecosystems	Long remediation time
	Plant floating bed	Less pollution	Low efficiency

Sonication as a means of cyanobacterial control has been under investigation for the past two decades at lab scale. The widely acknowledged effects of sonication on cyanobacterial growth inhibition are by the collapse of gas vesicles/vacuoles, membrane and/or cell wall disruption, and interruption of photosynthetic activity. It has been shown in many cases that in addition to disruption of cyanobacterial cells via these effects, sonication can potentially selectively remove cyanobacterial species such as M. aeruginosa and A. circinalis and has the advantage of degrading microcystins (Rajasekhar et al., 2012).

The research on ultrasonic control of algae is still ongoing. In the future, the frequency, power, and exposure time used to control algal blooms at different initial densities in different scenes of water bodies should be examined, which will help improve the treatment efficiency and reduce energy consumption. At the same time, the impact of ultrasound on water quality, other aquatic organisms, and the release of algal toxins from bloom-forming algae should remain of concern (Zhan et al., 2021)

Disinfection for cyanotoxins removal

Conventional treatment processes such as chlorination and adsorption, as well as advanced systems like membrane technology, ozonation or photocatalysis have been investigated for cyanotoxins removal. In fact, most of these treatments are currently applied in DWTPs but their efficiency depends greatly on the kind of cyanotoxin, the source water characteristics as well as the operating parameters (temperature, pH, cyanotoxin level), which can frequently change in a DWTP. Chlorination has shown to be effective for the removal of certain cyanotoxins such as microcystin LR (MC-LR) and CYN, but relatively high chlorine doses are required (>2-3 mg/L) and the generation of trihalomethanes as well as chlorinated by-products from cyanotoxins (e.g. chlorouracil and 5-chloro-cylindrospermopsin from CYN) can occur. Furthermore, other relevant cyanotoxins such as anatoxin-a (ATX) and saxitoxin (STX) are resistant to chlorination. On the other hand, adsorption onto activated carbon (AC), which is another conventional technique widely used in DWTPs, allows to remove certain cyanotoxins (MCs, ATX and CYN) but high carbon dosages (10 mg/1 toxin: 20-200 mg AC/L) and long contact times (even above 12 h) can be required depending on the kind of AC and the operating conditions. With regard to membrane technologies, nanofiltration and reverse osmosis appear as the most effective for cyanotoxins removal while ultrafiltration is not a reliable treatment barrier (Kumar et al., 2018). Advanced oxidation processes (AOPs) appear as promising alternatives for the degradation of cyanotoxins as they can destroy organic pollutants by the action of in-situ generated hydroxyl radicals. So far, most AOP studies have been focused on the removal of microcystins, in particular MC-LR, as they occur most frequently in fresh water; CYN and ATX have been by far less investigated and very little work can be found for STX. Ozonation is widely used in DWTPs, but it is usually based on the direct action of ozone, which is much less reactive than hydroxyl radicals (Kumar et al., 2018). For instance, high degradation of MC-LR was achieved using H2O2/O3 (>90% in 1 min) compared to only O3 (60% in 30 min) under the same conditions. In general, the application of H2O2/O3 has proved to be effective for cyanotoxins removal. Nevertheless, the generation of toxic byproducts is an important drawback of this treatment (Lu et al., 2018). Photocatalysis has also proved to degrade cyanotoxins but the use of UV light, makes the process cost-intensive.

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Solar water disinfection (SODIS) is an inexpensive method widely proven to be effective in inactivating waterborne pathogens belonging to all realms of sanitary interest, including chlorine-resistant microorganisms, for example, Cryptosporidium spp. oocysts, Acanthamoeba spp. cysts and Bacillus subtilis spores (Chu et al., 2019). SODIS has also been widely demonstrated to be able to enhance the antimicrobial effectiveness of chlorine and to inactivate or degrade many chemical contaminants in water (Patel et al., 2019). In addition, SODIS is an accessible method, since it does not require the use of chemical disinfectants and uses thermal and optical energy from the sun to inactivate microorganisms present in the water. SODIS is based on exposing microbially contaminated water to disinfecting UVA and UVB radiation of natural sunlight. Although it has been proven to be an effective method in disinfecting water by extensive laboratory and field studies, there is still a lack of knowledge regarding its effectiveness in degrading cyanotoxins up to a level able to ensure drinking water standards (Munoz et al., 2019).

Tasks and demonstration site

In order to achieve objectives 1 and 2, a floating surface will be set up in the center of Lake Agulla (Figure 10) anchored to the bottom. Multiparametric sensors will be installed on this structure to measure, at least, chlorophyll-a (green algae), phycocyanin (blue-green algae), pH level, water temperature, turbidity, and dissolved oxygen. Parameter readings shall be complemented by sampling and analysis of the reservoir water.

Additionally, ultrasonic transmitters will also be installed in the platform. Ultrasonic programs and frequency shall be set according to the measured parameters and the manufacturer's recommendations in order to prevent and reduce HABs. With regard to cyanotoxins removal with solar treatment, thus for achieving objective 3, a bench-scale set up will be used to carry out solar disinfection. The bench scale set up has lamps able to reproduce solar light spectra, placed on top of a support where the water with cyanotoxins will be placed in order to carry out controlled disinfection experiments. Cyanotoxins degradation will be assessed under different solar light intensities, as a function of accumulated solar UV-A energy per unit of volume (kJ/L). During this activity, on top of the effect of the energy per unit of volume, additional factors will be evaluated aiming at assessing the potential of increasing the solar disinfection technology for enhancing drinking water treatment plants resilience to water borne pathogens. These factors are, (i) thermal enhancement, (ii) the application of catalysts (TiO_2) to perform heterogeneous photocatalysis, and (iii) the addition of chemical additives, alternative to TiO_2. Aiming at obtaining results which could be reproduced in other and different case-studies, different types of cyanotoxins will be used; in particular: Microcystin-LR, -RR, -LA, YR and CYN.

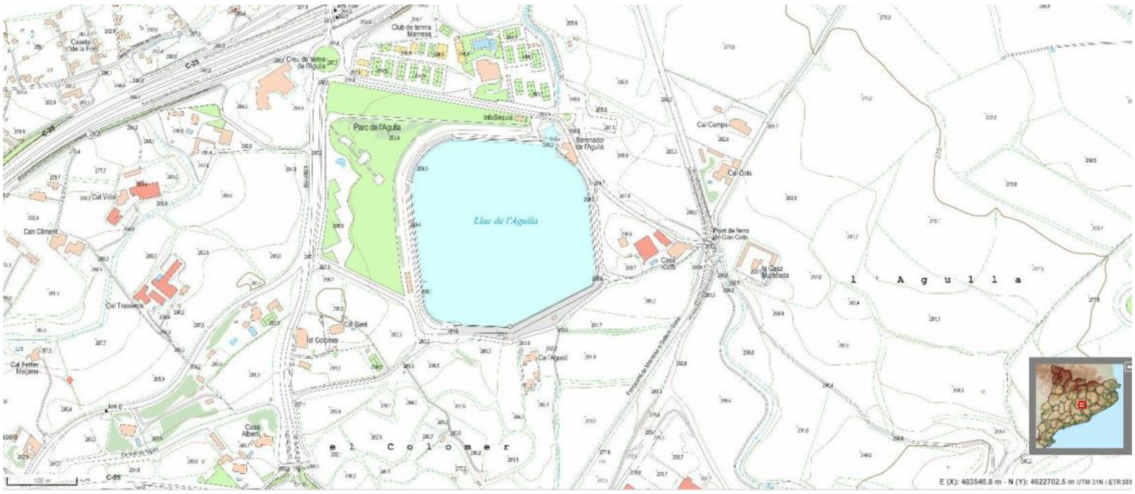

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Figure 10: Topographic map and orthophoto of the Agulla lake. Distance between the vertices of 300 m.

Data requirements and availability of data/models

The DWTP monitors different parameters at three different points: in the open-air ditch, at the inlet and at the outlet of the DWTP. At these points it monitors physical (e.g., temperature and electrical conductivity), chemical (e.g., nutrients and dissolved oxygen) and biological parameters (e.g., algae concentration and typology).

In order to be able to develop objectives 1 and 2, it is necessary to acquire the same type of data in the main water reservoir (Agulla lake). This will be done through the installation of advanced monitoring tools and periodic sampling. With regard to objective 3, it would be helpful to gather data on types and concentrations of cyanotoxins usually found in drinking water reservoirs. Those data will be used to set relevant experimental conditions, according to real case scenarios.

Added value and replication potential

The added value of the tasks carried out aims to increase the availability of surface water, preventing the harmful effects of HABs and cyanotoxins, aiming at increasing the resilience of DWTPs in the face of climate and global change.

Potential barriers (risks) and drivers

Frequency and intensity of HABs in the water reservoir uncertain, as the available data is from the open-air ditch, which is connected to the water reservoir. Additionally, the context of climate and global change increase the uncertainty of the representativity of the gathered data.

Regarding the solar disinfection of cyanotoxins, one of the potential barriers could be represented by the practical limitations of lab-scale conditions. In fact, it has been noted that continuous flow systems/reactors could allow for significantly better results than lab-scale batch systems. Therefore, a possible risk may be to underestimate the disinfection potential, by only evaluating the results obtained during lab experiments.

Key Performance indicators, added value and replication potential

The main Key Performance indicators for this subtask are:

- Reduction in the frequency and intensity of algal blooms
- Chlorophyll and phycocyanin concentration
- Microcystin removal efficiency in the range of 90%-100%

The added value would be the increase of the resilience to the dependant surface water DWTP to the increase HABs. The replication potential would be other water users with dependency to surface water reservoirs with increasing problems of HABs.

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Role of partners and relevant stakeholders

Relevant stakeholders have been identified and are going to be contacted to involve them into the project. They will be involved on the implementation of the tool and teach for its use. Also, they will be part of the discussions on the development to adapt the tool to their needs.

Actions and timeline

1. Planification and Preparation
   1.1. Collection and interpretation of the available data
   1.2. State of the art and design of the platform devices for monitoring and ultrasonic treatment
   1.3. Experimental design, set-up bench scale
2. Water Reservoir operation
   2.1. Platform installation
   2.2. Monitoring of the parameters
   2.3. Ultrasonic treatment
3. Solar Disinfection
   3.1. Test in a controlled situation (aritificial solar-light)
   3.2. Test in relevant environment (natural solar light)
   3.3. Set up the flow reactor (pilot plat at Agulla Lake)
   3.4. Tests with flow reactor (pilot plant at Agulla Lake)
4. Technical, economic and environmental impact analysis

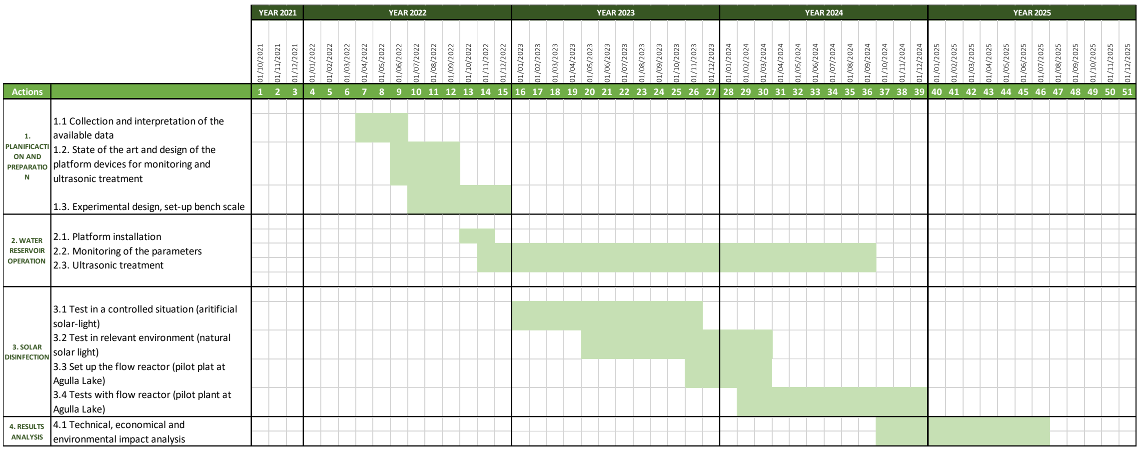


Figure 11: Chronogram of the actions and subactions.

References

Brooks, B. W., Lazorchak, J. M., Howard, M. D. A., Johnson, M. V. v., Morton, S. L., Perkins, D. A. K., Reavie, E. D., Scott, G. I., Smith, S. A., & Steevens, J. A. (2017). In some places, in some cases, and at some times, harmful algal blooms are the greatest threat to inland water quality. *Environmental Toxicology and Chemistry*, *36*(5), 1125–1127. https://doi.org/10.1002/ETC.3801

Chu, C., Ryberg, E. C., Loeb, S. K., Suh, M. J., & Kim, J. H. (2019). Water Disinfection in Rural Areas Demands Unconventional Solar Technologies. *Accounts of Chemical Research*, *52*(5), 1187–1195. https://doi.org/10.1021/acs.accounts.8b00578

Gaget, V., Lau, M., Sendall, B., Froscio, S., & Humpage, A. R. (2017). Cyanotoxins: Which detection technique for an optimum risk assessment? *Water Research*, *118*, 227–238. https://doi.org/10.1016/J.WATRES.2017.04.025

He, X., Liu, Y. L., Conklin, A., Westrick, J., Weavers, L. K., Dionysiou, D. D., Lenhart, J. J., Mouser, P. J., Szlag, D., & Walker, H. W. (2016). Toxic cyanobacteria and drinking water: Impacts, detection, and treatment. *Harmful Algae*, *54*, 174–193. https://doi.org/10.1016/J.HAL.2016.01.001

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 101037084.

Kumar, P., Hegde, K., Brar, S. K., Cledon, M., & Kermanshahi Pour, A. (2018). Physico-chemical treatment for the degradation of cyanotoxins with emphasis on drinking water treatment - How far have we come? In *Journal of Environmental Chemical Engineering* (Vol. 6, Issue 4, pp. 5369–5388). Elsevier Ltd. https://doi.org/10.1016/j.jece.2018.08.032

Lu, S., Wang, N., & Wang, C. (2018). Oxidation and biotoxicity assessment of microcystin-LR using different AOPs based on UV, O3 and H2O2. *Frontiers of Environmental Science and Engineering*, *12*(3). https://doi.org/10.1007/s11783-018-1030-2

Munoz, M., Nieto-Sandoval, J., Cirés, S., de Pedro, Z. M., Quesada, A., & Casas, J. A. (2019). Degradation of widespread cyanotoxins with high impact in drinking water (microcystins, cylindrospermopsin, anatoxin-a and saxitoxin) by CWPO. *Water Research*, *163*. https://doi.org/10.1016/j.watres.2019.114853

Patel, M., Kumar, R., Kishor, K., Mlsna, T., Pittman, C. U., & Mohan, D. (2019). Pharmaceuticals of emerging concern in aquatic systems: Chemistry, occurrence, effects, and removal methods. In *Chemical Reviews* (Vol. 119, Issue 6, pp. 3510–3673). American Chemical Society. https://doi.org/10.1021/acs.chemrev.8b00299

Rajasekhar, P., Fan, L., Nguyen, T., & Roddick, F. A. (2012). A review of the use of sonication to control cyanobacterial blooms. *Water Research*, *46*(14), 4319–4329. https://doi.org/10.1016/J.WATRES.2012.05.054

Sukenik, A., & Kaplan, A. (2021). Cyanobacterial Harmful Algal Blooms in Aquatic Ecosystems: A Comprehensive Outlook on Current and Emerging Mitigation and Control Approaches. *Microorganisms 2021, Vol. 9, Page 1472*, *9*(7), 1472. https://doi.org/10.3390/MICROORGANISMS9071472

US EPA - Agency, U. (ed). (2016). *Drinking water contaminant candidate list 4: final. EPA 81 FR 81099.*

Zhan, M. ming, Liu, P. rui, Liu, X. ya, Hong, Y., & Xie, X. (2021). Inactivation and Removal Technologies for Algal-Bloom Control: Advances and Challenges. *Current Pollution Reports 2021 7:3*, *7*(3), 392–406. https://doi.org/10.1007/S40726-021-00190-8

2.2.7 Changes in the spatial distribution of species

Objective and challenge

There is strong evidence for a wide range of impacts of climate change on species such as changes in distributions, phenology, community composition and habitat condition. By using modelling techniques and analytical frameworks it will be explored how likely the species will change their distributions (for migratory birds, their population sizes) due to the effects associated with climate change.

The assessment will help decide on the appropriate adaptation measures that might be necessary for selected species, given the levels of risks and opportunities identified and explore how to include measures for favouring species adaptive responses in some of the solutions proposed in IMPETUS (see 2.1.1 and 2.1.2).

Technical description

Significant changes in climate and their impacts are already visible globally and are expected to become more pronounced. In Europe, coastal zones and wetlands are particularly vulnerable. Climate change could have profound impacts on coastal zones due to sea level rise and changes in frequency and/or intensity of storms. This would result in threats to ecosystems, infrastructure and settlements, the tourism industry, human health and considerable losses of species and habitats throughout Europe, making necessary to prioritise action based on biodiversity conservation. As part of this, is needed to understand how to help species to adapt to climate change and to encourage species that might thrive under climate change if given the appropriate management.

In this action, we will use a framework to evaluate species' responses to climate change (Thomas et al. 2011) by assessing potential changes in the spatial distributions for a range of taxa that occur in coastal dunes and marshlands along the Catalonian coast. We will compare projected future distributional changes with past and current distribution.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 101037084.

The assessed species including vertebrates, invertebrates and plants will be classified according to their risk of local extinction/of significant decrease in local populations and their opportunities to expand their ranges. Adaptation measures to climate change that could benefit of the solutions proposed for this pilot site will be identified as a means of strengthening the resilience of target species and ecosystems. The action thus provides information for conservation practitioners to use within the context of their planning at national and local scales.

In order to collect the variables to be modelled, we will explore analytical information from geographic and climate platforms such as Copernicus Land Monitoring and Climate Change Service, MAES (Mapping and Assessment of Ecosystems and their Services – JRC: https://data.jrc.ec.europa.eu/collection/maes), Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES), Biodiversity information system for Europe, EUNIS Biodiversity Database, European Biodiversity Portal, UN Environment Programme World Conservation Monitoring Centre and others. For collecting global species distribution, we will collect information from the IUCN Red List of threatened species (https://www.iucnredlist.org/), which will be complemented with distributional data at regional and local scale from the National and regional biodiversity data banks and bibliographic search.

Key Performance indicators, added value and replication potential

KPI	Target value
Number of species and taxonomic groups included in the model.	20
Number of possible adaptation measures for species identified in the selected IMPETUS coastal solutions (1.2.1 and 1.2.2).	4
Project partners working on 1.2.1 and 1.2.2 solutions know the results of the analysis and the possible adaptation measures that can be taken in place to facilitate species persistence.	100%
# publications and posts to communicate results	2
Workshops completed in the demo site to generate awareness with project partners and relevant stakeholders	1

Added Value

The spatial analysis of species distribution will help the Catalan government, IMPETUS partners as well as local stakeholders to prioritize conservation and to decide on the appropriate adaptation measures that might be necessary for selected species, given the levels of risk and opportunities identified. It will also enable exploring how to include measures for favouring species adaptive responses in some of the solutions proposed in IMPETUS.

Replication potential

This species-based approach can be used for future infrastructure planning and design of coastal NbS and green infrastructures.

Role of partners and relevant stakeholders

Relevant stakeholders have been identified for data collection and are going to be contacted to involve them into the project.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 101037084.

Actions and timeline

	2022 (Y1)									2022-2023 (Y2)											
Project Months	M4	M5	M6	M7	M8	M9	M10	M11	M12	M13	M14	M15	M16	M17	M18	M19	M20	M21	M22	M23	M24
Calendar Months	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9
Project WPs and Tasks	Jan	Feb	Marc	April	May	June	July	Augu	Sept	Oct	Nov	Dec	Jan	Feb	Marc	April	May	June	July	Augu	Sept
Data collection and data preparation																					
Identification of datasources																					
Searching literature																					
data selection and standardization																					
Spatial data modelling																					
Analysis and validation																					
Comunication																					

References

Thomas, C.D., Hill, J.K., Anderson, B.J., Bailey, S., Beale, C.M., Bradbury, R.B., Bulman, C.R., Crick, H.Q.P., Eigenbrod, F., Griffiths, H.M., Kunin, W.E., Oliver, T.H., Walmsley, C.A., Watts, K., Worsfold, N.T. and Yardley, T. (2011), A framework for assessing threats and benefits to species responding to climate change. Methods in Ecology and Evolution, 2: 125-142. https://doi.org/10.1111/j.2041-210X.2010.00065.x.

2.2.8 Assessment of economic impacts of extreme storms in infrastructures

Objective and challenge

Objectives:

- Identify and develop a curated dataset of the areas most vulnerable to flood risk (vulnerability hot-spots) in the Catalan coast with combination of climate projections, morphological models and SAR-based monitoring systems
- Develop a framework to assess and estimate the related economic impacts of extreme storms to coastal infrastructure, focusing on transportation paths parallel to the coastline.

Challenges

- Access to data/data availability related to: infrastructure location and status; access to high-resolution DEM datasets.
- As the solutions will be developed locally, a challenge could be represented by the lack of relevant data to make the result scalable
- Access to data/data availability related to economic and damage data associated with past extreme events

Technical description

State of the art

Climate projections and hot-spot identification

Post-processing analysis will be performed with computational intelligence models trained with historical climate data from satellite and in-situ observations together with climate projections to investigate the correlation between projected sea level rise, historical and future frequency of storm surges and the associated coastal areas affected by floods. The analysis will identify the most vulnerable areas in terms of flood risk associated with typical coastal extreme events.

Lobelia is specialised in generating physical climate risk analytics to model the potential impacts of climate risks on revenue and operations at site-specific level and at different time horizons.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 101037084.

Lobelia produces analysis of climate trends in cities worldwide to support UN- HABITAT's Urban Resilience Hub to define action plans with city administrations. This includes downscaling and bias correction techniques to generate high-resolution, locally-adapted data describing the future climate in the target cities. Lobelia climate projections have been integrated into the UN-Habitat City Resilience Profiling Tool (CRPT) in various cities. Lobelia also provides climate projection and risk assessments for public and private customers in several areas of the word, at asset level.

Lobelia is currently producing - under a technical assistance contract to the Catalan government – the climate change scenarios for a variety of climate extreme indices that will affect the rail and road infrastructures e.g. storm surge, fire risk, wind storms, etc. This assignment is embedded within the vulnerability assessment of climate change to the transport infrastructure in Catalonia. The assessment will feed into the Catalan Climate Change Plan 2021-2030.

Observation-based coastal monitoring system.

Lobelia has conducted a study on 25 years of satellite imagery over 1000 km of European coastlines in an automatic fashion for the quantification of erosion and assessed the impact on coastal erosion derived from past and future alteration of wave dynamics and morpho-hydrological conditions features with SAR imagery. The study demonstrated the feasibility of the use of SAR missions as a cutting-edge approach for the study of coastal evolution in the Mediterranean, including validation, and compliance with the requirements of coastal management stakeholders.

The satellite-based system for coastal erosion monitoring is applicable to selected locations based on morphological conditions and provides data at high spatial resolution and consistently in time, with historical time series since 1990 and resolution up to 10km. The methodology for the observation-based system was presented at the ESA EO PHI-WEEK 2020. Recording is available at (https://www.youtube.com/watch?v=LS5HP7BRbuQ).

Economic impact of extreme events.

Lobelia provides expertise carried out with PwC for the assessment of economic impact on extreme events under the GLORIOUS project and is a recognised climate risk data provider to the Coalition for Climate Resilience Investment (CCRI), a United Nations Climate Action Summit and COP26 flagship initiative that represents the commitment of the global private financial industry, in partnership with key private and public institutions, to foster the more efficient integration of physical climate risks (PCRs) in investment decision-making.

AUEB provides expertise in behavioural economics modelling and econometric analysis for the assessment of the economic impacts of adaptation/mitigation plans under uncertainty and the pricing/valuation of non-market assets. AUEB's Research Laboratory on Socio-Economic and Environmental Sustainability (ReSEES) does policy relevant interdisciplinary research on environmental, natural resources and energy issues. ReSEES is a member of the AE4RIA (Alliance of Excellence for R&I on Aeiphoria) an unofficial umbrella (based on MoUs) of the following institutions and networks, which are founded, directed or chaired by Prof. Phoebe Koundouri : ReSEES Laboratory at Athens University of Economics and Business, Sustainable Development Unit (SD.U) at ATHENA Research Center, two innovation acceleration institutions: EIT Climate KIC Hub Greece and BRIGAID Connect Association, and four networks: SDSN Europe, SDSN Greece, Water Europe and NEXUS Cluster.

Data requirements

- Super high-resolution digital elevation models for the coast of Catalonia produced by lidar measurements
- Sea level rise and storm surge occurrence datasets for the historical and future periods
- Validation data (in-situ) for SAR-based coastal monitoring system
- Historical climate data and regional climate projections
- In-situ data (if available) can be used for improving local analysis and predictions
- Time series economic data on various attributes
- Historical data on costs from interventions
- Local infrastructure geolocation and status

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 101037084.

Data and model availability

- Open-access climate datasets: ERA5 reanalysis and CORDEX regional climate projections
- Sea level rise and storm surge historical and projected estimations from the JRC LISCOAST project.
- Super high resolution DEM from open-access global (30m) and regional (5m) DEM datasets.(30m). The regional DEM dataset currently presents download limitations.
- Internally computed satellite-derived datasets based on open-access satellite SAR missions(e.g. coastal erosion)
- Climate change scenarios for a variety of climate extreme indices that will affect the rail and road infrastructures e.g. extreme precipitation, fire risk, wind storms, etc. produced under a technical assistance contract to the Catalan government
- Choice Experiments models incorporating preference heterogeneity with respect to various socio-economic variables

Potential barriers

- Access/download to HR DEM for Catalonia. Currently presenting several download limitations
- Dataset preparation including data merging and normalisation/standardisation
- Broad participation in Choice Experiments
- Language barriers in facilitating the Choice experiments on local workshops.

