Wat€rnomics

SEVENTH FRAMEWORK PROGRAMME

Wat€rnomics

D8.4 PROJECT FINAL REPORT

Wassim Derguech, Edward Curry, Sander Smit, Eoghan Clifford, Thomas Messervey, Domenico Perfido, Louise Hannon, Schalk-Jan van Andel, Leonardo Alfonso, Souleiman Hasan, Umair ul Hassan, Christos Kouroupetroglou

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Name of the scientific representative of the project's co-ordinator, Title and Organisation:

Dr. Edward Curry, National University of Ireland, Galway

Tel: +353 91 492973

Fax: +353 91 495541

E-mail: edward.curry@insight-centre.org

Project website address: http://www.waternomics.eu

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Author name(s):	Wassim Derguech NUIG-DERI Edward Curry NUIG-DERI Sander Smit BMC Eoghan Clifford NUIG Thomas Messervey R2M Domenico P erfido R2M Louise Hannon NUIG Schalk-Jan van Andel IHE Leonardo Alfonso IHE Souleiman Hasan NUIG-DERI Umair ul Hassan NUIG-DERI Christos Kouroupetroglou Ultra4
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Executive Summary

Climate change, increased urbanization and increased world population are several of the factors driving global challenges for water management. In fact, the World Economic Forum has cited "The Water Supply Crises" as a major risk to global economic growth and environmental policies in the next 10 years. In parallel, the United Nations has called for intensified international collaboration.

To help reduce water shortages, Waternomics explored the technologies and methodologies needed to successfully reduce water consumption and losses from households, companies and municipalities. Waternomics, a three-year EU-funded project that started in February 2014, developed and introduced ICT as an enabling technology to (i) manage water as a resource, (ii) increase end-user conservation awareness and affect behavioural changes, and (iii) to avoid waste through leak detection. In saving water, energy will also be conserved (treatment and pumping) as will carbon emissions associated with energy production. Unique aspects of Waternomics include feedback about end-user water consumption, the development of a methodology for the design and implementation of systematic and standards-based water resource management systems, new sensor hardware developments to make water metering more economic and easier to install, and the introduction of fault detection diagnosis to the analysis of water consumption data.

Waternomics demonstrated its results in four high impact pilots that target a wide range of end-users/stakeholders: (1) Domestic users in Greece implemented by a water utility (Thermi), (2) Corporate operator in Italy of a major airport (Linate, Milan) and Public and (3) Two mixed-use demonstrations in Ireland (a school and a large university building at NUIG).

The project proposes a standards-based methodology that provides a set of knowledge, tools and references related to water efficiency and water management to help the different end-users targeted by the project in implementing a water management plan. Waternomics delivered a Real-time Linked Water Dataspace where water data is made available for application developers as a one-stop-shop for the required data. The dataspace features a pay-as-you-go management of its datasets, entities and applications. It has been used for the development of more than 20 applications that serve diverse user groups in 4 smart water management environments and provided relevant data for effective water data analytics to raise awareness and detect faults. The water saving opportunities identified at the different pilot sites (around 27,000 m^3/year) and their estimations in terms of costs (around 37,400 Euro/year) and CO_2 emissions (around 27,500 Kg CO_2/year) convinced building managers to take effective actions such as fixing their water networks (e.g., in Linate and CnaC) or further expanding the Waternomics platform to other areas (e.g., SEA plans to expand it to Malpensa Airport).

From an economic point of view, two key objectives of Waternomics were to maximise the business impact of the project and to enable post-project exploitation of project results. To create a link with markets and target customers, business design activities were defined that operated in parallel with the research and development activities. The goal of the business design activities was to identify markets and customer segments that could benefit from solutions based on technologies and methods developed within Waternomics and present viable value propositions. To this end, six exploitable results have been identified that the project partners will use in their future demonstrators, products and commercials service offerings. In addition a new company including outputs of Waternomics, named iSENSIT, was established in 2016.

The project results have been published in 26 papers written in collaboration between researchers from ICT and Water management sectors. More than 140 dissemination activities were carried out to approach a wide audience and disseminate the project results. This report summarises the key activities, development and results of the project.

