# *SAVE-WATER*: Increasing cross-border infrastructure's capacity for water management

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Abstract

The project titled "SAVE-WATER: Improving water management and supply infrastructure via smart technologies, policies and tools" aims to increase the capacity of cross border infrastructure in water management through planning and rehabilitation of water management / supply infrastructure in an effort to upgrade the drinking water quality monitoring systems and enhance the transnational management efficiency. The proposed joint intervention of the introduction of low-cost monitoring technology, initially developed by some of the project's partners for previously funded regional projects, is expected to support a cross border cooperation for a capacity building scheme between local authorities and regional institutions, in order to address common challenges about the effective and efficient management of the drinking water natural resource in accordance with the program's objective for a balanced cooperative sustainable regional development. This paper presents the key aspects of the SAVE-WATER project, including the consortium, the organization of project's deployment, key technologies that have been implemented so far and an outlook at the project's completion.

**Keywords**

Cross-border infrastructure, water management, planning & rehabilitation, water quality monitoring, low-cost monitoring technology, capacity building, sustainable regional development.

## 1. Introduction

"Water is essential for human life, nature, and the economy. It is permanently renewed but it is also finite and cannot be made or replaced with other resources. Freshwater constitutes only about 2% of the water on the planet and competing demands may lead to an estimated 40% global water supply shortage by 2030". Moreover, drinking water losses from ageing water distribution networks' leakage within EU Member States vary from 7% to 50% or more [1], **Error! Reference source not found.**. The aim of the SAVE-WATER project is to address these challenges to preserve our resource base for life, nature, and the economy and to protect human health. More specifically, the overall objective of SAVE-

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WATER is to increase the capacity of cross border infrastructure in water management by means of technology transfer and enhancing management efficiency. The expected changes that SAVE-WATER will initiate are to elaborate transnational and join-up approaches to respond to common drinking water pressures; to produce state-of-the-art sustainable technological solutions for robust drinking water monitoring; to elaborate the effectiveness of the local administrations for protection, conservation, and sound use of water resources; and lastly, to improve operational reliability, and safety of water supply systems especially in touristic areas. The project's main outputs focus on the creation of a transnational network and a protocol for common monitoring of drinking water demand and quality; an information system and a prototype of a smart sensor-network for effective drinking water monitoring and decision-making and their implementation in the pilot activities; the formation of a Transnational Action Plan and a Policy paper for joint strategies towards prevention and mitigation of risks and water resource vulnerabilities. The key target groups of SAVE-WATER project are the local population, the regional administrations and local entities achieving efficient & effective management of drinking water resources, and tourists due to the sustainable use of water resources. The project's approach is oriented on the enhancement of drinking water quality, the enhancement of partners' capacity to water management, and the sustainable use of water resources. The transnational approach is essential for SAVE-WATER since the key causes of negative impacts on water status, such that climate change, industry, agriculture, and tourism have a transnational character, given that 60% of the EU's territory has transboundary river basins. The originality of SAVE-WATER stems from the introduction of low-cost smart sensors and networks which will cover very large transnational areas leading to the development of a robust monitoring infrastructure and decision-making tool producing valuable equipment with significant added value.

# 2. SAVE-WATER Project

## 2.1. The Call

The Interreg IPA II Cross-border Cooperation Programme "Greece –Albania 2014-2020" is a cross-border co-operation Programme co-financed by the European Union under the Instrument for Pre-accession Assistance II (IPA II). The Instrument for Pre-accession Assistance for the period from 2014 to 2020 ("IPA II") shall support the beneficiaries such as Prefectures, Municipalities, etc. in adopting and implementing the political, institutional, legal, administrative, social and economic reforms required by those beneficiaries in order to comply with the Union's values and to progressively align to the Union's rules, standards, policies and practices, with a view to Union membership. The overall strategy of Interreg IPA II cross-border cooperation programme "Greece - Albania 2014-2020" is "to find the balance between sustainable regional development and enhancement of cross-border cooperation among local population & regional institutions, in accordance with EU & national policies, in order to address common challenges through joint interventions". Within this framework, the Interreg IPA II Cross-border Cooperation Programme "Greece – Albania 2014-2020" consisted of three Priority Axes and four Thematic Priorities. SAVE-WATER was submitted at the first Priority Axis, the "Promotion of the environment sustainable transport & public infrastructure", which was to be implemented via two thematic priorities. The first one is focusing on promoting sustainable transport, information and communication networks and services and investing in cross-border water, waste and energy systems and facilities, and the second priority is about protecting the environment & promoting climate change adaptation & mitigation, risk prevention & management. More specifically, both priorities are about planning, construction and rehabilitation of small wastewater management infrastructure and surface water quality monitoring systems. Other Priority Axes are for boosting the local economy and technical assistance.