Key Performance indicators, added value and replication potential

Table 6: KPIs

KPI	Target value
Written declaration of local stakeholders with an aim to adopt the outcome of the Task within a five- year period following the conclusion of the project.	2
# stakeholders involved and to which results are communicated	10
Increase in Catalan Government budget for the planning and deployment of mitigation solutions to address coastal infrastructure within a five- year period following the conclusion of the project (Euro)	+30%
Planned reduction on disaster risk insurance expenditure within a five- year period following the conclusion of the project. (Euro)	-25%
# of articles published related to the task outcome in media (newspapers / television)	2
# post published to communicate task status and result on social media	4
Workshops completed in the demo site (including other solutions of the Catalan coast) to generate awareness with local stakeholders	2
Workshops completed in the demo site to facilitate choice experiments	2

Added value

The hot-spot identification will enable the Catalan government as well as local stakeholders to:

- Deploy targeted risk reduction strategies including implementation of artificial and Natural Based Solution to protect the coastal infrastructure in the most vulnerable locations;
- Use the data for future development of the coastal infrastructure, including physical climate risk into investment decision making processes and infrastructure planning and design;

For specific locations, particularly vulnerable to coastal erosion, the task will provide an operational observation-based system for coastal erosion monitoring and unprecedented historical time series of the coastal evolution since1990. The system can support the monitoring and evaluation of coastal erosion and be used to assess the impact and effectiveness of mitigation solutions implemented.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 101037084.

The quantification of economic impact on infrastructure due to extreme events enable to:

- Integrate climate risk into future infrastructure and investment planning, and deploy more resilience-oriented actions;
- Develop targeted adaptation/mitigation plans and interventions;
- Reduce social and economic costs associated with future extreme events by acting on preventive measures and insurance products.

Replication potential

The SAR-based coastal monitoring system can be adapted and replicated in similar coastal areas meeting the system requirements.

The hot-spot identification methodology can be adapted and replicated in similar coastal areas with the ingestion of local data. The methodology used to assess the impact on coastal infrastructures can be further extended to assess the risk on other types of coastal infrastructures not limited to transport (e.g. residential buildings).

The economic impact framework developed can be adapted and replicated in other areas with the ingestion of local data and the design of local choice experiments. Regional results can also be upscaled - value transfer- to other sites.

Role of partners and relevant stakeholders

Lobelia (Task leader)

- Dataset preparation
- Computation of climate projections
- Analysis for the identification of hotspots and deployment of observation-based coastal monitoring systems in relevant locations

Athens University of Economics and Business (AUEB):

- Cooperation with local stakeholders via the RKBs to co-design experiments and estimate the associated costs more accurately
- Guidance for the implementation of choice experiments and development of behavioural economics models.
- Econometric analysis of the results of choice experiments
- Development of a framework to estimate future economic impact on the coastal infrastructure caused by extreme events risk occurrence in the future.

Actions and timeline

- The task starts in M7 (May 2022) and is expected to be completed in M42 (July 2025)
- Initial meeting will be held between Lobelia and Athens University for the planning and coordination of the data needed for the economic assessment.
- Initial meetings will also take place between Lobelia and the Catalan demo-case partners, to identify relevant stakeholders for data provision and involvement.
- Lobelia will be in contact with the Catalan Government and with the Cartographic and Geologic institute of Catalonia for the data provision
- Further planning will be communicated after the Task starts.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 101037084.

2.2.9 Behavioural change for climate-resilient tourism

Objective and challenge

Costa Daurada is a tourist destination located in southern Catalonia, in the province of Tarragona. This destination mixes coastal and mountain destination attractiveness. From natural resources such as mountains to beaches. Also, there are main cities where leisure and culture are one of their main tourist attractions. Costa Daurada is formed by six regions; each one has its specific characteristics. El Tarragonès (1) is a well-known area for tourism and was declared UNESCO World Heritage. El Baix Camp (2) offers interesting routes with modernism buildings as well as hiking routes such as the seaside path between L'Hospitalet de l'Infant and Vandellós. El Baix Penedès (3) is characterized by its diversity of tourist offers, going from sun and beach tourism to wine tourism. La Conca de Barberà (4) is defined by its monasteries and towns and recognized by routes that can help to understand the templar culture an example of this is the Cister's route. In El Alt Camp (5) human towers, named els casetllers were originated. As well as gastronomic traditions such as eating calçots, a kind of long onion. El Priorat (6) presents the Natural Park of the Montsant with relevant active tourism activities to be done, this area also is so visited for wine tourism purposes.

Les Terres de l'Ebre were listed in 2013 as a World Biosphere Reserve by UNESCO, an international recognition that includes them as a unique natural environment on the planet. This seal highlights a land where farmers, livestock breeders, fishermen, and artisans have relied on its natural resources as a source of subsistence and inspiration, as well as a modus vivendi that has been translated into traditions, festivals, and gastronomy. In this place, well-being tourism and nature tourist activities such as birdwatching are the activities that define the typical tourism activities of the region.

Tourism in the province of Tarragona concentrates an important part of its GDP (16%, Duro, 2020). In this sense, any phenomenon that affects the sector will have a significant impact on the local economy. Climate change in particular (affecting temperatures changes, rain rates, sea levels increases and extrem events) and the global measures necessary for its mitigation foreseeably imply important needs in terms of adaptation by the territory in question. At a tourist level, the province, at least, is divided into the 2 zones described above. One, the Costa Daurada, with a significant density of demand (it is one of the great destinations in Catalonia and Spain in general), and the other, Terres de l'Ebre, much less dense and with a product with a higher natural content and landscape (perhaps with greater potential in the post-pandemic). Climate change is supposed to alter the coastal sun and beach products, the Ebro Delta itself (one of the main tourist resources of Terres de l'Ebre, and the behavior of the tourists themselves in the face of the rise in average temperature, its distribution within the year and climatic variability.

In the above context, this subproject aims to incorporate useful knowledge for all territorial stakeholders, both public and private, in relation to the necessary future adaptation of the territory to climate impacts and the need to maintain a transcendental economic activity for the agents and the territorial population. In particular, this case study subproject, within the framework of the global IMPETUS project, rests on three fundamental pivots that can have a global added value, based on new knowledge that can be operational.

In the first place, this case study focuses on the identification of indicators that may be useful in terms of a climate change monitoring system and its effects on territorial tourism, in a global framework. Thus, supposedly relevant climatic indicators for tourism are considered, as well as strictly tourist indicators useful in relation to the adaptation strategy.

Secondly, the subproject considers the need to identify specific tourism strategies and projects for this adaptation. Therefore, it includes both global and specific aspects. Tourism strategies and projects in relation to adaptation foreseeably revolve around the dynamics of markets, products, seasonality or territory.

Thirdly, the subproject is based on the design of different participation schemes, where the territorial stakeholders will co-create the global results, both public and private, and divided into the two tourist areas, that is, Costa Daurada and Terres de l'Ebre.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 101037084.

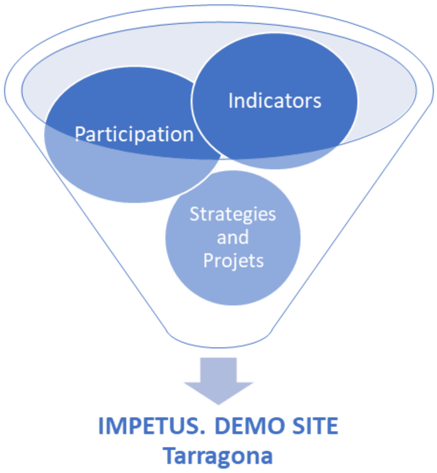


Figure 12: Relevant items in the subproject IMPETUS-Tarragona

In dimensional terms, and in terms of tasks, the subproject will provide referential environmental indicators in terms of the adaptation of territorial tourism for tourist agents; it will analyse the perceptions by the territorial sectoral stakeholders regarding the challenges of energy transition and, finally, it will provide demonstrative adaptation projects.

The case offers a useful complement to other cases included in the project, for example territorial (Terres de l'Ebre or Girona).

The team has proven and verifiable experience in the use and analysis of climatic and territorial tourism indicators, as well as in dynamics of participation and tourism strategies.

Figure 13: Dimensions analysed in the subproject IMPETUS-Tarragona

Subtask 1. CO-CREATION OF CLIMATE SERVICES FOR SUSTAINABLE TOURISM DEVELOPMENT IN COSTA DAURADA AND TERRES DE L'EBRE

Global description

As seen, in Costa Daurada and Terres de l'Ebre, there is a wide range of tourist types to be offered. Even so, each one of them needs specific climatological or meteorological conditions to make the activity/tourist product possible. As these weather/climate conditions do not constraint or benefit each kind of tourism in the same way, it is necessary to explore how each activity is linked to those variables. To know how this link is, workshops with the stakeholders of the territory are crucial to gather qualitative information about this issue. So, user engagement plays an indispensable action once co-creating tourist strategies to adapt to climate variability and change. In this line, thanks to the join of stakeholders and scientific knowledge it will be possible to define indicators that can assess the viability of each activity considering both spatial and temporal patterns.

As tourism is affected by climate variability and change, the results of this research expect to assess the decision-making of tourist activities in different time scales. This will be possible thanks to the monitorization of climate/meteorology tourist-specific indicators generated thanks to the co-creation process.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 101037084.

Subtasks and stages

Subtask 1.1. Selection of participants

his research will select participants to assist the workshops following Font et al (2021) who defined an applied methodology for user engagement and co-creation in European destinations.

We will identify which stakeholders are present in our case study to have the real perceptions of tourism. In this case, focus groups will be organized following different kinds of identified tourist activities and the close relation of each stakeholder with one of them.

The data required for this task will be the identification of the potential stakeholders.

The added value of this process will generate specific climate-smart indices to assess sustainable tourism considering local characteristics. The task will have not only scientific information but also territorials' agents' information. Our design will have enormous replication potential, as the design of mental maps of the workshops will help to structure the way on gathering qualitative tourist information into quantitative climatic information that will promote climate-resilient decision-making into the tourist sector.

Potential barriers would be the realization of the workshop online in the hybrid mode due to covid-19 measures. Even so, the online mode would be possible to implement if a presential one is not possible. Drivers for this task will be the increasing needs of the society to adapt to climate variability and change as adapting the economic activity to the sustainable development goals agenda.

The KPIs for this task will be (1) a list of participants and (2) a list with specific working tables linked to specific tourist types.

Subtask 1.2. Preparation of focus groups

Following previous task, once stakeholders are identified, focus groups have to be precisely designed. This means identifying the tourist type of activities that are going to be analysed. This can be, generating different focus groups based on different kinds of tourism, such as (1) birdwatching, (2) cultural tourism, (3) hiking tourism, (4) sun and beach tourism.

For addressing this issue, we will follow also Barnet et al (2021). To manage this task, we will need the location of each stakeholder and how their position relates to specific kinds of tourism. This procedure will be reproducible as we are doing following Barnet et al (2021) methodology, we add value information of the specific territory that is being studied, which has not any specific climate service for tourism.

The added value of this task is that the results of this will imply specific indices for specific sorts of tourism, so we will not generalize such as Mieczkowski (1985) who defined the tourism climate index.

The KPIs for this task will be having a table with the relation of the participants and the working table of each kind of tourism.

Subtask 1.3 Development of workshops

This task is defined by the realization of face-to-face workshops with the local stakeholders, thanks to the previous tasks.

For this part, the data requirements are a general description of the climate and weather of the region to make brief introductions to the assistants of the workshop. So, preliminary analysis of climate data will be presented at workshops.

Workshops will be organized in focus groups and conducted thanks to the material of manual thinking also following Barnet et al (2021).

Potential barriers and drivers are the same as in tasks 3 and 4.

The KPIs for this task will be having the mental maps with the results from the workshops.

Subtask 1.4 . Extraction of information

This task consists of extracting systematically all the information gathered in the mental maps used in the workshops. The results of this task will promote added value on information about how climate and meteorological conditions benefit or harm the activity, as well as which adaptation measures can be considered if information about these hazards occurs. Adaptation measures will be identified in different time scales.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 101037084.

The potential barrier of this task is that if the workshop is not developed face to face, the information will not be of the same quality as if it was.

The KPIs to measure the success of implementation and reaching of the objective will be the realization of the executive document with all the information inside the mental maps.

Subtask 1.5. Data collection/creation of database

Data collection will be based on the extraction of ERA-5 climate data (https://cds.climate.copernicus.eu/cdsapp#!/dataset/reanalysis-era5-single-levels?tab=overview), as of obtention of meteorological station data is required.

The extraction of data will be based on the procedure defined in the POTENCLIM project, in which Copernicus data store meteorologic data is extracted by Python and Rstudio software.

One of the challenges to obtaining data will be if stakeholders find relevant data that is not climatic, but we will try to get non-meteorological data if stakeholders require it. One of the drivers to solve these barriers is that stakeholders can also feed the project with data.

KPIs to measure the success of the implementation will be the creation of a climate database and socio-economic database (the second one if required).

Subtask 1.6. Definition of indices

From variables identified on the workshop's indicators are going to be generated giving special attention to the variables that most harm or benefit the specific tourist activity.

Definition of indices will be based on the procedure of Olano et al (2020) who defined a method to define the snow tourism index. Also, we will consider Boqué et al (2020) who defined an oceanographic index to know the expected surfing days per year.

For this task, it will be needed all the data coming from the development of the workshops. So potential risk of not doing the definition of indices is the low assistance of the workshops or the limited user engagement due to covid-19 restriction measures.

This task will add value, as specific territorial indices are computed considering its characteristics.

KPIs to measure success is an executive document with the indices' definition, explaining variables required, intervals, and heights of them.

Subtask 1.7. Computation of indices

Data requirements are a key issue in this task, so a climate database must be generated previously to compute the new indices.

Calculating the climatologies of the defined indices should be managed through R software using functions to compute them. For this purpose, we will consider the definition of an R code to calculate the sun and beach index presented in Indecis project work package 7 in Annex A.

This task will bring huge added value, as the indices will be the pioneer. Potential barriers and risks are if the indices that we define are composed of variables that are not available in the Copernicus data store. If this happens, we will try to explore other databases in previous tasks.

In addition, this task instead of using climate data, projection or forecast climate data will be additionally implemented.

This task is the one that presents more barriers, as getting forecast or projections data is a complex task (done before). So, depending on the data gathered in previous task 7, the computation of indices will proceed.

KPIs for this task is the executive document with the R code to compute the indices with the description of the results.

Subtask 1.8. Definition of the Mock-up design

This task is the one that will define the mock-up design. That means designing a platform to communicate the climate service as users defined their needs in the workshop.

Data requirements will depend on the results obtained from previous tasks. If indices are not computed, it will not be possible to represent them.

We will follow Boqué et al (2021) who designed a mock-up for surfing destination management.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 101037084.

Our mock-up can add value to the tourist sector on how to communicate climate information to manage a tourist destination.

One of the barriers is that the presentation of forecast indices will depend in some cases on the licenses of data.

KPIs for this task is the executive document with the design of the mock-up implementation of the Climate Service.

Subtask 1.9. Implementation of the Mock-up

Generating a real communication channel will depend on users' requirements and also on the prototype designed previously.

To develop this task informatic knowledge will be required.

Data requirements will rely on all the indices computed in previous tasks. And if users require, may be information about the relation of climate, weather, climate change, and tourist activity will be added.

This tool will give a potential added value as will help to manage the tourist destination in a climate-resilient way.

KPIs to measure the success will be the development of a platform where climate service is communicated (GIS-based platform, web, app) again depending on users' needs.

Role of partners and relevant stakeholders

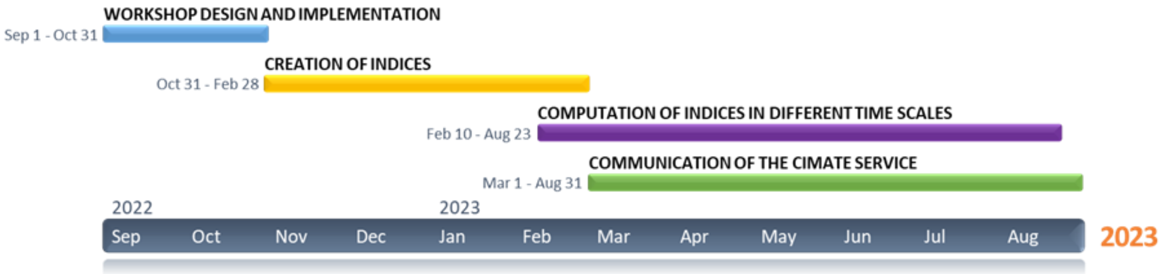
The study will implement the methodology to co-create climate services for the tourism sector together with stakeholders. As this methodology will be based on focus group work using mental maps; stakeholders' participation plays an essential role. So, thanks to the user engagement definition of optimal conditions for different tourism types will be possible.

The stakeholders that may participate have to be heterogeneous constituted mainly by local policymakers, local tourism offices, research centres/universities, conservation organizations, private tourism entrepreneurs, private consultancies.

The implemented methodology involves a sequence of steps to extract and validate such information through engagement, with destination stakeholders along the value chain (from accommodation managers to destination planners as well as final users). The process facilitates the design of numerical indices based on the information collected.

Actions and timeline

Actions and timelines are defined as in the following figure.



References

Mieczkowski, Z. (1985). The tourism climatic index: a method of evaluating world climates for tourism. Canadian Geographer/Le Géographe Canadien, 29(3), 220-233. doi: 10.1111/j.1541-0064.1985.tb00365.x.

Boqué Ciurana, A., & Aguilar, E. (2021). Which Meteorological and Climatological Information Is Requested for Better Surfing Experiences? A Survey-Based Analysis. *Atmosphere*, *12*(3), 293.

Barnet, A. F., Ciurana, A. B., Pozo, J. X. O., Russo, A., Coscarelli, R., Antronico, L., ... & Aguilar, E. (2021). Climate services for tourism: An applied methodology for user engagement and co-creation in European destinations. *Climate Services*, *23*, 100249.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 101037084.

Olano Pozo, J. X., Boqué Ciurana, A., Font Barnet, A., Russo, A., Saladié Borraz, Ò., Anton-Clavé, S., & Aguilar, E. (2020, May). Co-developing climate services with local agents: The INDECIS Snow Tourism Index. In *EGU General Assembly Conference Abstracts* (p. 8926).

Boqué Ciurana, A., & Aguilar, E. (2020). Expected distribution of surfing days in the Iberian Peninsula. *Journal of Marine Science and Engineering*, *8*(8), 599.

Subtask 2. ANALYSIS OF PERCEPCIONS AND CHALLENGES OF ENERGY TRANSITION AND TOURISM IN TARRAGONA

Global description

Tourism energy consumption is mainly attributed to the mobility between the place of origin of the tourists and the destination. Nevertheless, the energy demand is also determined by the mobility and the activities carried out within the destination, and accommodation (Gössling and Lund-Durlacher, 2021). Public administration, especially local, but also private stakeholders can play a significant role in the reduction of energy consumption in the tourist destination (Scott and Göslling, 2021). The energy transition will allow a reduction of GHG emissions (Lam-González et al., 2022), driving the tourist destinations to climate neutrality and, together adaptation measures (Kristofová et al., 2022), promoting the resilience of the tourist destinations.

So, the task will include the analysis of (i) how public and private tourism stakeholders are facing the challenges of the energy transition in tourist destinations; and stakeholders perceptions about (ii) climate change and energy transition, concretely reduction of carbon footprint, energy consumption and greenhouse gases (GHG) emissions, (iii) generation of photovoltaic solar energy in public and private urban and peri-urban areas, (iv) opportunities, and (v) risks and threats that can compromise the resilience of tourism destinations.

Subtasks and stages

Subtask 2.1: Preparation

A key element prior to the participatory dynamic (focus group) is determining the role that the local administration is playing in the energy transition process in tourism destinations as a tool to fight against climate change impacts. In this sense, it is necessary analysing public policies and strategies designed and implemented. Nevertheless, this stage will be incomplete if private tourism sector is not taken into account. In this sense, it is also necessary the analysis of the strategies that the tourism sector is implementing to reduce the use of fossil fuels, energy consumption and GHG emissions as a tool to contribute minimizing climate change impacts.

We do not foresee relevant problems in the information concerning to the collation of public policies. Some difficulties can rise in the case of tourism private stakeholders.

KPIs for this task is the executive document about how stakeholders are working on energy transition by means of policy document discourse and narrative analysis. Comparative analysis of the documents on public policies and strategies of the tourism sector, taking into account their content and discourse. It will allow generating knowledge about their coherence and possible shortcomings

Subtask 2.2: Identification and selection on participants

Previously to the activity (focus groups) with the stakeholders it is necessary the identification and selection of the participants. It is planned to form two focus groups. The first one with the public domain (local and regional administration): tourism, environment and planning arena. The second one with the private tourism stakeholders including the main activities involved in tourism sector.

KPIs for this task is the list of participants and their characteristics.

Subtask 2.3: Focus Group

The two focus groups will allow obtaining and analysing the perceptions of the public administration and tourism stakeholders regarding the energy transition process, their predisposition and the role to play by each one in order to increase the resilience of tourism destinations. These two meetings (public and private domain) will facilitate understanding how the challenges linked to the energy transition and the resilience of tourism destination are addressed.

KPIs for this task is the detailed data resulted from the meetings.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 101037084.

Subtask 2.4: Return of experiences

This subtask includes the analysis of the results obtained in the focus group. It will be nourished by the results of subtask 2.1 and will be completed with a return of experiences with the same stakeholders participating in the task 2.3.

KPIs for this task consists in the executive summary associated with the results

Role of partners and relevant stakeholders

Actions and timeline The objectives of the Task 2 will be achieved only with the proactive participation of the different stakeholders (subtask 2.3 and 2.4). The information obtained thanks to the focus groups is crucial. Public and private stakeholders have to realize the importance of the topic analysed and that their participation in the meetings is of interest for them

Actions and timeline

Subtask/Phase	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8
1								
2								
3[1]								

[1] Includes previous tasks (T3-T4), focus group fulfilment (T4), analysis of the results (T5-T6) and return of experiences (T6).

Subtask 3. CO-CREATION OF CLIMATE SERVICES FOR SUSTAINABLE TOURISM DEVELOPMENT IN COSTA DAURADA AND TERRES DE L'EBRE

Global description

Given the effects of climate change on the Catalan coastal zone, and in particular, in the province of Tarragona, associated with physical, climatic impacts and on tourism consumption, this task 3 of the TGN demo site (province) is intended, using participatory formats, to identify referential adaptation tourism projects given these effects. In this sense, the projects identified, after a technical analysis of the territorial effects of climate change on the tourism sector, will basically and possibly have to do with market, product and territorial elements that allow better adaptation. For this, the tasks include the creation of focus groups, which under the methodology of design thinking, will allow the identification, evaluation and realization of these adaptation projects.

Subtasks and stages

Subtask 3.1: Preparation

Prior to the participatory dynamic, it is necessary to collect technical information on the impacts of climate change on global tourism, and the area in particular. This preliminary task will include the creation of a database with tourism indicators of territorial relevance (global for the province and detailed for the two reference areas, that is, Terres de l'Ebre and the Costa Daurada). This tourist database is complemented by the territorial climatic indicators that will be identified and evaluated in task 1. In this sense, and as we know, given that climatic impacts refer to the impact on the coastline, markets, products or seasonality, it will be It is necessary to collect this information on tourism vulnerability at a territorial level, fundamentally through information from Eurecat/Turisme and Idescat. In any case, this subtask includes, for contextualization purposes, building a database at a territorial level in Spain. Below is an indicative summary (provisional and non-exhaustive) of indicators to collect and provide to focus group members

Indicator	Dimension	Source
Domestic Market	Markets	Eurecat/idescat/INE
International Markets	Markets	Eurecat/idescat/INE
Markets Concentration	Markets	Eurecat/idescat/INE
Expenditures	Perfil	Eurecat/idescat/INE
Stays	Perfil	Eurecat/idescat/INE
Seasonality	Estacionalidad	Eurecat/idescat/INE

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Density	Densidad	Eurecat/idescat/INE
High quality accomodation demanda	Perfil	Eurecat/idescat/INE
Inland Supply	territorio	Eurecat/idescat/INE
Age tourists structure	Perfil	Eurecat/idescat/INE

We do not foresee relevant problems in the information. The bulk of the information that is needed is free data, to which statistical analyses will have to be implemented.

KPIs for this task is the executive document about impacts and territorial indicators.

Subtask 3.2. Identification and selection on participants

In this phase, the identification and selection of the focus group participants is foreseen. Predictably, they will include public tourism managers (local and regional administration), tourism companies and society/consumer representatives. It is planned to form two focus groups, one for Terres de l'Ebre and another for the Costa Daurada.

KPIs for this task is the list of participants and their characteristics.

Subtask 3.3.: Focus Group

Carrying out the meetings for the 2 territorial focus groups. Two meetings are expected to be held. In the first, the preliminary report will be presented, and the members of the groups will evaluate the importance of the tourist indicators in terms of the adaptation to climate change, around the evaluation of the relevance of the dimensions markets, products, territory and seasonality, as well as the global adaptation tourism strategies. In the second meeting, the members will select projects, from a complete list of them, and will detail their specific components related to detail, the agents involved, the timing or the economic impacts. KPIs for this task is the detailed data associated with the meetings held.

Subtask 3.4: Definition of projects and strategies

This phase includes the synthesis of the results obtained in the previous phases. In particular, the list of indicators evaluated, the tourist adaptation global strategies and the detail of the territorial adaptation tourism projects.

KPIs for this task consists in the executive summary associated with the results.

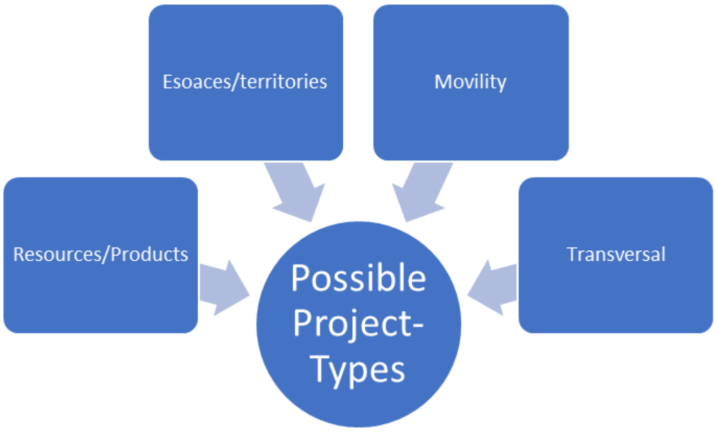

Figure 14: Possible Project-types adaptation projects selected subproject IMPETUS-Demo Site/Tarragona

Role of partners and relevant stakeholders

The study will implement the methodology to assess, evaluate and identify adaptation strategies and projects for the tourism sector together with stakeholders. As this methodology will be based on focus group work, stakeholders' participation plays an essential role. So, thanks to the user engagement definition of optimal conditions for different tourism types will be possible.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 101037084.

The stakeholders that may participate have to be heterogeneous constituted mainly by local policymakers, local tourism offices, research centres/universities, conservation organizations, private tourism entrepreneurs, private consultancies.

The implemented methodology involves a sequence of steps to extract and validate such information through engagement, with destination stakeholders along the value chain (from accommodation managers to destination planners as well as final users). The process facilitates the design of numerical indices based on the information collected.

Actions and timeline

Subtask/Phase	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8
1								
2								
3								
4								

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 101037084.