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1. Project Objectives and Key Contributions

Climate change, increased urbanization and increased world population are several of the factors driving global challenges for water management. In fact, the World Economic Forum has cited "The Water Supply Crises" as a major risk to global economic growth and environmental policies in the next 10 years. In parallel, the United Nations has called for intensified international collaboration. The need for more effective water management measures can be seen from the following statistics taken from the Europe 2020 Flagship Initiative Innovation Union [1], the Commission's initiative on Smart Cities and Communities [2] and the European Innovation Partnership on Water [3]:

- Global energy and water demand is expected to rise 40% over the next 20 years
- By 2025, 1.8 billion people will live in water scarce regions and two thirds subjected to water stress
- 20-40% of Europe's water is being wasted
- Water supply and sanitation is a large energy consumer. In California (for example) it represents 19% of electricity and 30% of natural gas consumption
- Current water consumptions and behaviours are not sustainable and we are almost crossing the global sustainable environmental threshold (tipping point)

Europe has the opportunity to pursue a global leadership position in water-related ICT technologies

To help reduce water shortages, Waternomics explored the technologies and methodologies needed to successfully reduce water consumption and losses from households, companies and municipalities. Waternomics was a three-year EU-funded project that started in February 2014 that developed and introduced ICT as an enabling technology to manage water as a resource, increase end-user conservation awareness and affect behavioural changes, and to avoid waste through leak detection. In saving water, energy will also be conserved (treatment and pumping) as will the carbon emissions associated with energy production. Unique aspects of Waternomics include personalized feedback about end-user water consumption, the development of a methodology for the design and implementation of systematic and standards-based water resource management systems, new sensor hardware developments to make water metering more economic and easier to install, and the introduction of fault detection diagnosis to the analysis of water consumption data.

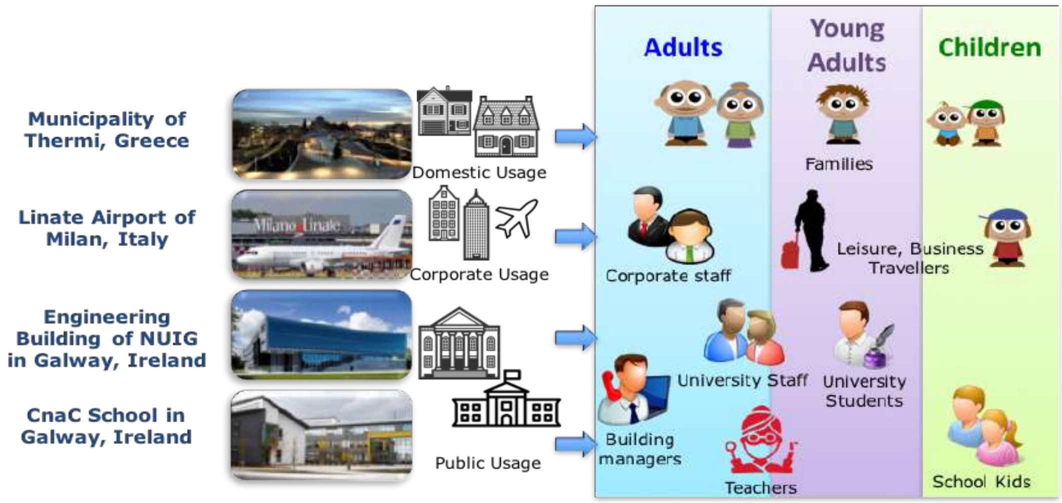


Figure 1: Waternomics targets a wide range of end-users

Waternomics demonstrated its results in four high impact pilots that target a wide range of end-users/stakeholders as shown in Figure 1:

- Domestic users in Greece implemented by a water utility (Thermi)
- Corporate operator in Italy of a major airport (Linate, Milan)
- Two mixed-use demonstrations in Ireland (a school and a large university building at NUIG)

Through these contributions, Waternomics initiated a new dialogue between water stakeholders. It enabled the introduction of Demand Response principles and open business models through an innovative human centric approach that uses personalized water data. To maximize impact, the project highlights business development, exploitation planning, and outcome oriented dissemination.