## 2.2. The proposal

During the implementation of two Interreg projects, BIG [3] and e-OLIVE [4], the possibility of transferring the gained expertise on low-cost smart technology to the field of efficient monitoring to other natural resources was evident. SAVE-WATER, addresses a plethora of common territorial problems and challenges. First, the existence of significantly varying approaches in water management by the regional administrations due to weaknesses in common monitoring protocols and surveys despite common challenges, e.g., in some cases participating regions share a common water basin for covering their drinking water needs. This discrepancy results in inadequate monitoring of human activities and local physical variables (geology, climate etc.) having a significant impact on water quality. Furthermore, there is loss of proper technological solutions for sustainable large scale monitoring infrastructures, since nowadays drinking water pressures are evolving in large spatial scales, e.g., climate changes, common water basins, geological hazards, etc. In addition, proper tools for decision making for on-line water flow management from regional administrations and authorities are absent while the current infrastructure is threadbare with numerous instances of non-revenue water cases. Effective management of drinking water at a transnational level is constrained by a lack of shared, practical strategies and uncoordinated national legislation. Furthermore, sustainable solutions for supplying drinking water in touristic areas, which experience significant seasonal alterations in demand, require a concrete action plan and policy. [7], [9][10].

## 2.3. The project

### 2.3.1. Aim and Objective

The overall objective of the SAVE-WATER project is to increase the capacity of cross border infrastructure in water management through planning and rehabilitation of water management / supply infrastructure to upgrade the drinking water quality monitoring systems and enhance the transnational management efficiency. More specifically, the proposed joint intervention of the introduction of low-cost monitoring technology, is expected to support a cross border cooperation for a capacity building scheme between local authorities & regional institutions, in order to address common challenges about the effective and efficient management of the drinking water natural resource in accordance with the program's objective for a balanced cooperative sustainable regional development.

One of the main objectives of SAVE-WATER is the transnational networking for recognizing, mapping, and assessing drinking water pressures. In addition, the management of drinking water infrastructures is aimed to be enhanced by means of low-cost smart monitoring technologies and custom decision-making tools. Another main objective is setting transnational Strategies, Action Plan and Tools for effective & efficient CB drinking water management. The last goal of the project is the creation of concrete pilot actions via transfer of best practices and capitalization of project's results for promoting financial growth and citizens' awareness for sustainable use of natural resources.

### 2.3.2. Consortium

The partnership is composed of 4 regional administrations, 2 research institutions & 2 regional / municipal companies. The lead beneficiary of SAVE-WATER project is the Region of Ionian Islands of Greece (LB-P1), while the rest beneficiaries are the Region of Epirus of Greece (PB2), the Regional Council of Vlora (PB3), and the Regional Council of Korca of Albania (PB4), the Environmental Centre Region of Western Macedonia (PB5), the Municipal Enterprise for Water Supply and Sewerage of Ioannina (PB6), the Ionian University Research Committee (PB7), and the Western Macedonia University of Applied Sciences of Greece[2] (PB8). PB5 and PB6 are regional/municipal companies the activities of which are solely focused on the key theme of this proposal (water supply & sewerage and chemical & microbiological water analysis & sampling laboratory). Both beneficiaries have experience and resources to achieve the projects objectives, while also ensuring the diffusion of the project's beneficial results to the stakeholders. The consortium's synergy was designed to have the following key outcomes to each beneficiary: first, LB-P1 authorities, PB2, PB3 and PB4 receive technology transfer, a decision support system, and the database protocol to better apply their policy making processes. In addition, the institutions LB-P1 and PB8, gain further specialization in water management thus increasing their expertise and ability to provide widely affecting solutions, while the regional / municipal companies such as PB5 and PB6 enhance their expertise in shaping effective water management best practices, making it thus more productive. All these were designed to lead to the improvement of the capacity and sustainability for drinking water management against man-made and natural pressures.

### 2.3.3. The work packages

The SAVE-WATER project is divided into 5 work packages (WP) to distribute the sub-tasks, and subsequently its deliverables, required for its implementation by all partners. In more detail:

WP1: Project management & Coordination, WP2: Communication & Dissemination, WP3: Networking and GIS Database, WP4: Sensors Networks and Pilot Actions, WP5: Strategies and Policies.

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In the following figure (Figure 1), a graphical representation is provided describing the relative contribution of each partner per WP using a heat-map. The redder, the more contribution.