3 Mediterranean DS: Attica, Greece

3.1 Introduction and background

The region of Attica, which includes the country's capital district, Athens, covers an area of 3,808 km^2 and has about 3,742,000 inhabitants (2019). Attica is a typical Mediterranean region subject to strong and increasing impacts caused by climate change and other global change drivers.

The region is stressed by different factors arising from human overpopulation, various activities and often competitive land use through the lack of proper and sustainable management and protection of the natural environment. Particularly, the large increase in heat extremes and risk of droughts and the decrease of precipitation has impacted human life and the environment. Additionally, the increasing water demand for agriculture and environmental green has led to a competition between different uses and users. This is intensified by increasing volumes of tourism and recreational activities. In several cases the increase of sea water intrusion due to over abstraction of groundwater has led to a decrease in crop yield, with repercussions in the economic sustainability of the area. The raising temperatures have also led to a dramatic increase in energy demand for cooling, intensification of flash floods and poor air quality.

This situation will put this region in a context of increasing social and economic conflict that requires transformative adaptation solutions to greatly increase community resilience. A new social and territorial agreement is needed in the region to enable rapid and far-reaching change to adapt to climate change and carry out the sustainable transition.

Thus, an agreement needs to be communicated effectively to many millions of inhabitants and visitors to induce necessary behavioural changes. A unique opportunity for the Region comes from the construction of the new East Attica Wastewater System (EAWS) with the ambition to become a major Circular Economy/Climate Change Resilience hub for the Region (1 Billion Euro investment). IMPETUS will leverage this investment.

Within the scope of the project for the development of a climate resilient region, the implementation of R&I solutions can trigger the development of the most important sectors of the economy: agriculture, industry and tourism. Building on existing initiatives, systematic adaptation solutions will be pursued:

(i) a Digital Twin of the Attica Region as a central hub for related data and knowledge will be developed to facilitate decision-making and green business development.

(ii) a network of on-the-ground innovation demonstrations will be created within the region, bringing local and regional Communities of Practice (CoP) in contact and engaging stakeholders in co-creation of solutions.

(iii) selected innovations in key systems will be implemented and tested to demonstrate the potential of mitigating climate change risks. Indicative activities include:
   - Sewer Mining technology as a decentralized water reuse innovation
   - Controlled Environmental Agriculture (CEA) solutions
   - Online tool on reforestation and biodiversity providing restoration strategies

(iv) a Master and Business plan will be compiled for increasing Attica Resilience to Climate Change to be submitted to the central government as a Recommendation Plan for adopting the IMPETUS adaptation pathway by the local and regional stakeholders.

In Table 1 the solutions implemented in the Region of Attica are summarised and linked to the different WP Tasks.

Table 7 Solutions and related tasks

Solution	Task No	Task title	Bundle No	Bundle
Forest fires and restoration	T4.4	Supporting Reforestation and Biodiversity	1	Nature-based solutions

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 101037084.

Decentralized circular-economy inspired water/energy/materials reuse innovations	T4.5.2	Sewer Mining for multi-sector climate proofing	2	Innovative technologies
	T4.5.3	Water-Energy simulation and optimization model for wastewater systems acting as regional circular economy and climate resilience hubs	2	Innovative technologies
Digital twins and advanced tools for climate adaptation	T4.10.4	A Regional Digital Twin for climate adaptation and green business development	2	Innovative technologies
Water-energy masterplan and business plan for autonomous climate-proof regions	T4.15	Water-Energy Masterplan and Business Plan for autonomous climate proof regions	3	Finance and Insurance
Controlled Environmental Agriculture (CEA) solutions	T4.20	Multi-purpose Controlled Environmental Agriculture	4	Governance Models, Awareness and behavioural change

3.2 Pre-requisites, design and concept for implementation

3.2.1 Forest fires and reforestation / Supportign reforestation and biodiversity

Objective and challenge

In this Task, an online service will be developed to monitor continuously the biodiversity of different landscapes in the Attica region to offer restoration strategies based on existing biodiversity and ecosystem services. It will be demonstrated as part of the offering of the Digital Twin for the Region of Attica and will act as a tool for relevant working groups within the RKB.

Biodiversity refers to the determination of the variety and variability of living organism and describes the ecological relations in the nature. Remote sensing can greatly aid the exploration of biodiversity dynamics. Using multiple environmental parameters as proxies we can determine species and habitats. As a scientific tool, remote sensing offers specific toolsets, datasets and analytical methodologies that can implement solutions at national and international level.

The consistency and relative ease of remote sensing measurements repeatability can provide cost-effective and efficient means for biodiversity monitoring, determination of plant species as well as ecosystem diversity and long-term biodiversity assessment. Localized studies of biodiversity are being supported by observations and measurements on the field. Remote sensing can be supplemented by in-situ sensing with camera traps, Unmanned Aerial Vehicles (UAVs), acoustics, smart phones, and electronic transmission tags. Those in-situ observations can complement each other since often they are sparse and localized if addressed one-by-one.

A large number of studies are following data-driven approaches with the main focus on classification optimization accuracy. Tree species classification provides results under certain conditions and most importantly it can produce unreliable results under other conditions, therefore it is necessary to first determine those conditions and their drivers.

The need for a holistic determination of the biodiversity in large areas calls for use of diverse datasets of great temporal and spatial resolution. As remote sensing and supplemented in-situ datasets will be in Big Data domain, the need for greater computational and processing power arises accordingly.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 101037084.

Technical description

Many methodologies can help us derive biodiversity information using modern tools and technics. Currently, the biodiversity of an area of interest is usually addressed by using classification neural networks which identify and categorize the different types of land use with the use of satellite images. The combination of satellite images with tagging images and biophysical risk assessment models measuring the impact of potential actions can help in biodiversity identification and the inclusion of additional information such as whether conditions, plant species, animals and various other parameters that constitute the biodiversity of an area.

A step further from pure classification would be the development of semantic segmentation networks by inferencing the number of pixels on an image and identify trends, with the use of Deep Learning techniques and the combination with additional data in order to provide meaningful results to support reforestation efforts based on existing biodiversity and ecosystem services. Additionally, the application of Reinforcement Learning techniques would be investigated in order to support decision making.

Finally, it should be mentioned that Task4.4 mentions the development of an online service that continuously monitors the biodiversity of various landscapes. Considering the speed of potential landscape changes, continuous would be to have an update once or twice per week. Let's keep in mind that for example Sentinel 2 images are updated couple times per month so this is the frequency that will be considered as continuous.

Data requirements and data & model availability

- Satellite imagery (passive and active remote sensing satellite products)
    - The European Satellite data (e.g. Sentinel2) are publicly available and would be a good starting point. Potentially, higher resolution images from other sources would be required
- In situ environmental measurements of the study area (Attica Region)
    - Such data are much more difficult to be found and potential not publicly open
- There is an existing classification model (EUT) that can be used as a booster and a basis for the work that will be undertaken in T4.4.
    - Additional models would definitely have to be developed and tested in order to fulfil the projects targets

Potential drivers and barriers

Drivers

- The experience of EUT in similar applications and the technical support that they will provide in the AI domain
- The existence of a model that can speed-up our initial development efforts

Barriers

- Multiple number of datasets that need to be combined but most likely will have temporal or spatial incompatibility
- Immaturity of holistic remote sensing approaches for biodiversity detection and species determination, great complexity of ecological systems and drivers impacting them.
- The amount of data that have to be processed for T4.4 can easily categorize it into the field of Big Data
- Difficulty to collect in-situ measurements and find local ecological georeferenced datasets

Key Performance indicators, added value and replication potential

There are various KPIs that can help measure and quantify biodiversity. Indicatively, we refer to the amount of forestry in the area of study, the number of plant/animal species (how many of those are endangered) and the weather conditions in the area. There are additional indicators that can quantify biodiversity, however at this stage of the project they are not still defined, and it will not be beneficial to list them all here since it is uncertain which ones we will be able to assess.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 101037084.

The added value of this Task would be the fact that the intended model would not only be working for the region of Attica that will be studied but with the appropriate modifications and adjustments most likely it will provide result for other DS's of the project. So, it has a very high replication potential provided that the result will be the expected ones.

Role of partners and relevant stakeholders

MAICH: Task coordinator, provide scientific and technical expertise

EUT: Provide technical expertise and hardware infrastructure

NTUA: Integration of the service into the Digital Twin for the Region of Attica

GSNEW: Test and provide feedback on the service as a potential end user

Actions and timeline

M7 – M8: Data determination

M8 – M11: Methodology and Action Plan Development

M11 – M30: AI Modelling – Assessment & Evaluation

M30 – M46: Provide Restoration Strategies

M36 – M42: Integration to the Digital Twin as an online service

3.2.2 Decentralized circular-economy inspired water / energy / materials reuse innovations

Objective and challenge

In this Task, a decentralised circular-economy system will be designed, constructed and deployed in the Attica Region and specifically in the area of East Attica as part of a wider intervention scheme based on existing and planned initiatives that have been or are planned to be implemented in the Region of Attica in order to address the climate change vulnerability matters and provide solutions to increase the Region's resilience.

In particular, in the specific pilot, wastewater will be mined from a sewer, using sewer mining (SM) technology, treated at the point of demand and reused directly for urban greening (and climate proofing against droughts) as well as municipal ecosystem services (park irrigation - heat island effect reduction).

Technical description

The Sewer Mining (SM) technology is a decentralised, flexible and autonomous CE solution in which wastewater can be extracted locally from the sewers that run under the city, through a prefabricated pumping station, be treated directly on site and create valuable high quality reused water at the point of demand to be used for green spaces irrigation and for aquifer recharge during the winter. The treatment residuals go back to the sewer to be treated by a regular wastewater treatment plant.

The pilot system will produce approximately 24 m^3/day water for irrigation and comprises essentially of a compact treatment plant that fits in a container and consists of a membrane bioreactor (MBR) unit, which is the combination of a membrane process with a biological wastewater treatment one. MBR is very efficient for removing the pathogens and also other parameters that are included into national and international legislation for wastewater irrigation. These parameters are emerging contaminants, heavy metals and priority substances. A UV disinfection unit will also be deployed and be added to the system to further increase the system performance mainly in terms of microbiological load.

Furthermore, a sophisticated control system fully automated controlled by a PLC will be implemented. The data that are collected from the installed sensors will be stored locally and also be available online through an advance information system.

Additionally, water-energy simulation and optimisation model for wastewater systems acting as regional CE and climate resilience hubs will be designed and deployed in the East Attica wastewater system (Mediterranean demo site).

The potential drivers and barriers are described below:

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 101037084.

Drivers:

- The citizens of Attica will benefit from greener parks and spaces, as they have a positive effect on human health and wellbeing. These green areas have also positive effects on climate change resiliency and help reduce urban island effects.
- Circular solutions that create valuable products from waste will help promote a shift in people's mindsets regarding the need for a transition to a circular economy.

Barriers:

- Public acceptance
- Regulatory framework (lack of legislation which frames the sewer mining solution)
- Financial feasibility
- Technical challenges (e.g. how to extract sewage, how to adapt to the variability of demand, what to do with by-products)

Key Performance indicators, added value and replication potential

The **impacts** to be reached by implementing the Sewer Mining solution are summarised below:

- Recovering value from waste, revalorising material that would be disposed otherwise.
- Reducing potable water used for irrigation, which equates to reduce water stress and preserves natural capital.
- Reducing volume of water that has to be treated by wastewater treatment plants and to be discharged in the environment.
- Reducing the need for water to travel for treatment, which means saving energy costs for the transport and treatment of the water.
- Reducing the Nitrogen and Phosphorus released by the wastewater during its travel, as the wastewater is locally recycled.
- Increasing the quality and the number of green spaces in urban areas.

SM is a very promising circular economy technology which brings significant **added value** as follows:

- provides 'climate-proofed' non-potable water e.g. for green space irrigation in dense and arid urban environments
- is proven to be very stable in terms of operation and highly efficient in terms of treatment
- has a very small footprint unit with limited space requirements for installation and minor landscaping and construction work due to its decentralized form, can be installed in the place of demand (CE concept)
- Provides longer lifetime of water in the urban water cycle

Due to the decentralised, flexible and autonomous aspects of the SM solution, it has a very high replication potential, as it is intended with the appropriate modifications and adjustments to be applicable to other urban areas beyond the region of Attica.

The SM technology intents to address the stakeholders' expectations through a dedicated engagement and publicity strategy engaging all the involved parties in the particular pilot site.

Role of partners and relevant stakeholders

Partners:

NTUA: Task coordinator of the pilot project, undertake the design, manufacturing, installation and operation of the SM, provide scientific and technical expertise. Also set up the water-energy simulation and optimisation model for the East Attica wastewater

EYDAP: Design, manufacture, install the prefabricated pumping station and be the end user of the simulation model as the main operator.

MAICH: Provide support to the SM pilot project.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 101037084.

Stakeholders:

The relevant shareholders (Region of Attica, competent Municipalities, etc.) will be engaged in their field of interest to be supporting the processes and address any issue of delay for the pilot (e.g. permits, public acceptance, etc.).

Actions and timeline

M2 – M7: Site location identification

M8 – M14: Request and granting of permits

M6 – M14: Design of the Sewer Mining unit and accompanying parts

M15 – M24: Construction, installation and start-up of the SM unit

M25 – M42: Operation and Optimization of the SM unit

3.2.3 Digital twins and advanced tools for climate adaptation

Objective and challenge

This Task intents to develop the Digital Twin (DT) of the Attica Region to be used as an advanced visualization tool to facilitate stakeholders' engagement and co-creation in the climate adaptation and green business development. The Attica DT will enable the knowledge of the engaged stakeholders and policy makers of the Region, in terms of existing or future interventions and initiatives with regard to the climate change adaptation, so that valuable information is illustrated digitally in a user-friendly way contributing to the policy making process for increasing climate change resilience. Also, potential green business opportunities will be highlighted.

Technical description

The Attica DT will be developed and built on existing data driven platform initiatives in the Region of Attica to create as a central hub for related data and knowledge to be turned into action in a co-creation process. In particular, the DT will provide access to relevant datasets (environmental, climatic, uses of resources etc.) as well as to relevant climate adaptation services (e.g. climate services, services to farmers, services to municipalities).

Toward this direction existing projects, initiatives and related data will be collected to be integrated in the DT platform. For the collection of the data and the development of the repository various methods and routes will be followed. Initially, direct communication with the key stakeholders will be performed to introduce the purpose of the project and particularly of the DT initiative. Furthermore, through further collaboration with the engaged stakeholders, links will be established to local and regional Communities of Practice (CoP) or other similar initiatives taking place in the Region of Attica. Thus, a network of involved parties will be established to be used for compiling the content of the DT platform.

After this research and interaction with the involved parties, a repository for demonstrations of climate adaptation innovations within the Attica Region will be compiled both created in past projects – such as NextGen, DESSIN and SUBSOL – and in IMPETUS. Indicatively, the material that could be included in the repository will refer to the type and name and it will include a short description of the innovative items (projects, initiatives, platforms, communities, committees, etc.). Additionally, the implemented technologies and solutions will be explicitly described as well as any relevant tool or product that has been developed or in under development. Finally, the related publications, promotion activities or any other relevant information (pictures, videos etc.) will be included to have a complete representation of the various initiatives and interventions in the repository; thus, the content of the Attica DT will be recorded.

At the same time, the DT platform will be developed and populated with the content of the above repository. Then, it will be presented to a group of key stakeholders and policy makers through the approach of WP1 engagement process and it will be available for feedback in order to optimise its functionality, usability and content. Finally, it will be launched at a wider audience under the auspices of GSNEW to be reviewed and improved.

The potential drivers and barriers are described below:

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 101037084.

Drivers:

- Policy makers of the Attica Region will benefit from the related data and knowledge
- Green business will be enhanced around climate adaptation innovations
- Sensitize public of Attica on climate change challenges

Barriers:

- Fragmented information and knowledge on implemented solutions
- Technical challenges of the platform
- Reaching out to the engaged parties to use the DT platform

Key Performance indicators, added value and replication potential

There are various KPIs that can help assess and quantify the success of the Attica Digital Twin. Indicatively, the number of initiatives / interventions, the number of visitors and the range of area they cover are mentioned. More indicators could be identified, however at this stage of the project it will not be beneficial to list them all here since it is uncertain which ones we will be able to assess.

The **impacts** and **added value** reached by developing the Attica DT are summarised below:

- all data, initiatives and innovations related to climate change resilience for the Attica Region will be included in a repository and visually illustrated through one digital platform.
- key stakeholders and policy makers could be using all the knowledge collected in the DT for increasing the resilience of the Region.
- new green business development will be boosted around climate adaptation innovations / interventions.

The stakeholders' expectations will be met once they will have a visual perception of their contribution in the Attica DT in terms of climate change knowledge and other relevant data.

Role of partners and relevant stakeholders

Partners:

NTUA: lead the development of the Attica Digital Twin, coordinate the collection of data and the compilation of the repository.

GSNEW, MANTIS: contribute to the collection of the data and material to be used as the initial content of the DT.

LOB: support the actions and provide feedback through their expertise when needed.

Stakeholders:

The Water Directorate of the Decentralized Administration of Attica, the Region of Attica and a series of key Municipalities can provide valuable material about initiatives in their range area.

Actions and timeline

M3 – M14: Collection of material from all involved parties

M7 – M14: Development of the Attica DT platform

M22 – M28: Launch of the initial version of the DT

M24 – M30: Promote the platform and collect feedback from stakeholders' and end users

M30 – M42: Launch of the final version of the DT and perform optimization work

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 101037084.

3.2.4 Water-energy masterplan and business plan for autonomous climate-proof regions

Objective and challenge

This Task aims to develop an Attica Region Masterplan and the associated Business plan, with regard to the reused water and nutrients extracted from the wastewater, for ensuring an autonomous climate-proof region.

Based on the repository compiled for the purposes of the Attica Digital Twin, regarding projects, initiatives and innovative solutions in the Region of Attica for reused water and nutrients extracted from the wastewater Attica system (both from WWTP and Sewer Mining units), a Masterplan will be compiled to explore which activities would be beneficial for ensuring a climate resilience region. Additionally, an associated Business Plan will be drawn using a mix of financial instruments (incl. insurance and water/weather derivatives) to ensure the plan's viability and uncertainty-proofing given climate change. A challenge to be addressed would be to have these Plans adopted by the central government to be implemented by the local and regional competent authorities.

Technical description

The Attica Masterplan will include the review of existing initiatives as well as ongoing ones (including the IMPETUS pilots) with regard to the reused water and nutrients extracted from the wastewater. Further, based on data that will be collected on the specific needs of the Attica region e.g. water needs, water stressed areas, etc., a series of targeted initiatives and solutions, will be proposed to be implemented in selected vulnerable areas of the Region in order to address the particular issues that have been recorded.

When the Plan will be compiled, it will also be assessed in financial terms in order to come up with the associated Business plan. Therefore, specific financial tools will be used. The final product will be the Master and Business Plan for increasing Attica Resilience to Climate Change and will be submitted to the central government, i.e. the Ministry of Environment, as a Recommendation Plan for adopting the IMPETUS adaptation pathway by the local and regional stakeholders to maintain plans up to date as part of formal procedures.

The potential drivers and barriers are listed below:

Drivers:

- Having a Master and Business Plan for Attica to increase the Region's resilience
- Mobilise competent authorities to adopt the IMPETUS recommendations

Barriers:

- Immaturity/applicability of solutions
- Public acceptance of innovative initiatives
- Coordination of various involved parties to determine suitable vulnerable areas of the Region for the interventions.
- Uncertainty in the financial assessment of the proposed interventions.

Key Performance indicators, added value and replication potential

The **impacts** and **added value** reached by developing the Attica Masterplan and associated Business Plan are summarised below:

(i) benefit local farmer communities

(ii) protect sensitive groundwater bodies under severe stress with excess water used through NBS (specifically Subsurface Water Solutions) to improve coastal aquifers and halt saline intrusion

(iii) restore sensitive ecosystems to also sustain environmental services

(iv) improve firefighting and support for reforestation activities in the Region devastated by forest fires.

The stakeholders' expectations (farmers, municipalities, touristic sector) will be addressed in the Plan itself by suggesting ways of engagement and co-creation for ensuring a climate proof community in terms of water availability despite the seasonal variations.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 101037084.

Role of partners and relevant stakeholders

Partners:

NTUA: coordinate the Task, collection and classification of material and the compilation of the final report to address climate change vulnerability in affected areas.

GSNEW, EYDAP and MANTIS: Contribute to the material collection process and provide targeted input in the Masterplan report with regard to their area of expertise.

AUEB: Compile the Business plan using selected financial tools to assess related economic impacts.

Stakeholders:

The Water Directorate of the Decentralized Administration of Attica and the Region of Attica can provide valuable material about the proposed initiatives in their range area.

Actions and timeline

M6 – M12: Collection of data from all involved parties

M13 – M36: Compilation of the Attica Master Plan

M27 – M42: Compilation and integration of the associated Business Plan

3.2.5 Controlled Environmental Agriculture (CEA) solutions

Objective and challenge

The objective of the Task is to co-design Controlled Environmental Agriculture (CEA) solutions, taking into account the current condition of the CEA farms of the East Attica region. In addition, proofs of concept will be demonstrated in the Mediterranean demo site, aiming at increasing the resilience and sustainability of Attica's region as well as adjacent natural habitats.

The anticipated challenges are mostly related with the greenhouses construction and functional conditions, which often lack of heating, cooling and ventilation systems or advanced technological tools installations. In most cases, local CEA farms are not heated, and this results in reduced plant growth as optimum temperature requirements are not met. An emergent need for more efficient practices has raised especially after the heavy snowfalls of January 2022 in the East Attica region, which led to yield loss for more than 50ha of greenhouse production. New technologies developed by the partners involved will be co-designed aiming to a shift towards a sustainable and more environmental friendly CEA.

Technical description

Real-time data from sensors will be gathered, allowing researchers to monitor climatic parameters, detect changes in the greenhouse (GH) environment and simulate/optimize different cropping models. The use of IoT equipment and AI algorithms technologies that can facilitate the operation optimisation can be investigated and reviewed for their suitability. Sensors, connectivity equipment (4G) and actuators could be deployed depending on the suitability and the conditions of the specific demo site (GH) selected. These states of the art technologies can support the identification and potentially the regulation of water supply and energy consumption.

Recent technological developments in areas relevant to IoT facilitates an easier adoption and use of smart farming with IoT. Such technological developments include, for example, network communications, reduction of hardware size, optimization of power consumption and devices price reduction. Furthermore, the world's largest agricultural producers are promoting the usage of IoT in smart farming by creating incentive programs and public policies to fund research and training. (Navarro et al., 2020, DOI: 10.3390/s20154231).

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 101037084.

Table 8 Data requirements, data and model availability

	Data requirements	Data & model availability
Outdoor climate data	temperature, rain, relative humidity, wind speed and direction, solar radiation, barometric pressure	Meteorological station, pyranometer
GH-indoors climate data	temperature, humidity, solar radiation, CO_2 levels	Sensor that monitors data (frequency: 20sec) with Cloud storage

The potential barriers and drivers are listed below:

Barriers:

- Lack of infrastructure of existing CEA farms
- Extreme weather conditions

Drivers:

- Increase the performance of the farms
- Promote innovative solutions to address impacts of climate change to the agricultural sector.

Key Performance indicators, added value and replication potential

The anticipated impacts of demonstrating the suggested solutions are focused on informing/educating producers on new technological tools and encourage the solutions adoption in greenhouse production. By implementing the solutions suggested for CEA farms of the Attica region, specific goals can be achieved, such as yield increase (%), water saving (mL / day / plant) or efficient energy consumption (KWh).

A workshop or info day will be organized, with the participation of local farmers and related to greenhouse production stakeholders, including the farmers' Association in the east Attica Region. The most suitable CEA farms will be identified, whereas for the solutions implementation, local farmers' needs and experience will be shared and thoroughly discussed. Specifically, the solutions will be scheduled according to specified targets (reduced water consumption, heating requirements, advanced use of technology, software). Throughout this co-creation process, data/knowledge exchange among stakeholders will be promoted.

Role of partners and relevant stakeholders

Partners:

MAICH – Greenhouses arrangements at demo site in Attica region

NTUA – Technological tools / DT platform integration of results

AUEB – Assessment/estimation of the related economic impacts

GSNEW – Provide info with regard to similar or equivalent CEA initiatives

MANTIS – Business models

Stakeholders:

Local Farmers / associations of farmers, agronomists, markets involved in the supply chain

Actions and timeline

M1 – M12: Selection of the farm(s) that will be involved in the CEA study, collection of historic and/or current climate data and assessment of current greenhouse control units.

M13 – M24: Installation and testing of the meteorological station, sensors and other systems.

M25 – M36: Optimization of the systems and technologies employed.

M37– M48: Analysis presentation and dissemination of outcomes/results.

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4 Atlantic DS: Province of Zeeland & Rijnmond, The Netherlands

4.1 Introduction and background

The regions of Zeeland and Rijnmond are taken as representative areas of the climate hazards that the Netherlands is facing.

With regard to flood risks and due to its long history dealing with it, the Netherlands applies a Multi-Layer-Safety Approach. Which is a risk-based approach to manage the consequences and probability of a flood through several types of measures. These measures include: 1) prevention through dikes, levees and dikes 2) mitigation via spatial planning and 3) crisis management through preparedness and emergency response.

Within IMPETUS we aim to focus on the second layer of the multi-layer safety approach: Mitigation via spatial planning. The need for new build spaces is high in the socio-political agenda in The Netherlands, increasing the pressure to built beyond the well protected areas within the dike system. Or these new-development will change the protected areas in such a way that risk assessments need to be continuously updated. In order to facilitate this demand and considering the climate challenges ahead is that our Decision Support System for Flood and Heat Stress is being developed.

We specify our domain for the Atlantic region as: supporting spatial-planning decision-making with flood risk information. In the same way for the heat awareness system our domain is: supporting spatial-planning decision-making with heat stress risk information.

The implementation that we are developing: Integration of advance visualization techniques, embedded in a Decision Support System, aims to support authorities in their decision making and moreover in their communication strategies towards a bigger audience.

Table 9 Solutions and related tasks

Solution	Task No	Task title	Bundle No	Bundle
Digital twins and advanced tools for climate adaptation	4.10.1	Heat awareness system	2	Innovative technologies
	4.10.2	Integrated decision support tool coupling a flood risk model onto a digital twin	2	Innovative technologies
System monitoring dashboard to support climate mitigation and adaptation strategies	4.25	Decision Support Tool to support the decarbonisation of industrial clusters	4	Governance Models, Awareness and behavioural change

4.2 Pre-requisites, design and concept for implementation

4.2.1 Heat-awareness systems

The objectives for the Decision Support Tool are:

- We want to develop a methodology that identifies indicators based on climate resilience goals with respect to the hazards of heat-stress in regard to spatial planning.
- We aim to develop the interactive coupling of Heat Stress mapping with a 2D viewer (Digital Twin).
- We aim to improve our heat awareness systems (PET) by allowing variability in weather scenarios.