1.1. The Water Information Challenge

The key problem addressed in Waternomics is the lack of water information, management and decision support tools that present meaningful and personalized information about usage, price, and availability of water in an intuitive and interactive way to end-users. This introduces limitations in the efforts to manage water as a resource which including the following:

- **Awareness**: End-users do not have access to water information (i.e. availability, consumption, pricing) at the moments that decisions about water consumption are being taken to make behavioural change.
- **Incentive**: Due to billing, pricing, awareness or metering aspects, end users may not have an incentive to make behavioural change.
- **Information provision**: Decision makers do not have access to information platforms to make organizational change.
- **Integration & Analysis**: Personalized water information can only be created by combining publically available water information with private water usage information only available to water service providers.
- **Methodology**: Guidelines for water management system design are lacking.
- **Faults**: Poor behaviour, organizational errors, systems faults and water losses go undetected.
- **Benchmarking**: End users at all levels do not know if their individual water consumption pattern is high or low compared to similar users.

The root cause is that in developed countries, water has not been adequately considered as a resource. The result is that our water infrastructure, business models, and behaviours at all levels of the water value chain reflect this fact. Subsequently, the drive to develop and implement ICT in the sector is lagging. However, there is the significant opportunity to accelerate the development and implementation of ICT-based water awareness, management and conservation solutions by following best practices and lessons learned from the energy markets. These include monitoring devices and services, dashboard interfaces, decision support tools, energy passports, energy labelling schemes, smart meters, variable pricing schemes, demand response, demand management, peak clipping, and peak shifting amongst others.

1.2. Waternomics Goal

With this background, the goal of the Waternomics project was to provide personalised and actionable information about water consumption and water availability to individual households, companies and cities in an intuitive and effective manner at a time-scale relevant for decision-making. Access to this information helped increase end-user awareness and improved the quality of the decisions from decision makers regarding water management and water governance. Waternomics accomplished this by:

- Combining water usage and related information from various sources and domains to offer water information services to end-users
- Making water usage related information accessible across devices and locations
- Supporting personalised interaction with water information services
- Conducting knowledge transfer from energy management systems to water management systems
- Enabling the sharing of water information with public users
- Showing that generic water information services can be used in a variety of environments, geological, environmental and social
- Enabling open (collaborative) business models and exploitation activities to facilitate the market

uptake of the project outcomes

Waternomics used both new and state of the art sensors and water meters to provide new services (applications) and add new features like leakage detection, fault detection and water awareness games. These services were bundled into the Waternomics Information Platform, or short name, Waternomics Platform. As shown in Figure 2, this platform was able to manage sensor data, integrate multiple sources of data, and driving the development of new water services and applications.