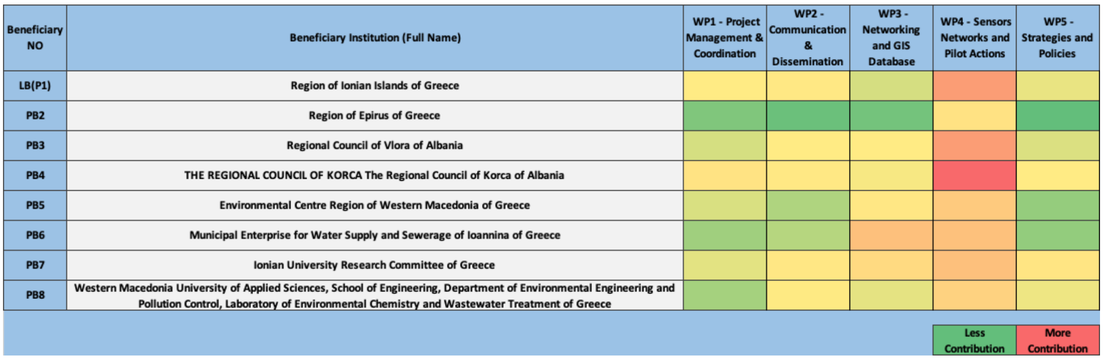


**Figure 1**: Total relative contribution per partner per Work Package in the SAVE-WATER project.

### 2.3.4. Proposed Technologies

A transnational network between the project partners and other authorities and institutions of the eligible areas has been developed to address existing and prospective related protocols for water monitoring, thus introducing a common understanding as well as a common scientific language for the description of water pressures. In the meanwhile, the PB7 and PB5 have begun the construction of a GIS info maps backbone system, where all partners contribute critical information for mapping and assessing water pressures in the project's designated region(s).

The database is to be designed to hold all the necessary information for water network monitoring, population needs, existing infrastructure, and water quality. At the same time, a smart monitoring network (SCADA) is being designed and developed by PB7 and is designed as to address the task of automatic data acquisition and transmission from several locations in the project's area(s), as well as bidirectional communication with water stations for remote command support. The collected data is of high importance for analyzing water pressures and includes water flow measurements, surface and drinking water level, water quality and non-revenue water monitor.

Additionally, the water network infrastructure has been rehabilitated by means of new technology as far as water flow meters - installed in numerous areas, as well as water installation of desalination units.  The decision-making system has been designed and is under implementation using data and contribution from all partners, to enable decision makers to choose the best strategies and policies in terms of cost and effectiveness for water management and increasing resilience of water networks.

### 2.3.5. Low-Cost Sensors

The proposed low-cost sensor network has been designed to cover very large geographical areas in near real-time. It consists of Maddelena's FlowPulse sensors [5] for observing the distribution of water through the water network and ultrasonic sensors connected with microprocessor Raspberry Pi 3 Model B+ **Error! Reference source not found.** for observations as far as the water level inside storage tanks is concerned. They are designed to utilize a cartridge system that houses the sensor's heads allowing for replacement of individual sensors' heads without replacing the entire device. The sensor network, precisely because of its low cost, can be particularly dense leading to high levels of information collection scaling, as well as with a much lower barrier of design, implementation, placement, and maintenance. The usage of low-cost sensors is ideal for the SAVE-WATER project due to their low cost, and the uncomplicated maintenance and installation processes these require. Moreover, their high sensitivity, sampling frequency, and measuring penetration capability, the ease with which they detect external and deeply layered objects, their accuracy, simple interface with a microcontroller or any type of controller, and low-power utilization. Low-cost sensors can be used in many different applications to improve reliability, increase production, and reduce error-rates compared to those of humans measuring the equivalent processes. The common trade-off of their low cost is usually the not so high accuracy of measurements. In the case of the SAVE-WATER project this is off-set by their volume and the "collective intelligence" arising from their swarming processes by use of stochastic and artificial intelligence methods.

### 2.3.6. Informational system

The proposed platform follows a modular architecture design. The main components of the platform are the database (DB) and the Application Programming Interface (API). Although there are many alternatives, the proposed system is based on the open-source, high-reliability, and high-availability database management system MySQL that manages both relational and document model structures, as well as streaming and geospatial information, all natively.