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- The visualization of different weather scenarios and spatial planning adaptation options will enable decision makers to assess the implications of adaptation measures.
- The technological solutions developed will support decision makers to make informed decisions with respect to spatial planning.

We identify two types of challenges; on the one hand we have technical challenges and on the other hand we see challenges related to expectations.

- Find the right balance in the size of the demonstrated area. The area should be small enough that the changes are made visible and it should be large enough that the influences in the system are also shown (technical challenge).
- The integration of the heat prognosis models with outputs from the other modules form other work packages (technical challenge).
- Not all possible measures can be interactively simulated in the heat stress system (expectations challenge)

Technical description

State of the art heat stress determination, visualization and interactivity

Heat stress is one of the 4 major climate hazards that the Netherlands is being expose to. The other hazards include flood, drought and extreme precipitations. The consequences of heat stress affect 5 different themes': health, networks, water, quality of life and outdoor space. The heat stress map, referred to as the PET (Physiological Equivalent temperature) map provides the experienced temperature and is mainly related to the quality of life and outdoor space theme. This temperature is computed from an empirical formula calibrated with measurements obtained in Rotterdam and Wageningen in The Netherlands.

The PET temperature can be computed on-the-fly and visualized in 2D dimension. These computations are possible thanks to the Dask-Geo technology implemented in our systems. Changes to a couple of elements within the domain are sustained by the system and the changing PET is re-calculated. The existing tool allows for a couple of adaptations or changes in the lay-out, such as tress, water bodies and changing the surface of the roads. The area of influence of the changes in the landscape is limited to the extend of the area of interest and are computed for a specific instant in time.

Data requirements and data & model availability

For the pilot areas within Zeeland and Rijnmond, we have the following data requirements:

- Land use map
- Location of green spaces
- NDVI (Normalized Difference Vegetation Index) maps
- Elevation maps for the determination of shade
- Sky-view maps
- Air temperature maps
- Windspeeds
- Relative Humidity
- Weather forecasts with high spatial resolution

The basic model for the computation of a PET map is currently available in N&S servers coupled to the input information provided in the form of raster's.

Potential barriers and drivers

The inclusion of large plans in terms of spatial planning might complicate the visualization of the changes in PET due to adaptations.

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Table 10: Models to be developed based on the DSS methodology for Heat

Model	General Description
Regional model Zeeland/Rijnmond	Based on all of the inputs collected a heat stress model will be developed for a region. This model will be coupled to several adaptation plans from the authorities and the results will be used for discussion with developers and citizens.
Heat stress awareness system	The results of heat stress model based on forecasts will be provided to authorities for the purpose of proving timely information.

Key Performance indicators, added value and replication potential

The technological solutions developed will support decision makers to make informed decisions with respect to spatial planning. These mainly focused to the visualization of the results of measures.

- After development, every year the authorities will test their possible measures. This leads to at least 3 elaborated tests and demonstration of the technology.
- Adaptation pathways outcomes are clear for every stakeholder: 3 key stakeholders.

The stakeholders are engaged to the project from the start. Dedicated workshops are planned to aligned desires, expectations to the technological development.

The methodology and tool could be replicated in other areas when the supported decision-making process is accepted.

Role of partners and relevant stakeholders

The development is mainly a responsibility of N&S. Regarding the climate scenarios, hotspot identification and connection with the RKB we are collaborating with EURECAT, UIT and NTUA.

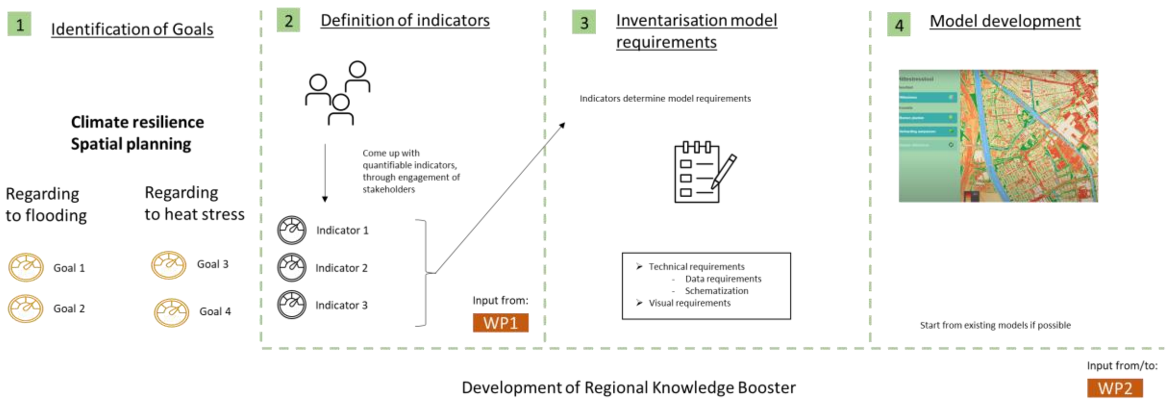
Together with KWR we have close contact with the key stakeholders.

- Municipality of Rotterdam
- Municipality of Schouwen-Duiveland
- Province Zuid-Holland
- Water Association Hollandse Delta
- University of Zeeland

The list of stakeholders is not limited to the ones mentioned above, more details are provided in the Toc and included in the stakeholder registry.

Actions and timeline

The development of the methodology includes the following 7 steps. We elaborated on a timeline focus on the first year of the project.



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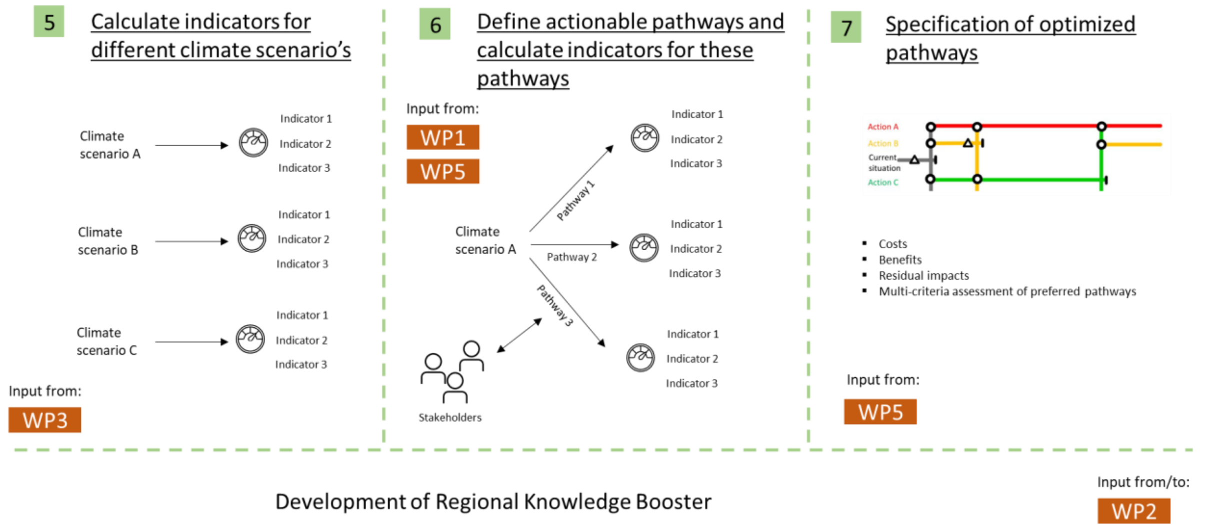

	M1	M2	M3	M4	M5	M6	M7	M8	M9	M10	M11	M12
Inventory of state of the art												
Assesment of the case study												
Establishement of goals												
Establishment of indicators												
Elaborate the methodology												
Validate the goal and indicators (workshops)												
Fine tune goals and indicators												
Improved Methodology												
Inventory model requirements												
Ineventory needed developments												

4.2.2 Integrated decision support tool coupling a flood risk model onto a digital twin

Objective and challenge

The major goal to develop a decision Support Tool has the following objectives:

- We want to develop a methodology that identifies indicators based on climate resilience goals with respect to the hazards of flooding in regard to spatial planning.
- We aim to develop the interactive coupling of 3Di simulations with a 3D viewer (Digital Twin).
- The flood scenarios computed with 3Di will highlight the stress that the water -system will face when changes are made due to new development and changing weather conditions.
- The interactive coupling will be available in the Atlantic RKB and optioning for different climate scenarios and measures will be possible.
- The visualization of different weather scenarios and spatial planning adaptation options will enable decision makers to assess the implications of adaptation measures.
- The technological solutions developed will support decision makers to make informed decisions with respect to spatial planning.

We identify two types of challenges; one is technical challenges and the second one is related to expectations challenges.

- Find the right balance in the size of the demonstrated area. The area should be small enough that the changes are made visible and it should be large enough that the influences in the system are also shown (technical challenge).
- The integration of the flood models with outputs from the other modules form other work packages (technical challenge).

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- Not all possible measures can be interactively simulated in the heat stress system (expectations challenge)

Technical description

Digital Twins + 3Di State of art

Digital Twins are an online representation of the real-world in 3D. Digital Twins simplify the physical world in an attractive and accessible manner which provides a variety of insights and changes. The integration of Digital Twins with advanced data products, simulations software, or models unlocks a clear and progressive insight in complex phenomenon. This can help to make more efficient and application-oriented decisions in various fields. An integrated system of Digital Twins and simulation software such as 3Di, available by API technology, allows processing, accessing, and simulation of data and scenarios.

The hydrodynamic software 3Di is frequently used for different catchment in the Netherlands and abroad. Its capabilities have been tested and benchmarked in terms of speed and accuracy of results. Furthermore, with the software different elements form the water system can be modelled in a coupled manner, this includes pipe simulation as 1D elements, barriers such as levees also in 1D, water sea level fluctuations in 2D. For the purposes of our innovation the tool can cope with on-the fly computations based on variations in forcing and landscape. The on-the-fly interaction of the changes and the coupling with a digital twin are still new and completely developed.

In The Netherlands 3D visualizations are available for some municipalities that cooperate with the Nederland in3D initiative. Not all of the information is up to date. The integration of Digital viewer and simulation outputs is starting to become interesting to different stakeholder.

Currently the integration and interaction done are a one-way coupling, meaning that based on the elevation information available flood scenarios are developed. The resulting visualization shows changing water levels in space and time. Here we aim to include changes in the elevation and spatial distribution that will have different flood results.

Data requirements and data & model availability

For the pilot areas within Zeeland and Rijnmond, we have the following data requirements:

- 3Di model + Digital Viewer
- Digital elevation model (DEM)
- Lan use map
- Friction map
- Infiltration map
- Hydraulic structures
- Levee system
- Sewerage system
- 3d Information available
- Improved elevation data
- Access to the platform with existing data
- API system for the integration of Digital twin + 3 Di
- Potential plans for spatial developments

Potential barriers and drivers

System-response times might be slower than desired. This referring to the interactions with weather forecast and adaptation measures.

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Table 11: Models to be developed based on the DSS methodology for Flood

Region	General description
Regional model Zeeland/Rijnmond	Based on the compiled information to build a base 3Di model an integration model will be developed within a Digital Twin. The coupled model will be included in the Atlantic RKB to demonstrate what if scenarios, related to climate, scenarios, adaptation pathways and inflection points. The results highlight the effects on the regional water system and where the system would become stressed.
Municipal model Zeeland/Rijnmond area	A smaller model with the regional area where measures taken at street level will be visualized together with the implication of adaptation measures.

Key Performance indicators, added value and replication potential

The technological solutions developed will support decision makers to make informed decisions with respect to spatial planning. These mainly focused to the visualization of the results of measures.

1. After development, every year the authorities will test their possible measures. This leads to at least 3 elaborated tests and demonstration of the technology.
2. Adaptation pathways outcomes are clear for every stakeholder: 3 key stakeholders.

The stakeholders are engaged to the project from the start. Dedicated workshops are planned to aligned desires, expectations to the technological development.

The methodology and tool could be replicated in other areas when the supported decision-making process is accepted.

Role of partners and relevant stakeholders

The development is mainly a responsibility of N&S. Regarding the climate scenarios, hotspot identification and connection with the RKB we are collaborating with EURECAT, UIT and NTUA.

Together with KWR we have close contact with the key stakeholders.

- Municipality of Rotterdam
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The list of stakeholders is not limited to the ones mentioned above, more details are provided in the TOC and included in the stakeholder registry.

Actions and timeline

The development of the methodology includes the following 7 steps. We elaborated on a timeline focus on the first year of the project

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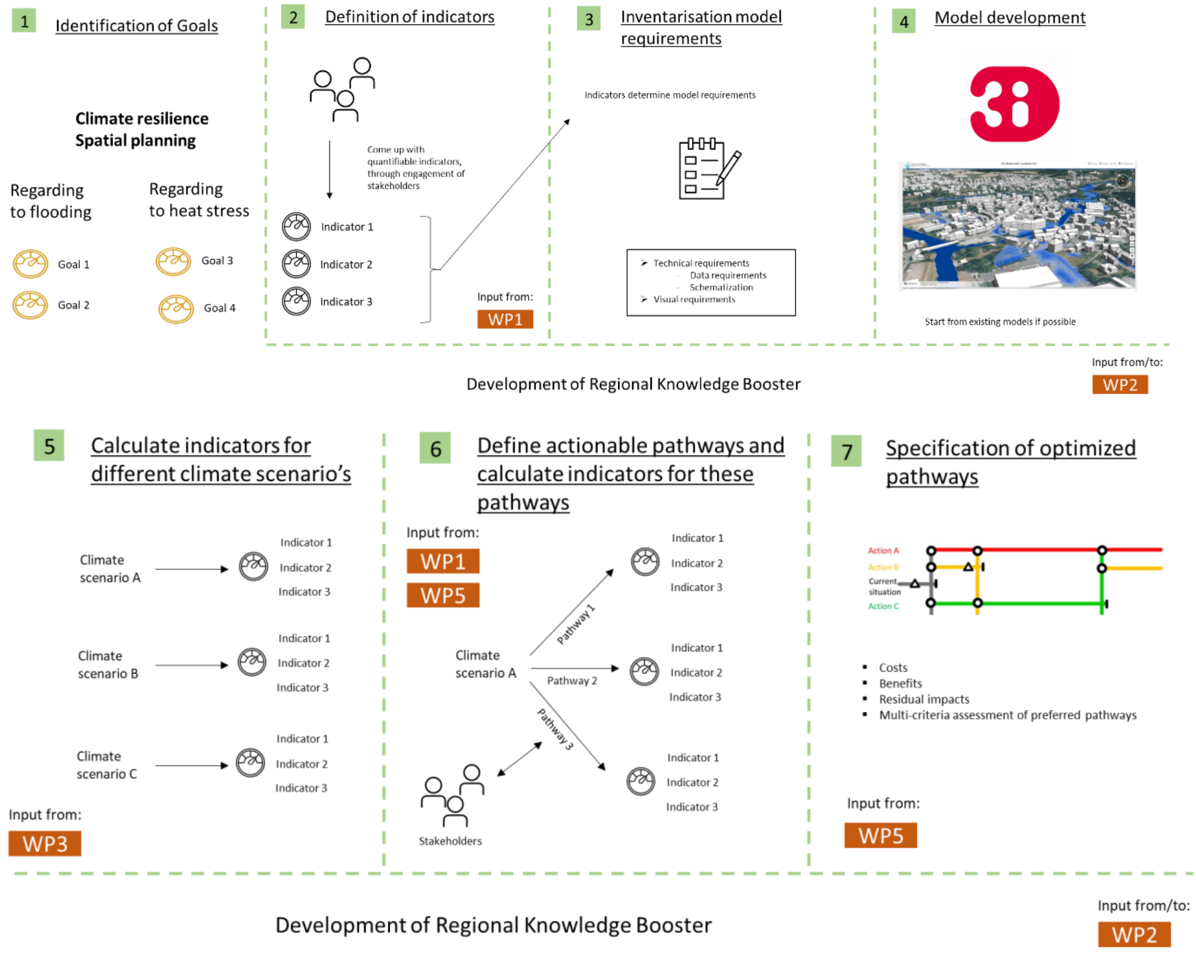

	M1	M2	M3	M4	M5	M6	M7	M8	M9	M10	M11	M12
Inventory of state of the art												
Assesment of the case study												
Establishement of goals												
Establishment of indicators												
Elaborate the methodology												
Validate the goal and indicators (workshops)												
Fine tune goals and indicators												
Improved Methodology												
Inventory model requirements												
Ineventory needed developments												

4.2.3 Decision Support Tool to support the decarbonisation of industrial clusters

Objective and challenge

WEI is leading IMPETUS activities related to the Netherlands-based demonstration site in the petrochemical industry cluster in the Port of Rotterdam (case study). We are developing a decision-support tool to enable local stakeholders to make intelligent and decarbonisation investment decisions.

Challenge addressed and objective of demonstration

1. The Dutch petrochemical industry needs to invest in new assets to enable CO_2 neutrality in 2050

The Dutch petrochemical industry is responsible for a third of all Dutch CO_2 emissions. Therefore, to fulfill the targets of CO_2 neutrality by 2050 set out by the EU Green Deal and Dutch national policy, many investments need to be made by the Dutch industry. Examples of these investment decisions are: dismantling polluting assets, electrification of heavy industrial processes, or using (green) hydrogen as input fuels.

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2. High investment risk prevents investment decisions and in turn delays the needed transition

Making these investment decisions is difficult for actors who own industrial assets for two reasons. Firstly, the investment risk is often very high. This is because these new assets have very high CAPEX, there are very high technically specialized processes in place, new investments do not necessary replace all the technical aspects of old assets and finally there are very long lead times before projects are realized. Second, there is a high degree of uncertainty. This deep uncertainty is caused by future prices, (international) competition, security of supply of energy, availability of infrastructure and policy intervention. The combination of high investment risks and deep uncertainty leads to unwillingness of investors to proceed, as they can't afford to make a wrong decision and therefore do not invest into new sustainable assets.

Technical description

Software and modelling are essential for solving this problem as accurate models can provide insights into the investment problems as mentioned above and thus enable the energy transition. However, the current models utilized by the industry are lacking in several areas.

1. No modelling of the physical flows in the industrial cluster

First, the industry uses mostly economic analysis models that are mainly excel based on cash-flows and typically they do not simulate the actual physical flow of molecules in the industry. This lack of physical flow analysis does not enable fundamental insights into what happens when changes are made to the industrial cluster. These missing crucial insights associated with a lack of modelling capabilities prevents potential investments and thus a deceleration of the energy transition. In turn, the models that simulate physical flows are very zoomed in to specific chemical processes, which do not make them computationally usable to simulate entire industrial clusters. And this makes these models not suitable to base investment decisions upon.

2. No modelling of the investment decisions in the industrial cluster

Second, in most models, investment decisions are exogenous decisions that arise from the cash-flow analysis. However, in a system such as an industrial cluster, most actors are intertwined. This means that an investment decision made by party A could have a significant impact on party B. Due to modelling and technical barriers, valuable insights are left on the table by not modelling this behaviour within the models.

3. No simulation of the transition for many futures

Finally, as discussed within the challenges section, the future is deeply uncertain, impacting the system. However, most models/analyses only look to explore a handful of futures, which gives not enough confidence to take away investment risk.

Technical description

1. Modelling the physical flows in the industrial cluster

We will use a quantitative tool that enables the modelling of industrial processes. Within this tool we can model production systems as a cluster of processes and allow for nested modelling. Furthermore, by assigning cash-flows to the simulated physical flows, we can optimize for maximizing cash flow. In this way, we simulate market behaviour while accounting for physical flows in industrial clusters.

2. Modelling the investment-decisions in the industrial cluster

We couple our tool that simulates physical flows with a Python script. In this way we can script/code the decisions that industrial companies would make. We can simulate investment behaviour in new assets while accounting for access to limited information and risk averseness by utilizing these techniques.

3. Not simulation of the transition for many futures

To enable the actors in the industrial cluster to generate robust insights, meaning that the simulation works for a wide variety of futures, we use the Exploratory Modelling and Analysis (EMA) workbench.

We couple our physical flow tool with a Python script, then, in turn, this Python script is also connected to the EMA workbench. EMA workbench is a research methodology that uses computational experiments to analyse complex and uncertain systems.

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4. Accessibility of the model to industrial actors

To make the model utilizable for industrial stakeholders with limited technical skills, we will consider the development of an accessible web application. This web application can utilize React as a JavaScript framework, HTML, and CSS. We are looking at including either Firebase or MongoDB for the database part.

Data requirements and availability of data/model

The data requirement for the project can be found in three realms:

1. Data on physical flows within the cluster

To gather this data, we are looking at existing databases (MIDDEN project owned by TNO/TU Delft mostly) and year report of large industrial players. On the other side, there are existing models such as the Carbon Transition Model and the HyChain project who also have utilized similar data on the physical flows, we are in close contact with these parties to gather the data.

2. Data on decisions rules investment behavior

To gather this data we need to collaborate with industrial players to better understand what their motives/analysis are before making an investment.

3. External variables data

We also need data on the parameters within the model e.g. future electricity prices or specific demand needs of certain chemical flows. Our main source for this data will come from scientific papers.

Added value and replication potential

Novelty of the approach:

After speaking to experts on the subject such as TU Delft professors, modeling consultants (e.g., Quintel/Siemens), grid-owners (TenneT/Stedin), governmental bodies, and prominent industrial players (who are also involved in like-wise projects such as GridMaster, the Carbon Transition Model, the EnergyTransitionModel). We can confidently conclude that there are no projects focused on integrating our four bottlenecks:

- modeling the physical flows of the industrial cluster
- endogenous investment decision-making within the model
- simulating many futures and making the model easily useable
- simulating key actors within the PoR

Added value of this for the industrial partners in the Por

Due to a lack of models that include all the elements as mentioned above the industrial players are not able to simulate what the future looks like, with a reasonable degree of confidence. Because of this uncertainty, they do not know how to act. This model can increase their confidence in the future and thus will lead to investment decisions in regards to sustainability.

Replication potential

The replication potential of our project can be found in two realms. Firstly, if we succeed to model the energy transition in the PoR and build a friendly interface this means that all parties could benefit from this. Secondly, due to the novelty of our methodology we hope to provide a method that could be replicated in other industrial clusters EU wide.

Potential barriers (risks) and drivers

Potential barriers:

- the actors do not want to utilize the tool we make
- the tool is too complex for them to understand
- due to the novelty of our approach we are not technically capable to built some aspects that we thought were possible
- our tool is very data-intensive – this might pose a problem

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Potential drivers:

- the energy transition is occurring and many actors have indicated that the problem we are looking to solve for them is something that they are actually experiencing.

Another driver can be found in the novelty of our approach, due to this reason we are generating a model/tool that has not been built before and this sparks interest of actors.

Key Performance indicators, added value and replication potential

The main KPI would be the number of stakeholders who want to utilize our decision support tool after the IMPETUS project

Role of partners and relevant stakeholders

1) **Industrial partners**: they will provide us with crucial feedback on how they are experiencing the tool and what we need to develop. Also we will ask them for data
2) **Other model owners/developers**: other model developers will provide us with data, feedback and information on how to collaborate with industrial partners,
3) **Knowledge institutes**: they will provide us with feedback and serve as sparring partners

Actions and timeline

With regards to the timeline of the project we see four big stages of the project.

1) First: minimum viable product phase (November - December 2022): we spend the first months of the project talking to other stakeholders and seeing what the needs are for such a tool. Based on this information we set-out the overall outline of the tool as described in this document so far. Now we have identified concrete industrial players who we are developing a demo-case for, so that we can validate our model on a smaller scale. Moreover, we will use this demo case to showcase all the other stakeholders we have interviewed what the model can do.
2) Second: fixing the feedback of the minimum viable product (January 2023- December 2023): after we have developed a minimum viable product we will present this to the industrial partners in the PoR. After having done this we expect the partners to have several remarks on what could be improved on our beta version, we plan to incorporate these elements in this time and thus generate a solid first product. Also in this time we will outline the plan on what partners we can add on during the scaling phase.
3) Third: scaling the minimum viable product to a real product (January 2024 - December 2024): now that we have a solid first version of the product this year will be about scaling up. We will include additional stakeholder companies within the PoR, including their respective physical flows and their investment rules. At the end of this step ideally we can model the largest part of the PoR.
4) Fourth: finalizing the real product (January 2025 – October 2025): in this final phase we have done all the ground work of the product and we will focus primarily on making the tool useable for everyone. So work a lot on the front-end and also on how to let stakeholders make independent use of the model elements. We will also work on how WEI can commercialize/exploit this model.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 101037084.

5 Arctic DS: Troms & Finnmark County, Norway

5.1 Introduction and background

Climate change already has significant impact on the region. The average surface temperature has increased almost three times more than the global average, in particular during winter months. The region is at particular risk to be affected by climate change effects. Increase in heavy rainfalls, floods, landslides and avalanches, with shorter winters and even drought in some areas, are among the already-perceived and expected changes. In addition, the sea level is expected to rise (at least) by 60cm in Northern Norway within the 21st century.

First, a warmer and more acidic sea has implications for the entire food chain in the sea. Species will move and change behaviour patterns, impacting heavily both coastal fishing and aquaculture through autochthonous species migration, disruption of ecosystems by alien species, or more frequent harmful algal blooms (HABs).

Second, higher temperatures and heavier rainfall/snowfall will make many coastal communities surrounded by mountain areas extremely vulnerable. In recent years, there has been many mass movements (rockfall, rock, clay, quick clay, loose mass, flood, earth, snow and mountain landslides), with significant consequences for people and the environment. Such geohazards can have catastrophic effects on communities and destroy infrastructure on land and sea.

Third, sea-level rise, storm surges and waves are already creating problems for low lying coastal areas in the Arctic. Most of villages and cities are built along the coast and, in recent years, some have undertaken large developments close to the shoreline. As the largest city in northern Norway, Tromsø is an excellent example of this challenge. In Tromsø, many areas will face an increased risk of flooding, occasionally or permanently. Even a moderate sea-level rise can have massive social, economic and environmental consequences.

Table 12 Solutions and related tasks

Solution	Task No	Task title	Bundle No	Bundle
Digital twins and advanced tools for climate adaptation	4.11	Climate-proofing of the city centre and of its urban water infrastructure against sea level rise	2	Innovative technologies
	4.12	Early-warning system for geological and avalanche risk sites	2	Innovative technologies
Digital twins to co-design a Marine Spatial Planning framework	4.19	Co-design a Marine Spatial Planning framework		

5.2 Pre-requisites, design and concept for implementation

5.2.1 Digital twins and advanced tools for climate adaptation

Objective and challenge

Polar amplification results in Arctic communities being at the forefront of climate change impacts, making them an important early reference point for how climate change may soon impact communities across the globe. The coastal areas in the region has already suffered in recent years episodes of extreme sea-level that resulted in the flooding of low-lying neighbourhoods affecting commercial and industrial sites.