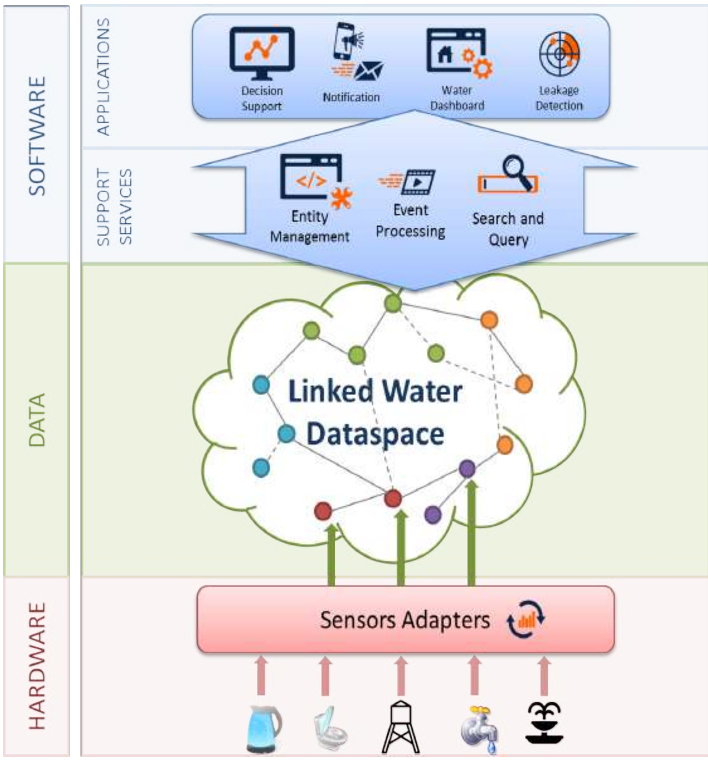


Figure 2: Overview of the Architecture of Waternomics Platform

1.3. Key Contributions

A standards-based methodology [4][5] that provides a set of knowledge, tools and references related to water efficiency and water management to help the different end-users targeted by the project in implementing a water management plan. Use of the developed methodology provides a standard-based pathway that can lead to both organizational change (management procedures) and individual change (behaviour change) and serve as a manual or guideline on how to get started. As shown in Figure 3, the Waternomics methodology has been tested and validated with the four pilots of the project.

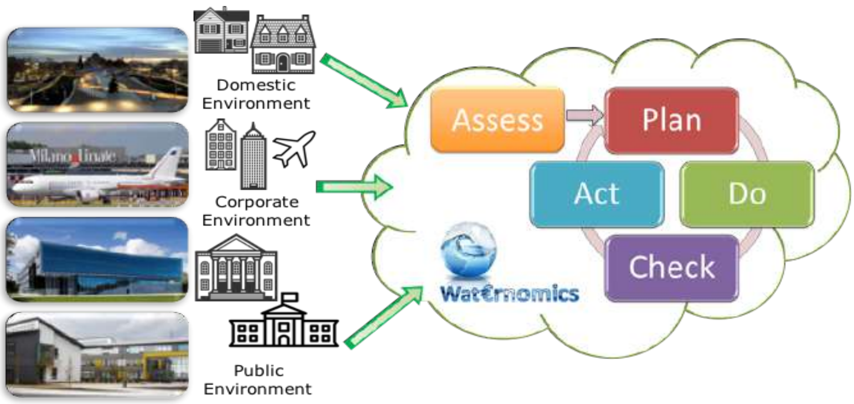
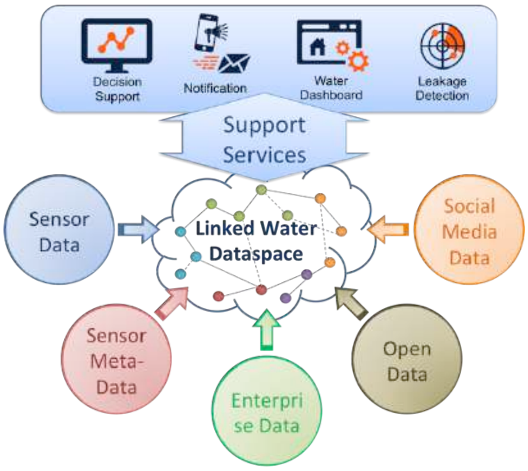
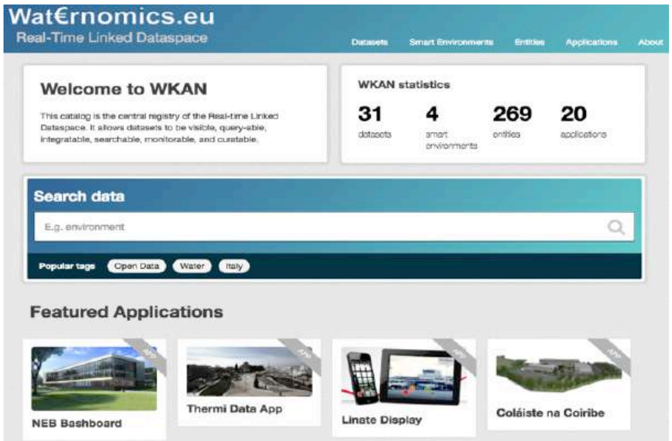


Figure 3: Four Pilots Managed with the Waternomics Methodology

A Real-time Linked Water Dataspace [6]: a collection of water datasets along with a set of services that supports the dataspace. The dataspace is designed to be an incremental view of how water datasets join the computational space targeted by applications. In contrast to the classical one-time integration of datasets that causes a significant overhead, the Linked Water Dataspace adopts a pay-as-you-go paradigm. Water datasets join the space in an incremental manner: the more interfaces they expose, the more links they provide, and the more linked dataspace services they support, the more integrated into the dataspace they become. Figure 4 (a) shows the types of data in use in the real-time linked water dataspace that includes: sensor data, enterprise data, open data, etc. These data sources are relevant to application developers that require search and cataloguing facility that is realised by a customisation of CKAN [1] [7] into WKAN (see Figure 4 (b)).