The collected data is of high importance for analyzing water pressures and includes water flow measurements, surface and drinking water level, water quality and non-revenue water monitor. The database is designed to hold all the information for water network monitoring, population needs, existing infrastructure and water quality. The data stored in the platform's database is organized following a loosely coupled methodology where entities are ad-hoc interconnected with other entities using a many-to-many interrelation for each entity. This allows easy expansion of the database, with a unique addition of interdependencies to all existing entities for each new entity, without the need to reorganize the database's schema with the unique cost that non-useful relationships are likely to arise. This cost is offset by the flexibility introduced by this design, where new interrelations can shape the design of the database after it has been designed and deployed, thus allowing for adaptive adjustment of the stored data. Thus, the general (i.e., for each potential entity) entity relationship diagram of the platform data follows an unconventional model, for entities 1 to k, where $1 \leq j \leq k$. Accordingly, some of the entities included in the platform are the following: **Building**, **Event**, **Image**, **Message**, **Path**, **Path_point**, **Sensor**, **Sensor_sampling**, **Tag**, **User**, **Video**.

For this project, the data in the database is to be accessible through the API which ensures access by applying authentication / credential solutions, enforcing project restrictions (business logic), user management and specialized access based on the type of application which will access the data. The API has detailed documentation and acts as an intermediary for all information exchanges and service provision and furthermore provides for the organized extension of the proposed platform to accredited third parties. The management subsystem is for monitoring and setting all parameters of the platform, while the web portal serves as an access point over the network. Through the public portal, content is to be provided which contains information presented through a Geographical Information System (GIS), i.e., geo-referenced on a map, as well as through a Decision Support System (DSS). The network of low-cost sensors (sensors' feeds) provides information that allows the DSS to support the decision-making process in addition to manually entered information.

### 2.3.7. Decision Support System

The purpose of the water supply system plan is to develop water supply system management methods, which will then be characterized by: rationality, efficiency, sustainability, reliability, and economy.

The water network management mainly refers to regulating the flow in the reservoirs, in the apportionment of withdrawals by primary, secondary or reserve source, and in the transport of water through the network of external aqueducts. The design of a real-time monitoring system of hydrometric parameters requires a combination of tools consisting of the measurement stations of these parameters, the telematic data transfer systems as well as the terminal systems in which measurements will be stored, analyzed and presented as well as the systems that will subsequently be issuing the appropriate alerts based on the knowledge extracted from the data. Therefore, the user will be able to utilize the data in a short period of time and make those decisions that will allow the maintenance of water management at high levels.

The purpose of the Decision Support System (DSS) is to design, install and evaluate a pilot water system management system using new technologies and to construct a water system management model. The consumption measurement telemetric systems are to be installed in aqueducts, pumping stations and water tanks and the low-cost sensors will record and then transmit data via the mobile network (GSM/GPRS). The collected data are sent telemetrically to the Data Management System (DMS) in near real time with timestamps. After the evaluation of the data, the corresponding alerts are presented, analyzed, and issued in the DMS. The data are being stored in a Database.

### 2.3.8. Current Status

The project's original end-date was by the end of November 2019 but that had to be extended due to unexpected difficulties. The pandemic of COVID-19 [6], delays in the supply of electronic components, in addition to the increased complexity of the project as well as difficulties in asynchronous & remote communication between all the partners, all have led to the postponement of the project's end-date. As of the end of February 2023, PB1-8 have completed their respective Deliverables in an average percentage of 80%. As far as PB7 is concern, the IURC has installed several prototype systems in different areas around the water network of Corfu Island, Greece. Furthermore, all systems have been built and are expected to be installed in more areas around the Corfu Island water network by May 2023. In addition, some deliverables are still under construction, such as the database and the API software, and the DSS, due to their complexity. All in all, SAVE-WATER project is aimed to be completed by the end of August 2023.

## 2.4. Results

### 2.4.1. Collected data from the field

**Water tank volume**: The water tank volume, was developed with low-cost electronic components and technologies such as Raspberry Pi 3 model B+ [4] and a low-cost ultrasonic sensor. The main idea was to collect data from an ultrasonic sensor every 1 minute, which detects the distance from the surface of the tank to the water level. After the data collection, the system can be programmed to send them to the informational system periodically via GSM network, to save them securely and to make more calculations leading to knowledge extraction. Additionally, knowing the size of the tank can accurately calculate the volume of water inside it using the equivalent optimal formula.

**Water flow**: The water flow system uses a FlowPulse sensor from Maddalena [5] that provides a pulse / 100 lt. The system's microprocessor samples every 1 minute the pulses and calculates the final output representing the liters passing through that exact point per minute. All data collected are structured and stored initially locally and then sent to the database every 5 minutes via GSM network.

### 2.4.2. Sensors' placement

As mentioned in Section 2.3.3 where WPs are presented, one of the main goals of this project is to install the systems mentioned in the previous paragraph, on the field. The points where pilot flow recording and tank measurement systems have been installed are shown on the map of Figures 7, 8.