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The Arctic location and other climate change factors may further affect in particular the design and operation of urban water systems in the region.

A values-based approach to adaptation focuses on sustaining the things that people value about the places in which they live. This is particularly relevant if applied to urban planning processes. Incorporating such values into adaptation strategies should ensure that the process and outcomes of adaptation are more equitable, inclusive, and legitimate. Social Innovation, as a territorially embedded dynamics, derives from this potential to change, locally and in specific institutional, political, socioeconomic and cultural contexts the approach and the processes that underlie spatial plans design, content and scope. The 'lived values' concept provides one way of conceptualising social values for the purposes of evaluating the fairness of climate adaptation. The benefit of understanding the importance that residents attach to the attributes of places in which they live, their everyday activities, and social interactions is that it provides insights into the distributive fairness of adaptation policies, which is likely to have flow on effects to the perceived legitimacy of decisions.

The emergence of institutional ambiguity in new issue areas such as sea level rise (SLR) coupled with shifting governing terrains create complex challenges for local government in creating capacity to govern. An issue area such as SLR, cuts across traditional divides between scales, policy sectors and interest-groups.

The complexity of challenges and of prevention and adaptation solutions requires collaboration among different stakeholders with sometimes conflicting interests and the development of new methodologies to support decision-making processes leading to low-regret decisions. The challenges are both of a physical, administrative, and political nature that calls for collaborative governance cutting across traditional divides between scales, policy sectors and interest-groups. The capacity to govern involves co-ordination and integration within the municipality and with a range of stakeholders and communities. It is important to design and stage conflicts and dynamics in a way that contribute to stimulate change and innovations.

Engaging new development perspectives rely strongly on the capacity of the local actors to transform planning and governance approaches and practices. These changes in planning approaches require from planners and developers, but also from the citizens themselves.

Soft and flexible planning tools are needed linking actors together, sharing and developing knowledge to overcome a fragmentation of institutional environments or a need to enter partnerships to achieve common goals.

Moreover, the extreme setting of many Arctic communities renders them particularly reliant on critical infrastructure, making their socio-ecological systems extremely vulnerable to disruption and impact. Mass movements (landslides, rockfalls, rockslides, snow avalanches) and secondary consequences (tsunamis, dams, flooding) resulting from changes in the temperature, snow and water regime are identified as a key threat to the Arctic and Subarctic society and infrastructure, generating unforeseen challenges in societal adaptation.

In Norway geohazards such as landslides and avalanches commonly result in fatalities, evacuations, road closures, data/mobile communication and energy supply networks disruptions. There is widespread recognition that climate change will increase the number and scale of these disasters, which in the last 10 years in Norway amounted to over 90 MEUR/year - an increase by 260% compared to the three previous decades – and is projected to arrive to 112,5 MEUR/year as an average in the next decade because of climate change.

At least 27% of Norway's roads are located within risk zones, and the use of mass movement-prone terrain has increased dramatically in the past decade. This increases the vulnerability of society, key networks such a transport routes, food networks and other relevant industries. All these factors bring greater challenges as society must try to prepare for and minimize the impacts.

Climate change is also increasing the frequency of snow avalanches. Early season snowfalls, followed by rainfall, melting and refreezing, increase the instability of snow slopes. Snow avalanches are therefore an ongoing protection issue in northern Norway, due to the increasingly unpredictable weather and unstable snowpack.

Undisrupted livelihood and access from the north and south is vital for health services, the transport of food and other goods, tourism, indigenous activities (e.g. reindeer herding), national border access (Norway/Finland border) and daily life for the inhabitants of the area.

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Climate-change-driven warming air temperatures, intense precipitation, decreased snow cover, permafrost thawing, glacial retreat, and changes to groundwater regimes each contribute to the increasing risk due to geohazards. Many of these mass movement processes are related to the alteration of the surface and groundwater regime. Fluctuations in the water regime both act as preparatory conditioning factors for the mass movements, and as triggers over a certain intensity threshold. Mass movement risk adaptation pathways rely on climate projects for rainfall and temperature change thresholds.

The establishment of the Knowledge Resilience Booster and the definition of a co-creation space among stakeholders and policymakers supported by the Digital Twin will result in agreed adaptation policies for managing elevated sea levels, as well as increased threats from mass movements and snow avalanches, specifically in the Arctic context.

IMPETUS will contribute to the adaptation of infrastructural systems and water management including improved political capacity towards more resilient development. Specifically, Coastal area development under various spatial planning strategies based for instance on the size of coastal buffer zones or on the implementation of nature-based solutions may help the co-design of optimal alternatives within a dynamic environment for climate change adaptation in coastal zones. IMPETUS will also contribute to the adaptation of infrastructural systems and urban water management strategies.

Moreover, observational data linking mass movements and environmental factors must be incorporated into the knowledge booster. The first step is the integration of knowledge booster data with landscape dynamic models to determine the exact climate change thresholds required for unacceptable frequencies of mass movements, i.e. what thresholds must be exceeded to trigger X number of failures in the site area. These thresholds (in terms of rainfall intensity and temperature) will determine critical points in the adaptation pathway. Secondly, the adaptation method at each future critical point of the pathway must be determined. The solution to protecting the community will be a combination of approaches including direct safety installations, improved early warning systems for evacuations, and resiliency planning for unstoppable events- for example, identifying which communities are in danger of being isolated, trapped or directly impacted and mapping resiliency needs for such.

These solutions must be co-developed together with the regional government, affected citizens and stakeholders, and other public actors with the responsibility for ensuring safety. In this respect, the development of the Digital Twin proposed by IMPETUS would play a key role to enable the co-creation of these measures and policies for climate change adaptation and mitigation in the Arctic.

Technical description

State of art

The municipality of Tromsø has developed a number of plans relevant for CC adaptation, although the ambitions, as well as mechanisms for implementation, vary between plans.

- 21.11.2018 the municipality of Tromsø adopted the current plan for climate, environment and energy. This plan contains six actions regarding climate adaptation. The actions in this plan are on a strategic level with actions like:
- The municipality of Tromsø will make a plan for surface water management
- The municipality of Tromsø will set aside resources for a 50% position to coordinate the climate adaptation work in the municipality
- This plan is supose to be evaluated every year
- 27.05.2020 the municipality of Tromsø adopted a plan for managing of surface water. The purpose of the plan is to make a robust strategy for managing surface water. This plan contains six actions including a locally adapted blue green white factor. The white part of the factor is to secure space for snow managing
- 10.02.2022 the municipality of Tromsø adopted to put out a plan for Tromsø centrum for public hearing. This plan is the first plan in Tromsø that contains provisions regarding blue, green white factor. This plan also includes provisions about that the seafront should be zone planned to protect against sea level rise and storm flood

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- 10.02.2022 the municipality adopted the planning programme for a revision of the masterplan of Tromsø municipality. One of the focuses of this revision is climate adaptation

Data requirements and data & model availability

The development and use of a digital twin as part of this project will provide a solution to the challenges of collecting, analysing and presenting different forms of georeferenced information from a variety of geodata producers. In a governance perspective this is however only a partial, or lower-level, solution, as central questions of whether and how such knowledge is actually used in planning and decision-making processes, call for different kinds of solutions. The proposed "decision theatre" model within Impetus is one such potential contribution. We must, however, not unnecessarily expect our stakeholders to spend time and energy on participatory processes *in addition to* actual ongoing and upcoming planning processes, so the exact nature of how to design these collaborative efforts must be decided later.

Potential barriers and drivers

Barriers: Within the formal planning process, we can already identify a few potential barriers.

The Planning and Building Act provides options for the sequencing of consecutive steps in building processes. How this is actually implemented may produce opposition and deadlock because of the distribution of costs and benefits across actors over time. This is directly correlated to another barrier: The lack of agreed-upon models for cost-sharing for preventive measures re: climate change.

Some potential barriers are more political in nature, e.g.:

Varying degrees of acceptance of climate change claims, and willingness to accept local/regional/national regulations, as well as varying willingness to accept present-day costs for longer term benefits.

Drivers: There is an increased recognition/awareness of the potential effects of climate change in the population at large, and also in both public and private decision-makers. Especially for long-term investmests (e.g. infrastructure), even potential adverse events decades away gain relevance for present-day decisions, thus bringing the future closer (more relevant for investment decisions)

The occurrence of "focusing events" – dramatic incidents of the effects of non-adaption, typified by floods, landslides and avalanches, brings the necessity of CC adaptation to the foreground.

We have recently (March 2022) seen how an "alarmist" report from The Office of the Auditor General onnational climate adaptation policy (and its' regional/local implementation) has lifted CC adaption as an issue on the public agenda.

Some "green" policy entrepreneurs and parties also contribute to the elevation of CC adaptation issues on the agenda, which is also a polarizing political issue.

Key Performance indicators, added value and replication potential

In the Tromsø City Case, key performance indicators will be related to the development of a more resilient water management system. Stakeholder expectations are not yet identified. These have to be mapped in the next step of the project / couple of weeks.

An initial mapping of stakeholders across the quintuple helix has been conducted. At this stage the stakeholder portfolio must be regarded as highly dynamic, and will change and evolve through iterative steps throughout the project period.

Measuring impacts will, with regard to stakeholder preferences, have to address whether proposed (and implemented) solutions are aligned with stakeholder preferences regarding both content and process.

We must assume that stakeholder expectations are quite varied, and may also be contradictory – at least from the outset. Even so, impacts must be compared to stakeholder expectations: are there systematic variations between some stakeholders expectations and actual results? Can we discern common traits between stakeholders that share positions on CC adaptation issues? Are burdens and benefits from CC adaptation solutions measures somewhat evenly distributed, or can we identify adaptation winners and losers, respectively?

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Role of partners and relevant stakeholders

The Tromsø city case involve approximately identified approximately 50 stakeholders all together. More stakeholders may be added at a later stage. The core stakeholder group are represented by the Municipal organization, and includes several departments such as the Planning Department, including Built Heritage, The Water Management Department, The Cultural Department and the Climate, Environment and Agricultural department, and the Harbour Authorities. Some politicians are also identified as stakeholders. They will play a particularly important role in the co-creation process, making the necessary political decisions, update their spatial plans and in reorganizing the Municipal organization to be able to handle climate change and sea-level rise.

Other stakeholder groups outside the municipal administration forms four categories:

A Urban developers and financial actors, such as construction companies, consultancy agencies such as architects, designers and engineers, banks and insurance companies, and land owners. The role of these actors will be to bring in hands-on experience and competence on urban development at the seafront, the challenges they addressed in their approach to the issue of climate change and sea level rise, and what type of solutions they find necessary at medium and long time perspective.

B S number of state agencies at different levels in the hierarchy with formal roles in municipal planning, such as the County council, the Sami Parliament, the Road Authoities, etc. These actors have all a say in planning processes at the local level and can put down veto in certain cases if a plan is in conflict with interesests of national or regional level. They also represent expert knowledge on numerous issues that might become important at some point.

C Civic society actors, such as voluntary organizations such as Neighborhood councils, the City Business association, The Forum for Arctic Urban Development, and environmental organizations. These actors will play different roles depending on their interests which covers local businesses, use of urban space, preservation og build heritage etc.

D Media actors, such as the two main newspapers in Tromsø, and the regional broadcasting agency. We will use these actors throughout the project period to promote the project and its development to the broader public.

Actions and timeline

As part of the timeframe set forth in figure 3-2 in the final Impetus project description (p.39), we will in the subcase of the Tromsø city case, arrange workshops, with certain stakeholder groups. The most important ones are:

- The planning department, Climate, Business and Agricultural Department & the water department in the municipality,
- A group from the building and construction industry and financial sector.
- A group of civic actors

Timeline:

Workshop 1: autumn 2022

Workshop 2: autumn 2023

Workshop 3: late spring 2024

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5.2.2 Digital twins to co-design a Marine Spatial Planning framework

Objective and challenge

A warmer and more acidic sea will change the living conditions in the marine environment and have significant consequences for fishing communities along the fjords and the whole coastal area of the Troms & Finnmark County, which is heavily dependent on aquaculture, traditional coastal fishing and marine fishing tourism. This will have implications for the entire food chain in the sea, leading to species migrating and farmed fish that may have poorer living and growth conditions. Global warming and subsequent changes in oceanographic variables such salinity, ocean circulation and mixing, and changes in sea levels, and changes in frequency of extreme events have strong influence on fish productivity, abundance and spatial-temporal distribution of fish stock, reproduction and disease, changes in aquatic habitat and change in site suitability for aquaculture. For fisheries-dependent communities such the effects of these changes can be dramatic. More rainfall and extreme weather will worsen these problems and increase physical and biological risk. Avalanches, rockfalls and landslides - whose frequency and dimension is increasing because of climate change (more rainfall/less snow, permafrost thawing, fracturing of rocks because of increased number of melting/infiltration/freezing/cracking events) – have already impacted on fisheries and aquaculture, either directly on ports and aquaculture facilities or by blocking transport routes which are essential for supplies and deliveries. Increased runoff from land will change the salinity in the fjords and increase the risk for browning of coastal water. It reduces the light penetration and thereby affect plankton composition. Increased rainfall and floods will also increase the risk of water pollution.

The Troms & Finnmark County has launched a Marine Spatial Planning action on its entire coastal area and on the related ocean shelf through the co-design of a coastal area Digital Twin. However, for demonstration purposes, the IMPETUS action area will use the magnifying glass in several areas, focusing on the analysis of the climate change-related impacts and the development and demonstration of a portfolio of resilience and adaptation solutions, of which the Resilience Knowledge Booster will be a key feature itself. In fact, it is primarily through continuous operational observations, monitoring, and forecasting that it is possible to take flexible Marine Spatial Planning decisions. Very detailed already available circulation and climate models will help to forecast the local impacts of climate change in the marine environment and other drivers and visualize different adaptation strategies and solutions' response. Solutions will also imply the flexible allocation and re-location of fishery and aquaculture zones and other marine activities, the design of Marine Protected Areas, strategies to respond to alien species invasion, and monitoring and control techniques to prevent toxic algal blooms. This will result in a more efficient marine environment protection, a more sustainable seafood production, and in more equitable economic development for the local society.

Technical description

The project will develop and demonstrate the transformation on date into smart 4D models and visualisations in GIS. In addition, the project will demonstrate the use of GIS with game engines, and how to establish direct access to GIS data and operations within a game engine. By this, we will take advantage of high-end graphics capabilities on modern devices and utilize hardware designed specifically to support extended reality (XR) experiences. These highly interactive, visually compelling, and deeply immersive applications will be tested as a way to increase engagement, improve understanding, and optimise the decision-making experiences and processes. These solutions, which include client applications that target specific workflow, require a photo-realistic experience driven by real-world data.

The Arctic Digital Twin will require data and models from various sources. The starting point is the existing data ecosystem in the county and our municipalities used for regional development and planning purposes. This data ecosystem will be expanded and enriched with all available sources of data relevant to marine spatial planning. In this respect, we will both work to develop more detailed and enriched data, as well as to increase their historical dimension. Further we will transform the data ecosystem to a nervous system by including and streaming real-time, or near real-time data. With respect to models, we will make use of a highly detailed coastal circulation model that have been developed in previous projects. In this project, the focus will be on using this model in the digital twin.

Potential barriers can be access to some data sources. Both in relation to ownership and sensitivity. Some data owned by the industry might be restricted due to commercially reasons, and some national data, for instance detailed seafloor data, might be restricted due to national security reasons.

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However, there is an ongoing collaboration between the state and the industry in the seafood industry where the main ambition is to realise the benefits of digitising and sharing data in the industry and between the industry and the government for management and planning purposes. Thus, a significant improvement in data access is therefore expected in a relatively short time. In addition, we will also connect, collaborate and participate in other relevant processes and projects related to the work on the Digital Twin of the Ocean and the Destination Earth Program.

Key Performance indicators, added value and replication potential

The key Performance indicators must reflect changes at special and temporal scale of relevance to marine spatial planning and what needs to be measured. As well as obvious environmental KPIs, we will also develop social-economic indicators and governance performance indicators. The details for this will be further developed in a collaboration with both management authorities on national, regional and local level, and other relevant stakeholders. In general, the KPIs shall both register the improvements in making better marine spatial plans in relation to more efficient coexistence, increased seafood production, and improved restoration and protection of the coastal ecosystem. Further, the KPIs will also register the changes in Marine Spatial Planning processes, both in terms of efficiency and co-creation. The first step in this process has started with developing a baseline on the current situation.

Together with the Digital Twin the baseline and the KPIs will really add value to the marine spatial planning processes. To bring in the complexity of the costal ecosystem and the the human and nonhuman interaction within it into a digital twin will create a place of digital co-creation, bringing together different disciplines, stakeholders and communities. Together with researchers we will be able to predict how climate change and human activity will affect the coastal areas and communities.

The replication potential for det digital twin developed for MSP is regarded as high. This applies not least to coastal regions who will develop the Climate-Smart MSP. We will present and demonstrate our digital twin to a number of coastal regions and nations across the Atlantic and in the Arctic that collaborate on MSP in general, and on Climate-Smart MSP in particular.

Role of partners and relevant stakeholders

The partners in Impetus will contribute with extensive experience and knowledge in their field of expertise. Together with our expertise in Marine Spatial Planning and our contextual knowledge we will together develop a state of the Art digital twin for MSP. In this connection, we will focus in particular on developing a digital twin that can convey understandable and actionable insight into the planning processes.

During the development of the digital twin we will make use and test the solutions in relation to our ongoing planning processes related to MSP in the county. These process have already a high degree of stakeholder involvement, but we will focus on expanding this so that we facilitate even wider participation and facilitate good co-creation processes. They will play a central role in testing and providing feedback on the practical use and usefulness of the digital twin during the project. In this way, we will be able to improve and strengthen its usefulness and relevance in action.

Actions and timeline

1. Stakeholder involvement
2. Develop KPIs and baseline
3. Enrich and detail our existing data ecosystem for MSP
4. Transform the data ecosystem into a nervous system for MSP
5. Develop the digital twin in a GIS-environment
6. Develop a data pipeline between the GIS-environment and the Gaming-environment
7. Adding climate models and What If scenarios
8. Test and demonstrate UX-solutions

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6 Boreal DS: Zemgale region, Latvia

6.1 Introduction and background

Zemgale Region is in the central part of Latvia in central part of the Zemgale Plain. The area covers 10 742 km^2 which is 16.6% of the territory of Latvia. Cities occupy 6% of the total territory of Zemgale Region. Zemgale region comprises five regional municipalities - Jelgava, Aizkraukle, Bauska, Dobele, Jekabpils and Jelgava City municipality (see Figure 6.1.).

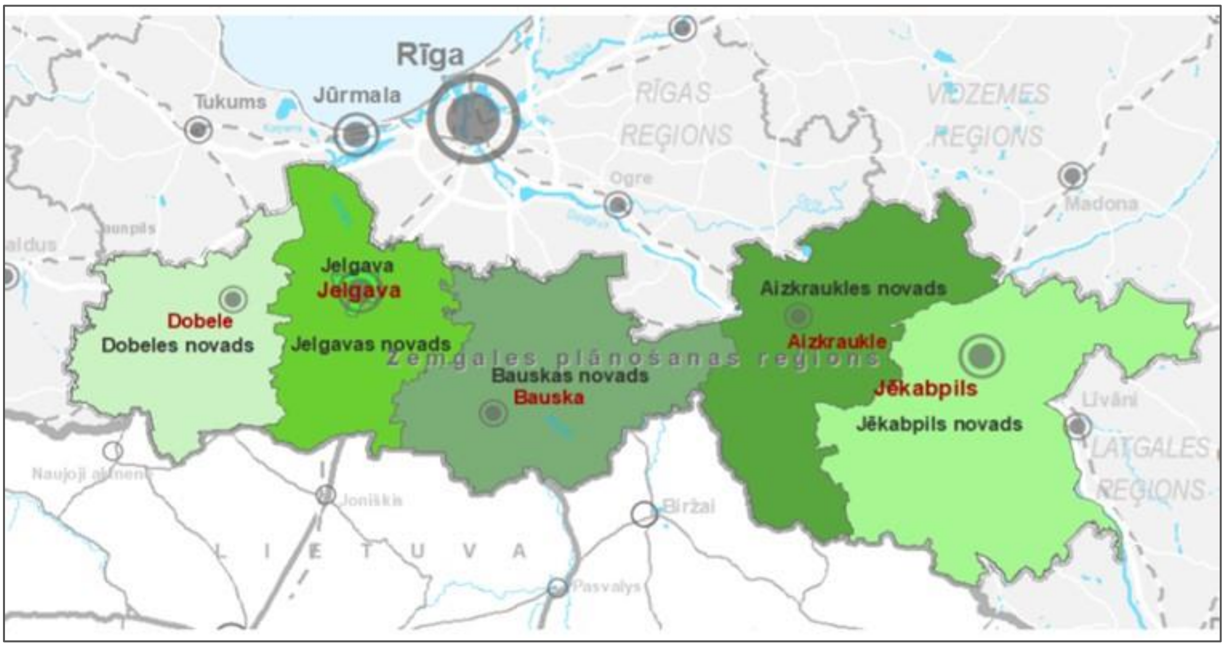

Figure 15. Administrative division of Zemgale region. Source: Zemgale Planning Region Administration

Zemgale is crossed by 2 major Latvian rivers: Daugava and Lielupe. Stocks of water resources are sufficient for economic activity and human consumption. The drinking water supply is ensured by a groundwater supply source. Lowland landscape in Zemgale Region is characterized by a flat terrain and a dense river network providing ecological corridors essential for biodiversity and recreational opportunities for people. At the same time, thanks to its fertile soils, this area has developed into an intensive agriculture land – the large-scale farming covers ca. 40% of the area. This has led to a severe decrease in biodiversity as well as pollution of water bodies, increasing flood risks and other environmental problems. Agricultural activities are well developed and focus on the cultivation of crops. During the last decade, the area of croplands has increased while meadows and pastures have been reduced putting pressure on grassland habitats. The region is characterised by high flooding risk potential including flooding from snowmelts, high precipitation and hydrotechnical infrastructure. In case of flood events, the flooding risks are associated with fast and high rise in water level thus causing risks to society, settlements, and infrastructure.

IMPETUS in Zemgale region will develop climate resilient innovation packages and adaptation pathways used for further policy and decision-making, raising awareness, enhancing behavioural change, and for the development of adaptation measures towards climate change. Implementation of activities at the demo-site are aimed to demonstrate:

- Development of a regional GIS-based communication system for exchange of information and real time analytical approach related to decision support and early warning in case of potential flood events to support flood risk management and civil protection in Zemgale Region.
- Up-scaling of the good practice management system at Jelgava City to the regional level by linking other cities within the region in one integrated system.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 101037084.

- Application of systems perspective to create a framework for turning away from the *ad hoc* activities to a systemic implementation approach in Zemgale Region by involving innovative multi-stakeholder and multidisciplinary co-creation Quintuple Helix stakeholders.
- Incorporation of knowledge on nature-based solutions (NBS), especially in relation to agriculture and forestry but also considering other key community systems (water and biodiversity) and tourism.
- Realisation of the innovative framework for enhancing ecosystem services and integration of NBS to increase the sustainability of agricultural practices, improve water quality and foster restoration of habitats.

Table 13 Solutions and related tasks

Solution	Task No	Task title	Bundle No	Bundle
Digital twins and advanced tools for climate adaptation	4.10.3	Multi-layer integrated flood risk management, Decision Support and Early Warning System for civil protection	2	Innovative technologies
Climate change adaptation governing plan	T4.24	Establishment of a Climate Change Adaptation Plan governing climate risk management	4	Governance Models, Awareness and behavioural change

6.2 Pre-requisites, design and concept for implementation

6.2.1 Digital twins and advanced tools for climate adaptation

Objective and challenge

Multi-layer integrated flood risk management, decision support and early warning system for civil protection **aims** at enhanced preparedness for flood risk management at Zemgale Region. Demonstration will be upscaled from city level (Jelgava City) to regional level through the involvement of stakeholders in co-creation processes to ensure multi-governance approach.

The **objective** of this task is to expand the early warning system to include artificial intelligence driven algorithms connected to national hydro-meteorological monitoring system and other databases. The upgraded data sets will be accessible as open data to experts and society. Such multi-layer system will ensure possibility to evaluate flooding risks prior the event and to provide public institutions and citizens with the necessary information package to select appropriate measures for effective protection of people, health, environment, economic activities.

The **challenge** for implementation is related to an update of the civil protection aspects, which calls for coordinated activities among the region cities and municipalities, the development of a multi-layer system to ensure possibility to evaluate flooding risks prior the event; and to provide public institutions and citizens with the necessary information package to select measures for effective protection and adaptation measures.

Technical description

State of art

Early warning system is currently operating in Jelgava city but requires much human operational intervention. Early warning service provides an easy way to receive the most important information about alerts, e.g., potential flooding, fire hazards, power cuts. Inhabitants receive warnings by SMS or email.

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Sub-system is intended for automatic creation of lists with the persons by using data sets from the State Land Service of Latvia and the Office of Citizenship and Migration Affairs, adding new data to the data sets using information available to Jelgava City municipality institution "Pilsētsaimniecība" (e.g., number of persons in a building which should be evacuated), for automatic sending out of the messages for whole list and creating reports for Civil Protection management.

Early warnings sub-system is linked with Jelgava City municipality Geographic Information System (GIS) using Oracle data base and desktop software "CADDGN" which provides data exchange between data sets from the State Land Service of Latvia and the Office of Citizenship and Migration Affairs. GIS also provides early warnings system with background maps using GIS application server Geomedia Smart Client. Background map content and updates are provided by Jelgava municipality specialists (Figures 6.2, 6.3).

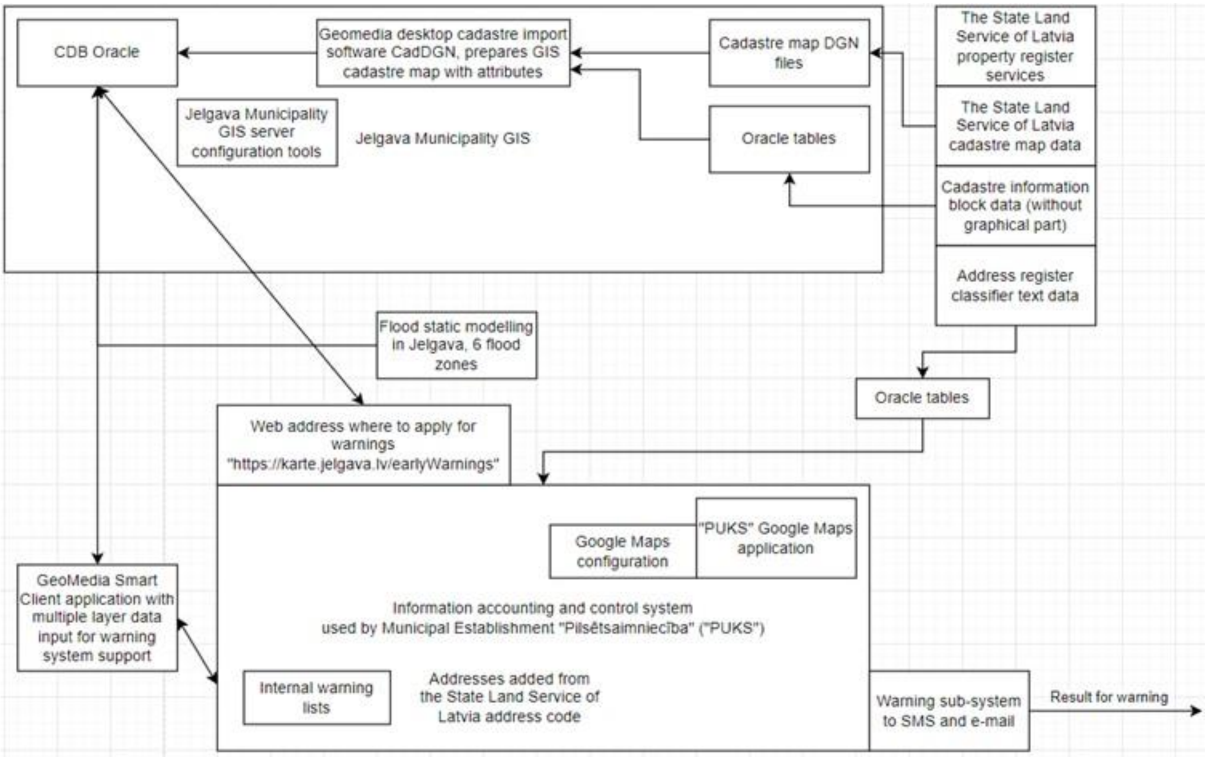

Figure 16. Scheme of early-warning sub-system in Jelgava City municipality

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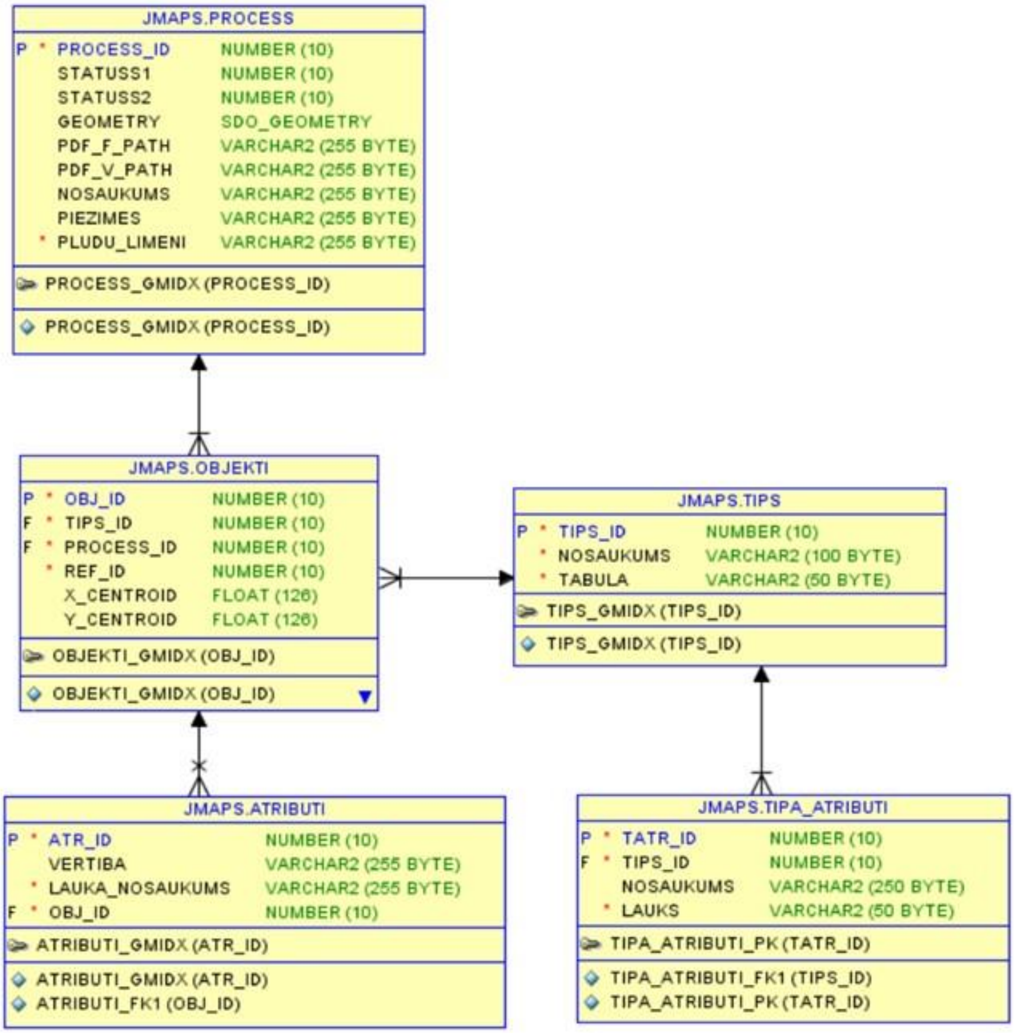

Figure 17. Data model diagram of early-warning sub-system in Jelgava City municipality

Data requirements and data & model availability

Decisions on the necessity to issue a warning are based on hydrological data. In Jelgava City such data are obtained from two hydrological stations of the national network (located on Lielupe river in Jelgava and on Svete river – tributary of Lielupe river) and from one municipality owned station in the city. Water level is measured using BAS-77 (Baltic Height System).

Upgrading of the early warning system will require hydrological data for other cities relevant, e.g., Jekabpils, Plavinas. Several hydrological stations of the national network are operational in these locations as well where data can be obtained (Figure 6.4.).

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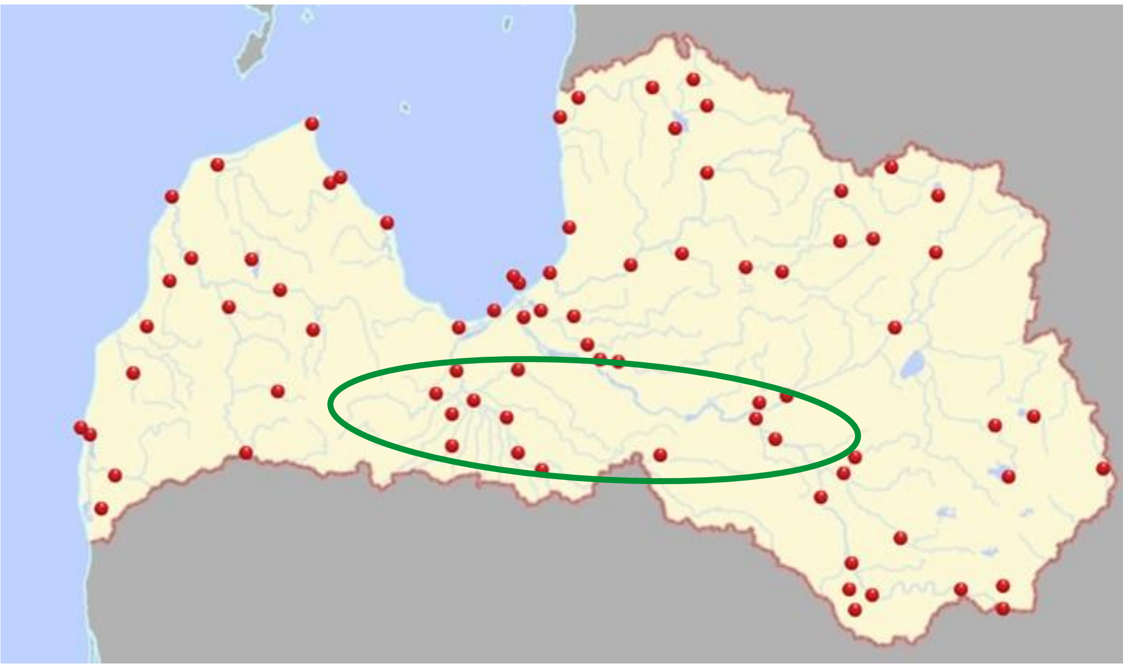

Figure 18: Network of National hydrological stations (stations in Zemgale region are highlighted). Source: https://www.meteo.lv/hidrologijas-operativa-informacija/?nid=464

Technology of the planned multi-layer integrated flood risk management, decision support and early warning system for civil protection in Zemgale Region will require application of several methods:

- **A regional GIS-based communication system** for exchange of information that is extended with a real time analytical approach integrating water level (monitoring and visual evaluation) measurements to build a decision support and early warning system to enhance flood risk management and civil protection in case of potential flood events in the Zemgale Region.
- Updating and upscaling **geospatial information for precise prediction using satellite data** (provided by LOB), as well as the **riverbed bathymetry data** and LIDAR or satellite **scanning of terrain**, as well as **topographic surveys**.
- Upscaling of existing Jelgava city **Interactive map** to a regional level. Interactive maps with layered flooding possibilities, embedded from the Latvian Geospatial Information Agency will be used for operative reporting. Early warning registry module for Early Warning System (EWS) will serve to provide information about potential flooding, and upscaling Jelgava City Unified Information Exchange System to a regional level. Linking the local/regional EWS module with the national monitoring system (operated by the State Limited Liability Company “Latvian Environment, Geology and Meteorology Centre”) for automated data exchange and use in civil protection and daily operations. Such multi-layer system will ensure possibility to evaluate flooding risks prior the event and to provide public institutions and citizens with the necessary information package to select appropriate measures for effective protection of people, health, environment, economic activities.

Potential barriers and drivers

For implementation of the IMPETUS task on multi-layer integrated flood risk management, decision support and early warning system for civil protection several potential barriers must be considered in areas of data availability, interest from municipalities concerned, suitable technical solutions and acceptance from the society. On the other hand, there are enabling factors (drivers) that enhance preparedness to flood risk management and provision of information to inhabitants (Table 2).

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Table 14 Potential barriers and drivers for implementation of the Task 4.10.3

Barriers & drivers	Description
Potential barriers	• Incomplete data sets – handling – to define tasks for experts for data collection to the full extent • Difficulties to convince local municipalities regarding data storage and/or payment for data storage, services, etc. – handling – targeted effort to reach an agreement on collaboration from municipalities • Lack of high-skilled experts to operate AI driven prediction system at municipalities – handling – supporting handbook is prepared and made available for municipalities • Issues with system dependence from the external data from different GIS-based sources – handling – ensuring appropriate data transfer and building on functioning technical solutions in Jelgava city. • Potential mistrust of local inhabitants towards received warnings from the early-warning system – handling – provide easily accessible evidence of flood related risks to stakeholders
Drivers	• Willingness of stakeholders to create comprehensive multi-layer system • Intentions and interest in enhancement of the flood risk management in the region • Availability of good practice examples on functioning technical solutions (digital twins) • Increasing awareness of stakeholders on climate change related flood risks and frequency of flood risk occurrence

Key Performance indicators, added value and replication potential

The key performance indicators in Zemgale region are related to outputs, outcomes, and impact from the IMPETUS solutions for development and application of multi-layer integrated flood risk management, Decision Support and Early Warning System for civil protection (Table 3).

Table 15: Key performance indicators related to output, outcome, impact

KPIs	Description	Value
Output indicators	Enhanced Early Warning System for the Jelgava City is in operation	1
	Elaborated Early Warning System with AI driven prediction for Zemgale is in operation	1
	Elaborated Digital twin and advanced tools for climate adaptation are in use	1
	Handbook for know-how to stakeholders is developed and available	1
	Municipalities having obtained and using the elaborated system	>2
Outcome indicators	Methods applied for enhanced preparedness to flood risk management for integrated and coordinated national and regional multi-layer Early Warning System related to flooding	6

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 101037084.

KPIs	Description	Value
	Training for municipalities to use information from the handbook thus increasing knowledge of local authorities to prevent and avert flooding risks and disasters	3
	Inhabitants are provided with early warning information on flood risks (% of inhabitants residing in flood risk areas)	100
Impact indicators	Enhanced public safety at flood risk events in Zemgale region due to elaborated Early Warning System	Y/N

Added value

Implementation of Decision Support and Early Warning System will bring an added value for Zemgale region:

- Improved planning of regional climate change resilience actions by integrated decision support system.
- Improved resilience of critical infrastructure, and households against flooding and other climate change related risks and impacts.

Replication potential:

- Multi-layer integrated flood risk management, decision support and Early Warning System for civil protection will be replicated from Jelgava city to regional level (Zemgale) at the same time connecting system to the national monitoring network.
- The provided AI driven prediction system's algorithms of the regional Early Warning System would have a high transfer potential for the similar systems in the IMPETUS and other EU regions.
- Experience gained and described in the Guidelines/Handbook for stakeholders where lessons learned will be presented can be replicated to other municipalities for operation of Early Warning System towards flood risk management.

Role of partners and relevant stakeholders

The project partner **Zemgale Planning region** (P27, ZPR) in cooperation with **Baltic Environmental Forum – Latvia** (P7, BEF) will take care for the relevant stakeholder and local authorities' (municipalities) involvement to ensure the coordination of the elaboration of the Early Warning System for civil protection by the mean of the external expertise. **Jelgava Municipal Operational Information Centre** (P28, JPOIC) will provide the existing technology's enhancement and ensure the know-how transfer for the upscaling Early Warning System in Jelgava city to the regional level. Stakeholder pool that will be involved in implementation of the task consists of the local municipalities of Zemgale region, State Ltd. "Latvian Environment, Geology and Meteorology Centre" being responsible for hydrometeorological monitoring in the country, research institutes and IT companies (quadruple helix approach).

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 101037084.

Actions and timeline

Table 16: Actions and timeline for elaboration of Early Warning System for civil protection in Zemgale Region.

Nr.	Actions for elaboration of Early Warning System	2022				2023				2024				2025		
		I - III	IV- VI	VII - IX	X-XII	I - III	IV- VI	VII - IX	X-XII	I - III	IV- VI	VII - IX	X-XII	I - III	IV- VI	VII - IX
Elaboration of Early Warning System for civil protection in Zemgale																
1	Stakeholder involvement: consultations, discussions, proposals, coordination.															
2	Existing technology investigation and transfer from Jelgava city for the further upscaling to the regional level															
3	Identification of the places for the new equipment establishment for the water level measurement equipment															
4	Identification of available data from national sources for the needs regional Early Warning System functionality															
5	Provision of the technical specification for the Early Warning System upgrade for Jelgava city (including measurement equipment)															
6	Provision of the technical specification for the regional Early Warning System functionality (including measurement equipment)															
7	Establishment of the water level measurement equipment															
8	Elaboration of the regional Early Warning System: elaboration of the algorithms for AI driven prediction system, IT infrastructure, application. (External expertise)															
9	Enhancement of the Jelgava city Early Warning System (External expertise)															
10	The elaborated Early the regional Warning System testing and troubleshooting															
Approval of the enhanced Early Warning System of Jelgava city by JPOIC																
Approval of the elaborated Warning System by ZPR																

6.2.2 Climate change adaptation governing plan

Objective and challenge

Zemgale Regional Climate Change Adaptation Plan **aims** to create the framework for turning away from the *ad hoc* activities to systemic implementation approach in analysing challenges and solutions, creating pathways for adaptation to the climate change and selection of the consequent strategy for making investments.

Objective is to apply tailored participatory planning approach for the stakeholder involvement from public, private and civic sectors to develop a shared vision and pathways for the climate change adaptation in the region. The planning aspects are relevant to the key community systems in Zemgale CS and cover cross-sectoral dimensions, e.g., agriculture, forestry, water, energy, environment, tourism, industry. Regional Climate Change Adaptation Plan shall reflect the adaptation needs of municipalities and sectors in Zemgale region.

The governing **challenge** manifests in potentially conflicting interests from various territorial units as municipalities implementing their own development plans and sectors striving for economic conditions.

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The regional planning approach shall ensure that appropriate solutions and actions for municipalities and sectors are selected and accepted to climate change adaptation. Applying of innovative tools will strengthen the cooperation of stakeholders on set of measures for climate change adaptation.

Technical description

State of art

Climate change related aspects have been highlighted and tackled in several policy documents elaborated for Zemgale region within the period of 2010 - 2020. The focus of these documents has been mainly on climate change mitigation aspects in relation to production and utilisation of renewable energy and increase of energy efficiency at various sectors.

The current policy documents for Zemgale region comprise **Zemgale Planning Region Sustainable Development Strategy 2015-2030** and **Zemgale Planning Region Energy Action Plan 2018-2025** where particular attention is paid towards green transport and alternative fuels. The most recent policy documents for Zemgale region are **Zemgale Region Mobility Plan 2021-2030** and **Zemgale Planning Region Development Program 2021-2027** being developed and approved in 2021.The Development program defines the green deal and climate change as horizontal priorities covering 9 key policy priorities defined in the program. Moreover, the priority 5 “Environment, Climate Change and the Circular Economy” is having the closest link to climate change related issues. Several activities are addressing both mitigation and adaptation to climate change. The aim of these actions is to ensure the sustainable and environmentally friendly management of resources particularly water resources. The envisaged actions include the development of municipal climate change adaptation strategies and the coordination of these strategies within the Zemgale region.

As the next step, it is planned to synchronize the regional planning documents in accordance with the national level documents e.g., the National Energy and Climate Plan for 2021-2030. It is planned to develop Energy and Climate Plan also for Zemgale region. Zemgale Region Climate Change Adaptation Plan to be developed within the frame of IMPETUS project is supposed to become a key element of this envisaged document. Based on stakeholders needs and proposals, it will cover a number of areas in the field of climate change both municipalities and businesses sector are concerned about e.g., green infrastructure, flood risk management, energy, agriculture, tourism, environment and nature protection and many other issues.

Data requirements and data & model availability

Development of the Regional Climate Change Adaptation Plan in Zemgale region will build on background data related to the climate change and socio-economic development projections:

- Assessment on *status quo* in sectoral dimensions e.g., agriculture, forestry, water, energy, environment, tourism, industry. Data sources for the desk research will be used from both, the national statistics (Central Statistical Bureau of Latvia) and research reports (e.g., Latvia University of Life Sciences and Technologies, State Ltd. "Latvian Environment, Geology and Meteorology Centre") with further downscaling to the regional level, and from the local municipalities with further upgrading to the regional level.
- Assessment of the key climate change risks in Zemgale region will be based on expert knowledge and judgement from respective stakeholders. This assessment will form basis for the content blocks of the Plan.
- Data on projections for socio-economic development in Zemgale region, climate change and the related risk factors in specific areas will be obtained by targeted research assignments.
- Addressing cross-sectoral dimensions, e.g., agriculture, forestry, water, energy, environment, tourism, industry in a view of climate change perspective will be performed by applying complexity science approach utilising experiences from Horizon2020 projects SIM4NEXUS (https://sim4nexus.eu/) and NEXOGENESIS (https://nexogenesis.eu/).

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Potential barriers and drivers

Table 17: Potential barriers and drivers for implementation of the Task 4.24

Barriers & drivers	Description
Potential barriers	• Compatibility of data from various sources due to different data collection methods and scales – handling – data processing, upscaling/downscaling and use of expert judgement • Unwillingness of stakeholders to actively engage – handling - inclusive stakeholder engagement methods will be applied • Contradicting business and nature conservation interests may hinder agreement on measures and solutions for climate change adaptation – handling – demonstration of opportunities and benefits from complementary solutions
Drivers	• Climate change adaptation policy objectives at the EU, national and regional level (strategies, action plans) • Increasing awareness related to environmental concerns as a market driver from consumers and government for the adoption of sustainable and environmentally friendly solutions • Support schemes for investments at municipalities require inclusion of climate change adaptation aspects

Key Performance indicators, added value and replication potential

Table 18: Key performance indicators related to output, outcome, impact related to elaboration of Regional Climate Change Adaptation Plan

KPIs	Description	Value
Output indicators	Developed regional Plan on adaptation to climate change	1
	Meetings and other events with stakeholders at the demo site	4
	Lessons-learned report on stakeholder involvement in demo site	1
Outcome indicators	Regional community has adopted a pathway for climate change adaptation reflected in the Plan	1
	Accepted solutions for climate change adaptation reflected in the Plan	10
	Stakeholder groups involved in co-creation activities for elaboration of set of measures for climate change adaptation thus strengthening the cooperation in the region	10
Impact indicators	Systemic approach and cross-sectoral dimensions for adaptation to climate change is taken up in strategic planning documents of the Region	Y/N

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Added value

- Demonstrated applicability of participatory decision support system to planning of climate change resilience.
- Inclusion of economic impact of physical climate risk into policy-makers decision-processes.

Replication potential

- Innovation driven solutions for the climate adaptation can be transferred to stakeholders at the Boreal Region.
- Approach to tailored participatory planning and stakeholder involvement from public, private and civic sectors to develop a shared vision and pathways for the climate change adaptation can be transferred to other regions in the Baltic States.

Role of partners and relevant stakeholders

Elaboration of the Zemgale Region Climate Change Adaptation Plan (Plan) will be organised in a close cooperation between the project partners **Zemgale Planning region** (P27, ZPR) and **Baltic Environmental Forum – Latvia** (P7, BEF) forming a core group for coordination and implementation of this activity (desk research, information, data collection and analyses, organisation of stakeholder involvement, dissemination of activities through social media). Within the project duration regular internal meetings (remote, face-to-face) will be organised to discuss the goals and tasks to be performed, to reflect on achieved progress and to plan further activities. Consultations with **Jelgava Municipal Operational Information Centre** (P28, JPOIC) are envisaged particularly for incorporation of the activities related to Zemgale regional flood risk forecasting and early warning system in the Plan.

In the course of preparation of the Plan several stakeholder groups are planned to be involved. The key stakeholder groups are **municipalities** of Zemgale region (5 regional municipalities - Jelgava, Aizkraukle, Bauska, Dobele, Jekabpils and Jelgava City municipality), various **economic sectors** from the key community systems - agriculture, forestry, water, energy, environment, tourism, industry as well as several **non-governmental organisations** representing society interests in the fields of nature and environment protection, human health and society welfare etc. These stakeholder groups will be actively involved to create a common vision of the Plan, define the goals and objectives as well as set priority areas and define priority activities to be implemented in the region.

Several institutions playing a role in climate change adaptation in Latvia will be consulted during elaboration of Zemgale Region Climate Change Adaptation Plan: the **Ministry of Environmental Protection and Regional Development** (responsible for climate policy development in Latvia and having elaborated the National Strategy for Adaptation to Climate Change 2030 and the National Plan for Adaptation to Climate Change until 2030), State Ltd. **"Latvian Environment, Geology and Meteorology Centre"** (responsible for developing of climate monitoring, modelling, projections and scenarios in Latvia). **Research institutes** and **insurance companies** will be approached to support elaboration of Zemgale Region Climate Change Adaptation Plan in the course of performance of the risk assessment and while carrying out in-depth studies in particular areas to be specified.

The involvement of the **society** is envisaged during the development course of Plan – press releases to inform the society about elaboration of the plan and its progress. A public hearing ensuring the opportunity for the society to express opinions and provide comments to the draft Plan will be organised.

Actions and timeline

It is planned that the development of Zemgale Region Climate Change Adaptation Plan will start in March 2022 and will be finalised (final draft prepared) by the end of 2023. The envisaged activities comprise e.g., desk-research on *status quo*, identification of the key climate change related risks, analysis of socio-economic development of the region, risk assessment, SWOT analyses, definition of priority activities. Several stakeholder meetings (distant, face-to-face) are envisaged in the course of preparation of the Plan (the first meeting with stakeholders will be held in April 2022). After the public hearing at the beginning of 2024, the Plan shall be adopted by the Regional Council representing the municipalities of Zemgale region until the end of 2024. Dissemination of the results and solutions to other planning regions in Latvia will take place in 2025 (Table 19).

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Table 19: Actions and timeline for preparation of Zemgale Region Climate Change Adaptation Plan

Nr.	Actions for preparation of the Plan	2022				2023				2024				2025		
		I - III	IV- VI	VII - IX	X-XII	I - III	IV- VI	VII - IX	X-XII	I - III	IV- VI	VII - IX	X-XII	I - III	IV- VI	VII - IX
Elaboration of the Plan																
1	Desk research on status quo (preparation)															
2	Identification of key climate change related risks															
3	Prognoses on socio-economic development															
4	Risk assessment (study)															
5	SWOT and other analyses															
6	Definition of priority actions															
7	Write up of the plan															
8	Stakeholder involvement		05.04 wsh		Prognoses		SWOT	Actions		Public hearing						
Approval of the Plan by ZPR																
Dissemination of the Plan																

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 101037084.

7 Mountain DS: Valle dei Laghi, Italy

7.1 Introduction and background

Status quo

The Valle dei Laghi area is located in the Autonomous Province of Trento (PAT), within the Italian Alps. PAT territory is entirely mountainous and, like many mountain regions, consists of a mosaic of valleys of different sizes. It is highly fragmented also at administrative level: the population (about 542.700 inhabitants in 2019) lives in 166 municipalities, the majority of which falls below 5.000 inhabitants. Few cities are found in the most easily accessible and better communicated valleys, the rest of the population lives in small villages in more marginal valleys, almost entirely relying on cities for services to their residents. Based on the above elements, quite typical of European mountains, the valley was chosen as the functional bio-geographical unit for the IMPETUS project demonstration, to allow the easier replication of the project results.

Valle dei Laghi comprises three municipalities: Cavedine, Madruzzo and Vallelaghi (surface 140 km2; population density: 78 inhabitants per km2). The agricultural sector is of primary relevance: the most relevant productions are grapes, apples and vegetables. Grapes, used to produce widely appreciated sparkling wines, are of very high quality and economic value. In the last decades, the number of farms has significantly decreased, and the land abandonment rate has been rather high. Today most farms are small (80% below 5 hectares), nevertheless, full time farming is very common, as permanent cultivations (essentially vineyards) dominate. Instead, grassland farming suffers significant decline. As the valley includes many forested areas, forestry for wood fuel is widespread. Some elevated areas are devoted to pasture. Electricity production from hydropower is very relevant: the biggest plant has a nominal installed power of 350 MW, but several mini/micro hydro systems have also been deployed recently. The provincial economy heavily relies on winter ski tourism. However, in Valle dei Laghi, this has limited relevance, while slow tourism (strongly linked to local food, typical wine and outdoor activities) is growing. The climate of the valley is very diverse, going from sub-Mediterranean to Alpine features, and so are natural and agricultural ecosystems. Water is rather abundant: many small lakes and a river are present. Water plays a key role in the main economic activities: agriculture, forestry, renewable energy production and tourism.