The data from the water volume tank system shown in Figures 2 & 3 is from one of the most significant tanks in the supply network of the island of Corfu, Greece. As shown in Figure 2, the data indicate significant periodicity due to the outgoing and incoming flows of the tank's water, which is the expected operation of the network. In Figure 2 is the low level discernible between 15 Feb 2023, 02:31 and 15 Feb 2023, 10:37 which requires further exploration to verify its status.

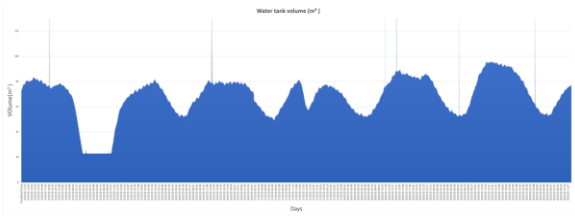

**Figure 2.** Water volume tank data analysis from pilot action.

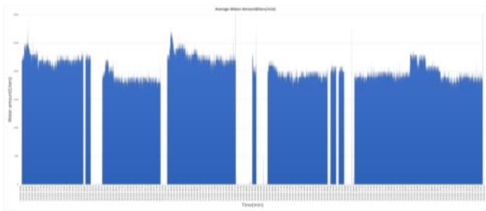

**Figure 3:** Water flow system data analysis from pilot action.

After analyzing the data provided from the water flow system's sensor, the first interesting point is about the periodicity of water consumption: in the morning hours the water flow is greater than the night hours when the water flow is significantly lesser or even close to zero. Moreover, each cycle of the periodic signal shows a pattern that begins with a short duration local high value, followed by a longer duration averaged plateau of values, ending with a short duration of zero or near-zero values. The data show some spikes, shown also in Figure 3, that require further study but are initially attributed to air flows during the shutdown process of the associated pumps. This system has been installed in the most active water pump in the whole Corfu Island of Greece.

### 2.4.3. Visualization

The collected data is presented by a user interface (UI), with the aim of directly informing all interested parties. Accordingly, a web-based platform with this UI has been created the also offers early warning in the event of a leak in the network, risk of tank overflow, or lack of water for a monitored tank. Figure 4 shows a map of Corfu Greece, and the registered / monitored water storage tanks. When a water tank is selected, a new pop-up html entity emerges and the attributed of the water tank are detailed. These attributes include the maximum volume of the tank, the current filling level as a percentage and in absolute value, as well as the current rate (in-flow) and consumption (out-flow) per minute. Along with this data, a graph is shown indicating the monthly consumption of the selected water tank for reference purposes.


**Figure 4:** User Interface.


**Figure 5:** User Interface's Alarm.

In addition, the user can designate the maximum and minimum level of water to indicate the event of a tank overflow or lack of water, for the necessary alarms to be activated, as shown in Figure 5. Following the initiation of the alarm, a sound is heard so users can be notified and act accordingly.

## 3. Conclusions and future work

The sustainability of the SAVE-WATER project outputs will be ensured in two different levels: (i) On the technical level the proposed low-cost smart technologies from the participating institutions ensures that they will have the capacity to retain and upgrade with their own funds the acquired-through the project-equipment. Sustainability of technical projects outputs is also ensured by the fact that project outputs are in line with the main scientific direction and corresponding research funding of the academic institutions involved. In addition, the public awareness portal (with the provision of context from all BPs) will be supported by BP7, while the produced information system will be supported by BP7, BP8 and BP5 accordingly. (ii) On the political level by means of the preparation and sign of the proposed Memorandum of Understanding where local authorities, stakeholders and academic institutions will declare their commitment for addressing present and future challenges in water management.

The project partnership entails the involvement of both authorities and stakeholders. The partnership has the administrative capacity, institutional authority, and the organizational status to ensure the durability of the results of the project. Moreover, the durability of project outputs is to be ensured by (i) an evaluation of the project's success to identify future improvements foreseen, scoping in identifying its impact on the predefined indicators; (ii) identification of the types and sources of funding to maintain the project beyond the initial funding period; and (iii) the creation of a transnational action plan for joint strategies and policy papers.

The knowledge and experience gained in WP5 is to form the basis and vantage point to be used for the smart management of drinking water in all other areas of the two participating countries, ensuring thus the applicability of project's output. Indeed, the selection of the different pilot activities in terms of monitoring systems, ageing infrastructures and desalination being the main drinking water challenges in all Programme areas, ensures the optimum spreading of gained knowledge. Finally, the software is to be accessible by providing documentation on methods used therein and cases of applicability to make the project's software outputs useful by other organizations outside of the current partnership.

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