Challenges

Being the Alps (and mountains in general) recognized hotspots for climate change and rising temperatures far beyond the average. As the impacts of the latter are intensifying, conflicts between the concurrent uses of the water resource (irrigation, hydropower exploitation, ecosystem needs, drinking water) are worsening. During summertime, competition between irrigation and hydropower production is already occurring. The altitudinal shift of areas compatible with vineyard cultivation will not only raise the need for optimizing irrigation and for new concessions, but also give origin to conflicts between land uses, such as agriculture, woodland and pasture. Shifting from woodland to cultivated surfaces will lead to increased hydro-geomorphological risks, in a territory which is by nature already particularly prone to natural hazards. Further land use conflicts are already in place, e.g. those between agricultural land and flood retention areas, and those between rearing and touristic exploitation (due to manure spreading). Rapid climate change impacts will lead in the future to the exacerbation of the already existing conflicts in water and land use described above.

Under this scenario, innovative policies are urgently required to manage such conflicts. New adaptation solutions, defined through participatory approaches engaging local population and stakeholders, must be implemented to ensure a rapid transition towards a sustainable and integrated approach to the management of the water resource under the WEFE (water-energy-food-ecosystems) nexus framework, as well as to pursue ecosystems balance for biodiversity conservation and disaster risk prevention and reduction.

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To achieve this, strict synergy with the Provincial Strategy for Sustainable Development - SproSS[1] (currently under definition) and with the Provincial Strategy for Climate Change Adaptation (whose development just started) is needed. The demonstration of the IMPETUS innovation packages will represent a unique opportunity for the PAT to identify and upscale effective innovative solutions to address both sustainability and climate resilience. The strong support to the project by the Bio-district Valle dei Laghi[2], a well-established cross cutting association bringing together local farmers, wineries, municipalities, economic operators in the touristic sector and others (>100 members), will facilitate engaging local stakeholders and achieving the ownership of the adaptation solutions by the community.

Table 20 Solutions and related tasks

Solution	Task No	Task title	Bundle No	Bundle
Decision Support System for hydrological forecasts	T4.7.2	Decision Support System integrating multiple information layers for the sustainable and integrated management of regional water resource	2	Innovative technologies
Innovative insurance products for agriculture, forestry, hydropower energy production	T4.14	Development of innovative insurance products for agriculture, forestry and hydropower energy production	3	Finance and Insurance
Implemented bio-districts to address altitudinal shifts of crop	T4.17	Implementing bio-districts to address altitudinal shifts of crops	4	Governance Models, Awareness and behavioural change
Activated cultural heritage to enhance climate resilience: win-win solutions for historic buildings to combine climate change adaptation and mitigation	T4.21	Activating Cultural Heritage to enhance climate resilience	4	Governance Models, Awareness and behavioural change
Improvement of risk management practices through the application of participatory approaches (Impact Chains and Rapid Risk management Appraisal)	T4.23	Improving integrated climate risk assessment and management through innovative participatory approaches	4	Governance Models, Awareness and behavioural change

[1] SproSS preliminary document available at: https://agenda2030.provincia.tn.it/content/download/4864/51148/file/Documento%20preliminare%20SProSS.pdf

[2] The Biodstrict Valle dei Laghi was founded in 2009 with the aim of promoting organic farming and agro-ecology practices in the area. It brings together a wide network of local socio-economic stakeholders from the agriculture and tourism sectors, as well as from the local governance level, with a strong focus on the sustainable development of the local communities through engagement and participation.

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7.2 Pre-requisites, design and concept for implementation

7.2.1 Decision Support System for hydrological forecasts

Objective and challenge

In the Mountain demo site, a participatory Decision Support System (DSS) will be developed for the sustainable and integrated management of the water resource under concurrent uses, inside the framework of the WEFE (water-energy-food-ecosystems) nexus approach. The DSS will exploit the regional Resilience Knowledge Booster and will be fed by tailored hydrological impact models, aiming at properly downscaling the following climatic datasets to the complex mountain morphology: (i) seasonal-scale operational forecasts, accounting for climate variability and (ii) decadal climate change projections. Proper hydrological models will be used, exploiting in-situ and satellite data, seasonal forecasts, and climate projections, provided by Copernicus and GEO Mountains platforms. Tools such as Machine Learning and Multi-Criteria Analysis will serve the DSS for an integrated medium-term usage plan of the water resource. This will be fully informed by projected decadal trends, allowing the design of longer-term management strategies concerning smart irrigation, flood risk alert, operation of water levels in hydropower reservoirs for energy production in small and large plants, flood control and ecosystem protection.

Technical description

State of art

Meteorological data represent the fundamental input for the determination of hydrological outflows in seasonal and climate projections. For these analyses, three types of data described here are used:

- Historical data obtained from in situ stations: these data are needed to downscale the forecast data properly. Downscaling models are necessary to improve the spatial resolution of the forecast data and should be trained using data from ground-based observations, so that local meteorological phenomena can be taken into account, which are very important in a mountain context;
- Seasonal forecast data: seasonal data provide information on the main meteorological variables with a time horizon of a few months considering global climatic conditions. The forecasts are simulated by different Meteorological Centers (like ECMWF, Meteofrance, etc.) that use different models by varying the initial condition of the different simulations to obtain ensembles that can be used for statistical analyses;
- Climate projection: these data provide climate projections based on the different Representative Concentration Pathway (RCP) emission scenarios. Various models and simulations are available to define ensembles and perform statistically based analyses on the information returned by the models.
- Simulations of forecasting models are typically also carried out in the past (reconstruction period) to train the downscaling algorithms by testing the goodness of the simulation with observations, in order to eliminate bias errors.

The hydrological model transforms the meteorological forcing into runoff (outflows) in the river sections of interest. The selected model is called NewAge (Formetta et al., 2011). It is an open-source semi-distributed model consisting of several modules to reproduce specific physical processes, like snow accumulation, evapotranspiration, infiltration and rainfall-runoff. The model requires in input also the geometry of the river basin, in order to subdivide the basin into sub-basins that will eventually become the calculation grid. The sub-basin will be extracted according to geomorphological analysis starting from the Digital Elevation Model (DEM). The model uses this information together with precipitation, snow melt and evapotranspiration to simulate the river discharge at the points of interest in the network. It is based on the object modelling framework (OMS version 3) that allows the creation of independent packages of software which can be connected at run-time in a working modelling solution. The behavior of each of the sub-basins is then simulated, also considering the contribution lost due to evapotranspiration. In mountainous contexts, runoff generation is also influenced by snowmelt. NewAge has a component to simulate this contribution by using the meteorological data of temperature and total precipitation to reconstruct the seasonal snowmelt pattern in the basin.

Both modules described require a calibration phase to define the values of the model parameters. Data from hydrometers or flow data reconstructed from reservoir balances are used for flow calibration. For

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the snow component, the calibration can be done directly on the total runoff (calibrating both snow and liquid rain contributions). In case this calibration is not satisfactory, it is possible to use the distributed model GEOtop (Endrizzi et al. 2014) for the generation of a simulation of the snow evolution within the basin to be used as calibration data for the snow module of NewAge. GEOtop is a physically based hydrological model capable of calculating the snow depth and snow water equivalent evolution solving mass and energy balances. It is already operating on the Alpine domain, so the results of this model can be used to calibrate the snow module of NewAge. For snow simulation, satellite data are assimilated within GEOtop because they provide information on the area of snow cover that can be used to improve the spatial interpolation of the simulation.

Machine learning algorithms (Ridge, Prophet, LSTM, etc.) are used to help models perform better especially in complex and/or highly anthropic contexts. Algorithms can generate input data for the models or use the results of the models to improve them and bring them closer to the target. Specific Python libraries are used for algorithm management and feature engineering procedures that allow the best selection of variables to be used without running into problems such as overfitting (situations where algorithms tend to over-represent the test case but cannot be used outside that test case because they cannot represent anything else).

In the modelling of runoff, the presence of hydraulic works within the basins, such as dams, intakes and conduits, is considered, typically modifying the calibration targets following specific analyses of hydrological balances or hydraulic patterns. These analyses allow to obtain natural targets on which to calibrate the models. In order to add the anthropogenic forecasting component, regression techniques or forecasting models (e.g. water demand) can be used to simulate the forecasts of anthropogenic operations alongside the natural ones.

Development of the Digital Twin

The technologies described in the previous paragraph will be improved and interconnected in order to obtain a digital copy (Digital Twin) of the watershed that can provide information on forecasts considering all the hydrological and anthropic characteristics of the basin. The Digital Twin will be developed with a modular infrastructure in order to achieve greater robustness and ease of management of the different components and also to easily replicate the solution in other contexts. Digital Twin will be supported by a user interface providing the necessary information to the user. The information and the structure of this interface will be discussed with the stakeholders involved in order to build an immediate and useful interface for the end user. The combination of the Digital Twin and the user interface will provide the stakeholder with a Decision Support System with which to properly manage the water resource.

Table 21: Data requirements and data & model availability

Info/data needed	***Possible sources***
Seasonal forecast	Copernicus Climate Data Store[1]
Climate projections – CMIP5/CMIP6	Copernicus Climate Data Store
Historical meteorological data	Collected by MobyGIS in its database
Existing infrastructures for water management	Local Hydropower Companies, Autonomous Province of Trento
Hydropower energy production	Local Hydropower Companies
Hydropower plants timeseries of reservoir levels, turbined flow, intake	Local Hydropower Companies
Digital Elevation Model (DEM)	Sentinel Hub[2], Geobrowser of the Autonomous Province of Trento[3]
Satellite data	Sentinel Hub
Environmental-economic-political constraints	Provincial General Plan for the Use of Public Waters – PGUAP
Land cover	Copernicus Land Monitoring Service[4]

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Water demand and supply	Pre-existing hydrological relationships, PGUAP, interaction with local communities

[1] https://cds.climate.copernicus.eu/#!/home
[2] https://www.sentinel-hub.com/
[3] http://www.territorio.provincia.tn.it/portal/server.pt/community/portale_geocartografico_trentino/254
[4] https://land.copernicus.eu/

Potential barriers and drivers

In order to correctly simulate the distribution of water resources within the basin, it is essential to be able to reconstruct with adequate accuracy the human interactions present. In particular, this refers to hydroelectric plants in the area and agricultural uses that create mass movements and hydraulic breaks that interrupt the natural flow in the system. It will be important to obtain a good amount of data and of good quality (e.g. reservoirs level, turbined flow rate, withdrawals, etc.) in order to adequately simulate these operations within the basin. However, these data are not always easy to obtain for the following reasons: they are not acquired because they are not used directly in the planning of the managers' activities; they are few and of poor quality; they are proprietary and confidential. It will be important to interact with the operators present in order to obtain the best information available.

Key Performance indicators, added value and replication potential

How to measure impacts reached by demonstrating/implementing solution

A list of KPIs to be assessed to evaluate the impacts of the proposed solution is included below:

- Performance: the performance of the solution in adequately identifying changes in forecast climate trends compared to the methodologies currently used by the user will be evaluated. The performance evaluation parameter is variable depending on the type of user. For hydropower companies, the evaluation can be done considering the gain obtained from the management of the resource by comparing the use of current techniques and the proposed solution. For agricultural use, the evaluation can consider the gain from improved crop management using the support provided by the proposed solution.
- Cost: cost of performing the same type of analysis with state of the art technologies and with Impetus.
- Accuracy: the accuracy of the results provided in correctly simulating climate change trends and extreme events will be assessed against the baseline currently used by the stakeholder.

How to include stakeholders' expectations

Stakeholders interested in this DSS will be involved during the development phases of the solution through questionnaires and meetings. In this way, it will be possible to receive feedback from the direct users of the solution and make any changes in time to provide a service with the functionality and the performance required by the user.

Role of partners and relevant stakeholders

The main tasks to be carried out by EURAC and MobyGIS for the creation of the DSS concern the design of adequate models for the simulation of the study basin and capable of providing information for decision support. The main operations are described below:

- Collection and processing of meteorological data needed for historical and forecast analyses.
- Collection and processing of data on plants, man-made works and uses in the basin.
- Collection and processing of data and development of a spatial-based methodology to develop different scenarios of water demand by local socio-economic-environmental-cultural sectors using the WEFE nexus approach, at different temporal resolutions as affected by changes in climate.
- Analysis of correlation between water change scenarios and land-use changes or land-cover issues.
- Statistical processing of projected weather analysis by analyzing different available scenarios (typically RCP 2.6 and RCP 8.5).

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- Historical reconstruction of outflows in the basin by developing a hydrological model that considers all the forcing factors involved and the anthropic characterization of the area. The same model can then be used to make forecasts and projections.
- Development of demand and supply forecast models to complement the hydrological model.
- Development of a user-friendly interface allowing the visualization of results and providing information for decision support.
- Development of modules/tools in the DSS to carry out risk analyses for floods or droughts.

These operations are aimed at providing a support service that can enable analyze how existing infrastructures for water management (reservoirs, channels, etc.) can be used in emergency situations to increase local resilience. The development will consider the need for a component model that is easy to manage and easily scalable and applicable in other regions.

One of the central points of the interaction with stakeholders concerns the definition of a baseline necessary to be able to quantify the improvements made by this project. In order to define this baseline, it is necessary to understand together with the stakeholders involved: a) how they make climatic/weather forecast at the state of the art and which predictor they use (e.g. historical mean); b) the dataset expected as inputs in their decision-making system (e.g., average/maximum temperature, monthly precipitation, etc.). Then the partners will figure out how to develop the information content for the stakeholders.

Relevant stakeholders

Stakeholders who may be interested in the proposed solution are those who use water in their activities and need careful planning of water use. Agricultural users could use the service to improve planning of irrigation and crop production activities by implementing operations to counteract extreme events that may damage crops. Public agencies could use this DSS to better deal, in case of water conflict, a possible solution when multiple stakeholders are present, by simply providing evidence of the impact of each choice and highlighting the benefits. In general, stakeholders who use water in their activities can benefit from this solution to improve their planning activities and become more resilient against extreme events and climate change.

Actions and timeline

The actions to be taken for the development of the described solution include:

1. Data collection and processing: the collection of the necessary data for the DSS development, from different platforms, and their processing (e.g. downscaling, timeseries analysis etc..) to analyse their consistency and make them readable for the models used. The interface with the local authorities for the collection of their data and for the understanding of the anthropogenic operations in the basin. *[M7-M11]*
2. Geomorphological analysis: geomorphological extraction of the study basin and the preparation of a GIS project to include all the information, also those related to the hydraulic works present. *[M12-M14]*
3. Hydrological modelling of historical period: execution of hydrological balances by subdividing the basin into smaller units, depending on the hydraulic works that interrupt the hydrological continuity, to verify the consistency of the data and the full understanding of the phenomena within the basin, calibration of the physical models used and the validation of the results obtained over the historical period. *[M15-M20]*
4. Forecast analysis: validation of the seasonal products over the historical period to verify the performance of the forecasts in correctly identifying the meteorological trends, climatological analysis in projection analysing the anomalies found by the different models and the climatic trends highlighted, validation of the climatic projections over the historical period to verify their performance, implementation of machine learning models to improve the modelling results, development of socio-economic-environmental-cultural models to evaluate phenomena that can involve the stakeholder activities (e.g. forecast water demand model). *[M21-M25]*
5. DSS interface: development of the end user interface. *[M26-M30]*
6. DSS delivery and test: interaction with stakeholders to obtain feedback from them and possibly improve DSS functions. *[M31-M42]*

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In all phases, the principle of component-based development of the various operations to be performed will be followed in order to achieve a modular infrastructure that is easy to manage.

References

Formetta G., R. Mantilla, S. Franceschi, A. Antonello e R. Rigon (2011), The JGrass-NewAge system for forecasting and managing the hydrological budgets at the basin scale: models of flow generation and propagation/routing. Geoscientific Model Development, 4, 943–955, 2011. https://doi.org/10.5194/gmd-4-943-2011

Endrizzi, S., Gruber, S., Dall'Amico, M., and Rigon, R. (2014). Geotop 2.0: simulating the combined energy and water balance at and below the land surface accounting for soil freezing, snow cover and terrain effects. Geoscientific Model Development, 7, 2831–2857, 2014. https://doi.org/10.5194/gmd-7-2831-2014

7.2.2 Innovative insurance products for agriculture, forestry and hydropower energy production

Objective and challenge

Parametric or index-based insurance products (offering pre-specified pay-outs on the basis of triggering events) as passive protection measures or sustainable financing instruments to invest in active protections (hail nets, drip or top crown irrigation) will be designed and tested in the Mountains demo site for protecting agricultural crop yields, forest stands, hydropower energy plants (especially small systems) against climate-related economic losses. As stakeholders, experts from agricultural insurance consortia and from ethical banking will be involved. The design of insurance and financing models will be supported by tailor-made climate-risk assessment tools which will exploit existing data platforms providing seasonal forecasts and climate projections (e.g., Copernicus, Geo Mountains), enriched by local-scale data, and impact models. They will allow economic evaluations based on the assessment of future return periods for adverse climate events (such as hail, storms, floods, droughts, forest fires, etc.).

Technical description

State of art

Distinguishing between active prevention (e.g., anti-hail nets) and passive prevention (insurance schemes), and between parametric (likelihood of adverse events calculated on specific indicators) and non-parametric (damage assessment based on previous events occurred in the past years).

- Parametric insurance, overview of payments mechanisms in other sectors (forestry, livestock etc.) as well as in agriculture, tourism, hydropower.
- Climate affects weather, which in turns generates the damage (connected to the life cycle of the crop).

Table 22 Data requirements and data & model availability

Info/data needed	***Possible sources***
Economic assessment metrics, future return periods for adverse climate events, current insurance products for different sectors, impact data (loss and damage)	Interviews with financial experts (Cassa Rurale Alto Garda) and with farmers/consortia (CoDiPra Trentino-AA) subscribed to insurance schemas, ISMEA datasets[1], ITAS

[1] https://www.ismea.it/flex/cm/pages/ServeBLOB.php/L/IT/IDPagina/11324

Potential barriers and drivers

Barriers: the collective insurance system is entrenched in the current practices: thus, it makes even more difficult to change insurance plans; size of farms in DS is quite small, for that reason farmers themselves are more prone to resort to collective insurance systems.

Drivers: shifts in the weather patterns hit the life cycle of a crop at different stages, with different degrees of damage involved (multi-faceted and interconnected phenomena: e.g., floods increase the risk of

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landslide etc.). This will force farmers to increasingly rely on new insurance schemes adapted to such shifts. Active measurements to prevent the yield from catastrophic events may not be sufficient anymore (many techniques or technologies in this regard can be costly): need for integration with insurance systems. The invasive species threatening the yield is also a potential driver for farmers to adopt insurance policies.

Key Performance indicators, added value and replication potential

How to measure impacts reached by demonstrating/implementing solution

- Number and type of insurance schemes in agriculture, hydroelectric production, and touristic sector; identify the potential existence of local most-used schemes vs other insurance practices in the alpine areas (Italy and foreign Countries).
- Altimetric parameters: terrain slope and light exposure.
- Mapping the type of soil in relation to altitude.
- Type of harvest and its yield value.
- Current maintenance costs.
- Average size of farms/vineyards/fields.
- % of how the soil is used (agricultural activities, waterways, urban areas, farmland…).
- Weather indicators (n. of days with/without precipitations, n. of frosty nights and their monthly frequency).
- Yearly % of yield lost due to biotic and abiotic damage.
- Relation between the occurrence of the hazard and the value of the yield.
- (Differentiate between the types of hazards and their related negative effect/damage).

Role of partners and relevant stakeholders

Eurac, Cantina Toblino, and BIM Consortium will:

- Test different insurance approaches (classical, parametric, etc.), using data already collected and developed by the local partners, e.g. on drought insurance contracts for grassland.
- Think about other climate hazards (forest fire, hail, flood, etc.) and/or other land use.
- Discuss with stakeholders about different impacts -> develop the solutions -> go back to them offering tailored insurance contracts.
- Passive protection tool + active solutions.
- Assess the use of insurance as an adaptation strategy and then in case develop something new.
- Design different risk profiles tailored to local socio-economic-environmental-cultural sectors.

Relevant stakeholders

- Cassa Rurale Alto Garda Rovereto (local bank).
- CoDiPrA (consorzi difesa produttori agricoli – farmers consortium) and CAA (Centri di Assistenza Agricola – agricoltural support services).
- Energy industries and utilities (Hydro Dolomiti Energia, Trentino Acque, AGS, Novareti, ASM Tione, GEAS).
- ITAS Assicurazioni (assurance company).
- South Tyrolean Hail Consortium (*Hagelkonsortium*).

Actions and timeline

1. Comparison between parametric vs non-parametric insurance products (data collection for mapping existing insurance schemes, including active solutions). *[M7-M13]*

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2. Set up consistent risk assessment framework, understanding where residual risk is significant + check where insurance seems the most appropriate instrument, understanding what needs to be insured (e.g. sectors with economic importance that can be influenced by climate change). *[M13-M24]*
3. Develop the model to forecast the expected losses. *[M24-M42]*
4. Identification of most relevant indicators. *[periodically from M7 to M35]*
5. Periodic feedback (e.g. interviews, focus groups, etc.) and assessment analysis with observers and stakeholders (South Tyrolean/Trentino Hail Consortium, ITAS, etc.) + on-site visits. *[periodically from M9 to M42]*

7.2.3 Implemented bio-districts to address altitudinal shifts of crops

Objective and challenge

Organic agriculture practices, alternative varieties' cultivation and engagement of socio-economic stakeholders & local community will be applied to address the challenges posed by the altitudinal shift of crops due to raising temperatures in the Mountain demo site, adopting the Bio-district Valle dei Laghi as main test case. Vineyards at different altitudes (up to 700 m above sea level) will be monitored for micro-climate conditions, vine productivity, grape quality parameters and their vulnerability to pests. Besides, future scenarios for local climate and hydrology, water availability (according to changing irrigation needs, hydropower exploitation and agro-forest ecosystems balance) and land use (e.g., changes from woodland/pastures to agricultural land) will be developed, based on climate projections downscaled to the local context and observed land-use trends. Innovative participatory activities (co-creation) and the concept of the WEFE nexus will be used to co-design multifunctional farming plans to manage in a sustainable and integrated way the future conflicts in water and land use in the Bio-district.

Technical description

State of art

What has been happening over the recent years with a certain regularity is an anticipatory shift of the vine cycle. More often we experience an early budding, which then translates into harvest operations to be carried out earlier than expected. The vine cycle per se has not changed as the time between flowering and harvest tends to remain stable: what has changed is the period in which the cycle takes place, on average earlier than the past. It is essential that the vine completes the cycle correctly, otherwise the grapes may come to the cellar with faults on their organoleptic and chemical characteristics.

What we are trying to do is to focus on careful management of the vineyards, which means thinking at 360 degrees: from the relationship of the plant with the soils and water to that with the light and heat, in order to preserve the ideal mix for production of high-quality wine as much as possible, even in a shorter production cycle.

The dogma must be: ripe grapes on a ripe shoot. This ideal situation is easier to maintain at high altitudes, where cooler weather and longer hours of light naturally prolong the cycle of the vine, while at the bottom of the valley more precautions are required.

There are many factors to keep an eye on. A fundamental one is water management, hence the irrigation of the vineyard. Irrigation is a crucial factor today. If the vine undergoes water stress or heat stroke, lymphatic flow breaks may occur, leading to qualitative deterioration and apoplexy.

The management of the foliar system is another determining factor: leaf stripping, intensity, sides, exposure, vine head management, shade and light areas. At the bottom of the valley an excessive insolation leads to early ripening with too high temperatures on the bunches that lead to a consequent qualitative decay; on the other hand, as you go up in altitude, the higher you go, the more you need grape ripeness, therefore more hours/day of exposure to sunlight and heat.

Considering all these factors, we want to find the ideal sustainable conditions to cope with climate change.

Table 23: Data requirements and data & model availability

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 101037084.

Info/data needed	Possible sources
Micro-climate conditions, vine productivity, grape quality parameters and vulnerability to pests, climate projections, land-use trends, historical data from farmers, info on other crops, ecological indicators	Climatrentino, Provincial Environmental Agency (APPA), Fondazione Edmund Mach (FEM), Consorzio Vini, ISMEA datasets

Potential barriers and drivers

In order to make the data and the results of the study in the field effective, it is necessary to immediately make the community perceive the need to act. Adaptation to climate change can no longer be considered an option but rather the only solution, so that people begin to seriously consider the problem. This will allow people to arrive prepared when it is mandatory to comply with certain requirements. Thanks to this awareness, not only at a popular level but also at an institutional level, it will be easier to obtain the authorizations that farmers will need to be able to operate on a large scale in the future.

In order to have a greater media impact, it is necessary to have the support of as many stakeholders as possible so that private companies and public entities cooperate in synergy with each other to implement an information / education campaign.

To protect farmers from an economic point of view, it is necessary to implement the insurance system by developing services that better cover the damage caused by atmospheric events which in recent years have increased in intensity and frequency. On the other hand, from a practical point of view, new techniques for protecting the vineyard should be evaluated (such as anti-hail nets).

Key Performance indicators, added value and replication potential

How to measure impacts reached by demonstrating/implementing solution

- % of how the soil is used (agricultural activities, waterways, urban areas, farmland, etc.).
- Maintenance costs.
- Terrain slope and light exposure.
- Type and use of soil.
- Weather data (time series) on frequency of extreme events.
- Data on the rate of protection of different types of anti-hail nets (new technologies/materials?).
- Transportation cost (or other relevant costs, also in terms of GHG emissions externalities) of moving agricultural activities uphill.
- Cost/benefit analysis indicators.

Role of partners and relevant stakeholders

Eurac, Cantina Toblino, and MobyGIS:

- Development of regional climate models/scenarios.
- Monitoring activities of micro-climate conditions.
- Combination of different scenarios for changing water demand with land-use changing scenarios to manage the possible raising resource conflicts, using the WEFE nexus approach.
- Mapping use of soil/property at relevant altitudes to foresee possible conflicts in the use of land with other relevant sectors/actors.
- Altitudinal mapping the types of grapes and wine: what grows and what doesn't at which height, what varieties of wine are possible at which height (considering factors such as: extended light exposure, need to build infrastructure to transport water uphill...).

Relevant stakeholders

- Members of Cantina Toblino.

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- Wine production farms.
- Municipalities (owners of properties at relevant altitudes).
- CoDiPrA (consorzi difesa produttori agricoli – farmers consortium).
- Citizen associations (field of forestry, etc.).
- Irrigation consortia.

Actions and timeline

1. Provide record of damage (and type thereof) related to extreme events in the last 10 years. *[M7-M13]*
2. Collect and share knowledge on harvesting practices in relatable bio-geographical areas undergoing similar extreme events affecting vines. *[M13-M19]*
3. Development of different scenarios of altitudinal shifts. *[M19-M42]*
4. Gather qualitative insights on what would happen with the different scenarios developed: who is affected and how, if and how costs and supply chains would change, how wine quality would change. *[M22-M28 and M37-M42]*
5. Gather qualitative perception of improved/worsened harvesting or perceived changes in wine-making activities. *[periodically from M12 to M38]*
6. Collection of on-field data (quality of soil, microclimate data, etc.) and monitoring activities. *[periodically from M18 to M42]*

7.2.4 Activated cultural heritage to enhance climate resilience: win-win solutions for historic buildings to combine climate change adaptation and mitigation

Objective and challenge

In the context of global climate change, mountains are predominantly facing an increase of already existing, locally occurring natural hazards of reversible risks. Although their high damage potential, they are well-known to the resident communities, who have been dealing with such threats for decades or centuries. Therefore, at local and regional level, a thorough understanding of how to cope with these risks has evolved. This endogenous knowledge will be untapped in the Mountains demo site, revealing inter alia how culture, values and beliefs influence risk perceptions (societal resilience) and enable/impede adaptation measures. Relevant cultural practices and traditions will be identified, researched and tested with regard to their potential for further development and upscaling/ transferability, aiming at compiling a 'template of protection facilities' to enable a secure and contemporary living at mountain sites. Being an essential part of local identities and shared values, the interconnected intangible and tangible components of cultural heritage will be identified and exploited to detect triggers of behavioural change to apply innovative climate change adaptation pathways. Tools (such as risks maps or performance coefficients) will be developed to foster societal awareness and facilitate win-win solutions for adaptation & implementation of low-carbon measures for historic buildings (tangible heritage).

Technical description

State of art

Climate adaptation and mitigation measures in the building stock are based on precise knowledge of historic buildings in order to prevent long-term damage to the substance and unacceptable impairment of the appearance. To be able to develop strategies for not only the individual case but also spatially, a building stock analysis must be carried out that applies to the diversity of buildings in the historically significant cities and cultural landscapes. Especially in preparation of energy retrofit plans for large building stocks, there have already been various approaches for such a building stock analysis. The building stock is normally grouped into a limited number of categories with similar or comparable features. Understanding the typical energy behaviour for each representative building helps to ensure that appropriate energy efficiency measures are selected. However, only few studies have incorporated

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aspects regarding historic buildings. Because of the inherent complexity and nuanced cultural value of heritage buildings, it is often difficult to define building typologies and evaluate energy-efficient improvements for large building stocks that include historic ones. As Briz (2022) describes, the development and use of categorization methodologies to calculate the energy performance of large building stocks has been a continuous focus since 2010. Projects specifically targeting categorization of buildings are TABULA (2009-2012) and EFFESUS (2012-2016). In many of these studies, the older building stock is summarized under main categories according to the building age despite the diverse constructions. Approaches that consider cultural values in the categorization process are mostly applied to local contexts, since an on-site survey is recommended as showed in the EFFESUS project. The typologies are mainly based on geometrical characteristics, and the main character defining elements of each typology, distinguishing between visual, material, and spatial characteristics, are identified. Using a scale of benefits and risks, each retrofit measure is then evaluated. Later studies have used the EFFESUS methodology in various contexts, such as Genova et al. (2015), Ibrahim et al. (2021), and Raslan et al. (2018).

EURAC established a similar study for the municipality of Madruzzo (village of Calavino), a municipality located in the alpine area of Italy (Province of Trento) in the area of the IMPETUS case study Valle dei Laghi. The study was commissioned and financed by the municipality of Madruzzo, and was developed for the historic centre including 220 buildings and followed the steps:

1. Analysis of the building stock status quo (phase A):
    - (A1) description of the building stock from the territorial, urban, historical, and architectonic viewpoint;
    - (A2) collection of data in specific datasheets; and
    - (A3) spatial-based analysis using a GIS software.
2. Building energy modelling (phase B):
    - (B1) Definition of representative buildings for each category to assess the baseline scenario of energy consumption;
    - (B2) projection of energy demand scenarios for the entirety of the building stock under consideration.

The results of both the historical study, carried out by architect Susanna Serafini, and the subsequent building categorization and energy analysis (EURAC) will be used as a basis for assessing the historic building stock within IMPETUS.

Vernacular architecture and traditionally built buildings form a large part of the existing building stock across Europe. Only a small percentage of these buildings has been renovated to modern standards of energy performance, leaving a high potential for mitigation of climate changed untapped. However, in a context where climate change is already certain and only its severity is to be managed, measures like improved insulation or airtightness may result in increased vulnerability to rising temperatures and changing rain patterns. Whereas research on flooding risk modelling and management has increased notably in recent years, the understanding of climate change impact on aspects like heat waves and wind driven rain (WDR) is still scarce (Quesada-Ganuza et al. 2021). For instance, previous studies have already shown higher risks of overheating for retrofitted residential building in the alpine region (Hao et al. 2022) or high moisture risk levels in the far future in places like the UK (Lu et al. 2021). The use of numerical simulation offers a great flexibility in studying the response of current renovation practices to any future climate scenario (Libralato et al. 2021). Simulation models are often divided in two different categories (Hao et al. 2020). At building level, the models look into energy demand and internal climate (mostly indoor air temperature), whereas at component level the model focuses on the moisture dynamics across the envelope.

Furthermore, cultural heritage is always understood as something dynamic, “it being the product of cultural aspects which are produced and reproduced by communities over time” (Branduini and Carnelli 2021, p. 402). Specifically, intangible elements such as cultural and traditional practices, traditions, values, beliefs, and elements of local environmental knowledge are increasingly recognised as relevant factors in risk management (Reichel and Frömming 2014) and climate change adaptation (Adger et al. 2013). Moreover, Adger et al. (2013) emphasize the need to frame climate adaptation as a social process, which “requires increased attention to the meaning of climate change, including to the opportunities created, and the ways it can influence community and identity” (Adger et al. 2013, 114). For these reasons, we would like to integrate into our analysis the main traditions/myths, values, local

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practices and places related to tangible heritage, combined with local environmental knowledge and local coping strategies, which are both part of the construction of a sense of belonging and potential drivers of climate risk awareness. Starting from a review of local publications and the community map developed by the Ecomuseo Valle dei Laghi (whose mission “is aimed at the cultural growth of the community, conservation and transmission of knowledge and traditions”, (Comunità Valle dei Laghi 2022), we will conduct focused observations, interviews/surveys, and workshops to develop a participatory mapping of the aforementioned intangible factors. Indeed, a multimedia participatory map can offer “a particularly valuable possibility for visualizing the hidden structures of environmental knowledge and enables the researcher to analyse the deep connection of this knowledge to the people’s perception of the environment (Reichel and Frömming 2014, 45). This can foster societal awareness and facilitate win-win solutions for adaptation & implementation in two main ways. First, by collecting, visualizing, sharing, and discussing through different actions data on local perceptions about tangible elements at risk, climate change and coping strategies, local environmental knowledges embedded, eventual traditional building practices which can support climate adaptation. Secondly, use these data to prioritize the simulation models of the building stock in order to facilitate adaptation pathways based local values.

Table 24 Data requirements and data & model availability

Info/data needed	*Possible sources*
Building stock information including types of buildings/ settlements, Digital Surface Model (DSM) and Digital Terrain Model (DTM), traditional construction crafts, historic maps, cultural practices, values and traditions, local perceptions of climate change and coping strategies, local environmental knowledge, climate data (hourly data for temperature, precipitation, humidity, wind)	Geobrowser of the Autonomous Province of Trento (PAT), other online portals of PAT, weather stations, IPCC, EuroCordex, surveys/interviews

Potential barriers and drivers

Barriers:

- As the studies conducted so far have shown, a building analysis that does justice to the diverse characteristics of the stock is very time-consuming, and by far not all buildings can be assigned to a category and require special consideration. While this problem is manageable within settlements and cities, it becomes substantial especially in rural areas with different geographical situations. In addition, although there are initial baselines for the case study VdL with regard to energy scenarios, an analysis of the existing historic building stock is new ground with regard to climate adaptation and mitigation measures.
- Accuracy and representativeness of numerical simulations is determined by the quality of the input data, that ranges from user behaviour to air infiltration levels in the case of energy simulations, and from material characterisation to detailed climatic data in the case of hygrothermal models. Also, the definition of failure models (including criteria and thresholds) used to evaluate the output of the simulations have a crucial effect on the interpretation (and usability) of the results. Previous studies, such as the research project RiBuild3, have started paving the way for a more reliable and useful application of numerical simulation in the study of mitigation and adaptation strategies for the built environment.
- Lack of participation and stakeholder engagement, insufficient data on intangible elements due to time-consuming data collection and stakeholder fatigue.

Drivers:

- In order to have impact, we will focus on residential buildings. Here, the users are also the operators of the buildings and thus have a direct influence on sufficiency measures which can

[3] https://www.ribuild.eu/

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lead to increase the efficiency and the comfort of a building. Furthermore, the study can serve as guidance for the design of new funding opportunities in historic building renovation considering not only energy efficiency but also ecological, cultural and social impact.

- In addition to the flexibility that numerical simulation offers in assessing different future climate scenarios simultaneously, they will support the identification of suitable intervention strategies that will contribute to climate change mitigation while at the same time offering adaptation solutions for the conservation of the local built heritage.
- Visualising and sharing data using a multimedia map can reactivate local environmental knowledge, boost engagement and raise awareness.

Key Performance indicators, added value and replication potential

How to measure impacts reached by demonstrating/implementing solution

- Extent of historic building stock ← in m^2 per typology/use.
- Energy demand now and in the future ← in kWh, CO_{2eq}.
- Climate related damages to the built stock ← Quantification of heritage loss.
- Collection of data on intangible elements ← interviews, 2 workshops and focused observations.
- Mapping of relevant cultural practices, traditions and local environmental knowledge ← Identification/visualization of main elements and good practices.

How to include stakeholders expectations

- Guiding municipalities in long term management of historic building renovation strategies (e.g. subsidies).
- Providing adaptation and mitigation solutions for future climate scenarios for building owners.
- Raising awareness to activate local knowledge for climate adaptation.

Role of partners and relevant stakeholders

Eurac:

- Twofold approach addressing material and immaterial elements.
- Show how intangible cultural heritage (cultural practices) can support on finding solution for climate change adaptation (e.g. creating a map of intangible heritage).
- Historic building stock analysis regarding, describing relevant traditional constructions/ materials with relations to their environment (availability of construction material, climatic conditions, values, vulnerability).
- Development of mitigation/adaptation solutions for historic building renovation.

MobyGIS:

- Providing detailed resolution (spatial and temporal) climatic data for the simulation of the selected reference buildings.

Relevant stakeholders

- Building managers at municipal level (planning application officers);
- Heritage authority;
- Local architects to understand local realities regarding historic significance of the buildings in the area as well as the current practice of conservation and renovation;
- Local associations and communities who are active in the preservation of cultural heritage (knowledge bearers);
- (Eco)museums.

Actions and timeline

1. Detail assessment of building stock data for the municipality of Madruzzo. *[M7-M12]*

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2. Validation for the other municipalities in Valle dei Laghi by means of on-site survey. *[M13-M18]*
3. Assessment of past and present climatic conditions in Valle dei Laghi. *[M19-M24]*
4. High spatial and temporal resolution data for future climate in Valle dei Laghi. *[M25-M30]*
5. Numerical simulation of two representative archetypes for Valle dei Laghi under future climatic conditions. *[M31-M36]*
6. Proposal of adaptation and mitigation solutions based on the outputs of simulation and participatory process. *[M37-M42]*
7. Preliminary data collection on intangible heritage (literature + focused observations). *[M8-M12]*
8. Interviews for mapping local intangible aspects. *[M13-M18]*
9. Development of a multimedia map. *[M13-M33]*
10. Communication actions to share local knowledge and engage stakeholders, e.g. workshop to prioritize future risk assessment (considering tangible and intangible elements). *[M28-M30]*

References

Adger W., Barnett J., Brown K. et al. 2013. Cultural dimensions of climate change impacts and adaptation. Nature Clim Change 3, 112–117. https://doi.org/10.1038/nclimate1666.

Lara Briz, Building stock categorization for energy retrofit of historic buildings: A literature review. The paper is going to be published in the proceedings of the EEHB2022 Energy Efficiency in Historic Buildings Conference, Benediktbeuern, 2nd to 3rd March 2022. The following information regarding the development of building categorization models are taken from that work.

Branduini P., Carnelli F. (2021). The Preservation of Rural Landscapes for Building Resilience in Small Towns: Insights from North Italy. In: Arefian, F.F., Ryser, J., Hopkins, A., Mackee, J. (eds) Historic Cities in the Face of Disasters. The Urban Book Series. Springer, Cham, 399-416. https://doi.org/10.1007/978-3-030-77356-4_23.

Carnelli F., Short C., Mugnano S., 2020. Local knowledge as key factor for implementing effective nature-based solutions for flood risk mitigation. Rassegna Italiana di Sociologia, LVI (2): 381–406. https://doi.org/10.1423/97838.

Comunità Valle dei Laghi, 2022. Website: https://www.comunita.valledeilaghi.tn.it/Aree-Tematiche/Ecomuseo-della-Valle-dei-Laghi/La-mission. Last access: 29 May 2022.

E. Genova, G. Fatta, and T. Broström, "Categorization of the Historic Architecture in Palermo for the Purpose of Energy Assessment," pp. 499–504, 2015

H. S. S. Ibrahim, A. Z. Khan, S. Attia, and Y. Serag, "Classification of heritage residential building stock and defining sustainable retrofitting scenarios in Khedivial Cairo," Sustain., vol. 13, no. 2, pp. 1–26, 2021, doi: 10.3390/su13020880

E. Raslan, A. Donarelli, and E. De Angelis, "Categorization of the heritage building stock in Cairo for the energy planning purposes. A method and the typical buildings," in Energy efficiency in historic buildings 2018, 2018, pp. 503–511

Quesada-Ganuza, L., Garmendia, L., Roji, E. and Gandini, A., 2021. Do we know how urban heritage is being endangered by climate change? A systematic and critical review. International Journal of Disaster Risk Reduction, 65, p.102551.

Hao, L., Herrera-Avellanosa, D., Troi, A.; Future energy performance and overheating risks in retrofitted historic buildings, in The 4th International Conference on Energy Efficiency in Historic Buildings EEHB 2022 Benediktbeuern, Germany

Hao, L., Herrera, D., Troi, A., Petitta, M., Matiu, M. and Del Pero, C., 2020. Assessing the impact of climate change on energy retrofit of alpine historic buildings: consequences for the hygrothermal performance. In IOP Conference Series: Earth and Environmental Science (Vol. 410, No. 1, p. 012050). IOP Publishing.

Lu, J., Marincioni, V., Orr, S.A. and Altamirano-Medina, H., 2021. Climate resilience of internally-insulated historic masonry assemblies: Comparison of moisture risk under current and future climate scenarios. Minerals, 11(3), p.271.

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Libralato, M., De Angelis, A., Tornello, G., Saro, O., D'Agaro, P. and Cortella, G., 2021. Evaluation of Multiyear Weather Data Effects on Hygrothermal Building Energy Simulations Using WUFI Plus. Energies, 14(21), p.7157.

Reichel, C., Frömming, U.U., 2014. Participatory Mapping of Local Disaster Risk Reduction Knowledge: An Example from Switzerland. Int J Disaster Risk Sci 5: 41–54. https://doi.org/10.1007/s13753-014-0013-6.

7.2.5 Improvement of risk management practices through the application of participatory approaches (Impact Chains and Rapid Risk management Appraisal)

Objective and challenge

Innovative participatory approaches like Impact Chains (IC) and Rapid Risk management Appraisal (RRA) will be combined to improve risk management capacities and hence resilience to climate change. IC allow breaking down each risk into exposure, vulnerability, and climate hazard factors, and consequently pinpointing in which field adaptation measures need to be taken.

RRA systematically investigates how regions address the integrated management of risks, promoting mutual learning between data and model experts, subjects in charge of emergency procedures (e.g. mayors, civil protection, firefighters) and local communities. This framework, currently implemented in the PLANALP platform, will be expanded by including additional climate-related hazards: sudden extreme events like e.g. floods, windstorms, heatwaves, and slow-onset processes, like e.g. the gradual temperature increase. IC & RRA will be applied to conduct participatory processes not only in the Mountains demo site, but also in other mountainous regions, to co-create an improved and integrated risk management strategy for the Valle dei Laghi area and foster the exchange of best practices within and beyond the Mountains region. This will help bridging the gap between disaster risk reduction and climate change adaptation, encompassing flexible preparedness, recovery, and response measures.

Technical description

State of art

Risks result when climate-related hazards dynamically interact with exposed and vulnerable human or ecological systems. They are driven not only from potential impacts of climate change but also from human responses to climate change. Understanding current and future impacts as well as human responses and capacities in place is of paramount importance. In this context, the Impact Chain and Rapid Risk management Appraisal have been used for such purposes.

The Impact Chains are an analytical concept to better understand, systemise and prioritise the climate factors as well as environmental and socio-economic factors that drive climate related threats, vulnerabilities and risks in a specific system. When developing the impact chains, in particular, when identifying the vulnerability factors (e.g. “what makes your system vulnerable against a specific climate hazard?”) specific sensitivities (e.g., drought-sensitive crop types) or the lack of technologies and capacities (e.g., the lack of an efficient irrigation system, the lack of a hazard zone planning or the lack of an integrated water resource management strategy) can be pinpointed by involving local experts. Appropriate adaptation measures to tackle these shortages can be discussed and recorded. The impact chain have been adopted internationally, from Germany to Burundi. However, while the hazard and exposure components are usually more easy to analyse, identifying the factors which characterise the vulnerability component of risk constitutes a bigger challenge.

The Rapid Risk management Appraisal (RRA) can be adopted to systematically explore the vulnerability component of the Impact Chains (in particular the institutional/adaptive capacity). Up to now the two approaches have been adopted independently. Moreover, the RRA has been mainly applied to gravitational natural hazards and in the Alpine Space. The Impetus Project will allow to extent such an approach to climate-related hazards and to further study areas, as well as to combine the two approaches.

Table 25: Data requirements and data & model availability

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Info/data needed	*Possible sources*
Exposure, vulnerability (e.g. risks management practices), climate hazard factors (heatwaves, gradual temperature increase, windstorms, floods), direct and indirect impacts, historical data on extreme climate events and impacts	Workshops and interviews with stakeholders as a first step

Potential barriers and drivers

Barriers:

- Unavailability of stakeholders to take part in participatory workshops and bilateral interviews.

Key Performance indicators, added value and replication potential

How to measure impacts reached by demonstrating/implementing solution

- N. of workshops, focus groups and training activities performed.
- N. of impact chains developed.
- N. of identified strengths/weaknesses in risk management practices.
- N. of new measures identified through Impact Chains and RRA.

How to include stakeholders expectations

Stakeholder expectations play a key role in this solution as this is mostly based on participatory processes. In particular, the expectations of stakeholders regarding how to improve current risk management practices will be addressed systematically thanks to the application of the Impact Chains and Rapid Risk management Appraisal approaches. These allow not only to better understand and pinpoint risks and the respective capacities and risk management practices but also to foster a group brainstorming on perceived strengths, weaknesses and potential ways forward to address current and future challenges.

Role of partners and relevant stakeholders

Eurac:

- Impact chains & rapid risk appraisal will be used as baseline assessment, part of setting the scene (since rapid risk appraisal is a method to detect strengths and weaknesses of risk management practices).
- Impact chains will be performed on different sectors addressed by other activities within the Demonstration Site: buildings and cultural heritage (ref. section 7.2.4), agriculture (ref. sections 7.2.1 and 7.2.3), forestry, hydropower energy production, and tourism (ref. section 7.2.2) addressing different climate hazards and impacts (e.g. water scarcity, floods, temperature increase and heatwaves).
- Impact chains will be also for detecting the weak points to propose new climate change adaptation measures, linking to the Disaster Risk Reduction practices.

Relevant stakeholders

Local and Provincial stakeholders responsible for the sectors and the management of the hazards/ risks addressed.

Actions and timeline

1. Predevelop standard impact chains for selected sectors (input from activities described in section 7.2.4 for building sector). *[M7-M10]*
2. Specific stakeholders outreach + invitation to the first workshop. *[M7-M10]*
3. Participatory workshop on analysing current situation through ICs and RRA (agriculture and forestry). *[M11-M13]*

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4. Follow up contact through bilateral meetings with stakeholders. *[M14-M15, M19-M21, M31-M33]*
5. Participatory workshop on analysing current situation through ICs and RRA (hydropower energy production and tourism). *[M16-M18]*
6. Final workshop to co-develop points for improvement in risk management and new climate change adaption options. *[M40-M42]*

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8 Conclusions and Outlook

D4.1 describes the baseline and necessary activities and roles to deploy and demonstrate the IMPETUS solutions. All solutions are translated into tasks within WP4 and the progress along the given timelines will be monitored together with

1. the case study leaders
2. the task leaders
3. the bundle managers

Further to regular exchanges within the WP and between the bundle managers and case study leaders, all WP leads are regularly consulted and one dedicated task (see below) is working across all demo cases. This provides opportunity to discuss lessons learned and derive common conclusions on the applicability and transferability of the IMPETUS solutions to other settings. The subsequent deliverables D4.2 to D4.5 will thus contain both, technical documentation of the IMPETUS solutions at the case studies, but also lessons learned across sites ad solutions.

8.1 Cross-task fertilization and bundle management

8.1.1 Assessment of economic impacts of physical climate risk across demo cases

Assessment of economic impacts across all demo cases is a specific task of WP4 as outlined below.

Objectives

- Develop the appropriate models for IMPETUS demo cases to generate high resolution local datasets.
- Assessment of economic impacts of physical climate risk across demo cases.
- Develop a methodology to integrate climate risk into investment decision making tools and prioritization processes to develop resilience-oriented plans and mitigation and adaptation strategies.

Role of partners and relevant stakeholders

Lobelia (Task leader)

- Dataset collection, selection and preparation
- Computation of climate projections
- Analysis for the identification of hotspots

Athens University of Economics and Business (AUEB):

- Cooperation with local stakeholders via the RKBs to co-design experiments and estimate the associated costs more accurately
- Guidance for the implementation of choice experiments and development of behavioural economics models.
- Econometric analysis of the results of choice experiments, upscale results – value transfer to other sites.
- Development of a framework to estimate future economic impact on the coastal infrastructure caused by extreme events risk occurrence in the future.

Data collection and selection

- Lobelia will organize one-to-one meetings with demo-cases partners to align on data needs and availability, as well as gain more insights on the climatic regions, for the selection of the most appropriate data and models and the provision of in-situ local datasets used for downscaling.

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- Lobelia will first select the most appropriate available climate datasets. Post processing steps like bias adjustment, downscale to local scale if in-situ data is available and the computation of specific climate indicators (i.e. climate extremes will be carried out depending on each case study requirements). In addition, Lobelia will generate exclusive satellite-derived climate data (soil moisture, water level, etc.) and risk indexes with proprietary AI algorithms that will help to assess the identification of critical hot-spots.
- The historical records developed of satellite-derived and non-climate data will be used to train AI algorithms and develop observation-based models. These high resolution site-specific trained models are used to improve regionalized climate projection and used to infer the future change in the probability of occurrence of different climate extreme events.
- This work plan will go hand-in-hand with the provision of data to the different demo-cases that lobelia is responsible for in Task 3.1 Generation of weather and climate data.

Economic impact assessment

- Once projections are developed, Athens University of Economics and Business will assess the economic impact of the extreme events analysed, leveraging on the tools developed in the Catalan Demo Case in Task 4.13.
- Using State of the art behavioural economics models and participatory methods, the team will conduct economic and environmental valuations of the costs associated with extreme weather events under uncertainty.
- AUEB will carry out meetings with relevant partners and stakeholders in the different demo-sites to adapt and co-develop a framework that can be used as a validated investment decision support tool for future resilient-oriented plans and adaptation/mitigation strategies.

Actions and timeline

- The task starts in M7 (May 2022) and is expected to be completed in M42 (July 2025)
- Initial meeting will be held between Lobelia and Athens University for the planning and coordination of the data needed for the economic assessments.
- Lobelia will organize one-to-one meetings with demo-cases partners to align on data needs and availability, as well as gain more insights on the climatic regions
- AUEB will organize one-to-one meetings with demo-cases partners and stakeholders, to design and coordinate choice experiments for the economic and environmental valuations.

8.1.2 Bundle management and harmonisation and transfer of information

Aim of the bundles is to enable exchange across demo cases on the specific domains (bundles) of the solutions and to facilitate progress monitoring and quality assurance across the large number of tasks and solutions. Bundle management is independent of and parallel to case study management.

The bundle managers will meet regularly under the coordination of the WP4 manager to discuss task progress and enable early identification of deviations, risks and mitigation actions.

8.2 Interaction with other work packages

8.2.1 WP1 Governance and stakeholder co-creation

All demonstration activities described in deliverable D4.1 are involving project partners as well as core stakeholders. The deliverable is thus closely linked to WP1 and at this stage to the stakeholder identification process within task T1.1 of WP1. The stakeholder identification guideline provided in December 2021 makes reference to D4.1 for the description of tasks and role of partners.

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8.2.2 WP2 Digital and knowledge dimension of the RKBs

WP2 provides the design of the resilience knowledge boosters (RKBs) and digital tools enabling data processing and visualisation. RKBs are to be developed one per case study. Their target is to engage with local communities in exploring and providing knowledge on climate adaptation and to showcase the IMPETUS solutions and pathways to adaptation.

Based on a conceptual framework provided by WP2 (D2.1, due M12), all case studies will work closely with the WP2 partners in developing the RKB design strategies, data architectures and tool integration.

8.2.3 WP3 Exposure and vulnerability assessment

Main relation between WP4 and WP3 is the provision of climate data and metrics and indicators to identify vulnerabilities and monitor efficiency of the IMPETUS solutions in improving the adaptive capacity of key community systems to climate change.

The case study and task leaders will be involved in hot spot identification (T3.3) and analysis and assessment of resilience, cost and effects from interventions. WP3 will organize regular meetings and activities with the case studies.

8.2.4 WP5 Adaptation Pathways and Innovation Packages

WP5 is at the heart of the IMPETUS project and aligns stakeholder engagement and vulnerability assessment based on indicators with demonstration and assessment of benefits of the IMPETUS solutions beyond the case studies. Starting in M30, WP5 will guide the case study leaders and teams towards the conclusion of Innovation Packages and their evaluation.

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