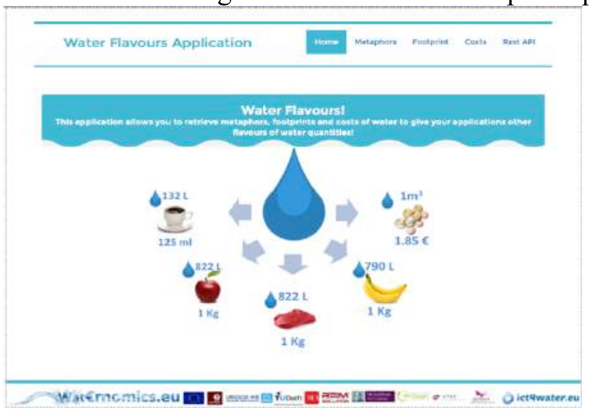
(a) Multiple Sources of Data



(b) WKAN an adaptation of CKAN data catalog

Figure 4: Real-time Linked Water Dataspace: An Incremental Data Management Paradigm

Smart Water Applications [8]: more than 10 support services and 20 applications have been developed by the Waternomics team to serve all the user requirements identified within the project. Some of these applications are depicted in Figure 5. Users are also offered the possibility to create their own apps (similar to Figure 5 (a)) for personalised and targeted water usage analysis. A market place for these apps to be shared among all users has also been put in place for enhancing social sharing of applications.



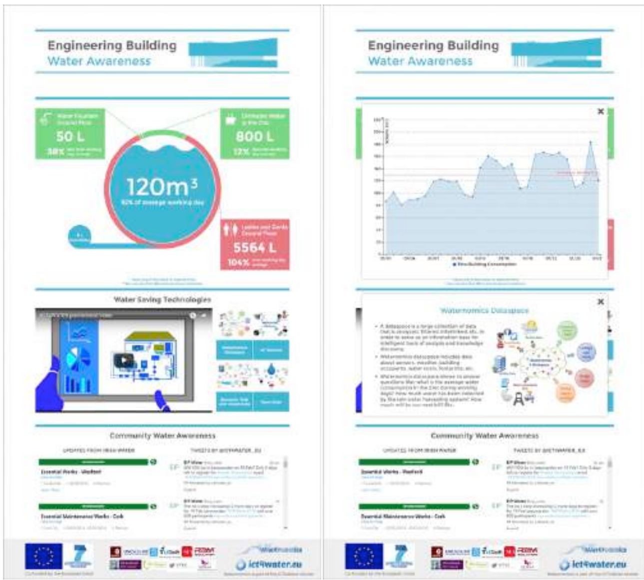
(a) Screenshot of the landing page of the Water Flavours application

(b) *Wearable Notification Centre for Smart Water Management*

[1] CKAN is an open source data portal developed for storing datasets and their descriptions. Available at http://ckan.org/

(c) *Public Kiosk at Linate Airport*

(d) Public Display at NUIG



(e) Public Display content at NUIG

(f) Public Display at CnaC

Figure 5: Wide Range of Waternomics Applications to Serve Diverse Users' Needs

Economic and easier to install sensors [9]: Through an extensive testing and validation of Ultrasonic flowmeters (see Figure 6 (a)), Waternomics was able to supply smart meters that offer a minimally invasive metering solution for mid-range pipe sizes with installation costs significantly lower than those associated with retrofitting inline solutions to existing pipes. Furthermore, Waternomics developed an acoustic leak detection sensor (see Figure 6 (b)) as an economic and easy to install solution for domestic environments.

(a) Ultrasonic flow meter

(b) Acoustic leak detection sensor

Figure 6: Two Prototype Sensors: Ultrasonic and Acoustic Leak Detection Sensors

Fault Detection and Diagnosis (FDD): Various techniques for fault detection and diagnosis have been implemented and tested within the Waternomics pilots. A Shazam-like acoustic leak detection technique [10] for domestic environments has been validated by IHE partner and installed in NUIG pilot. A rule-

based FDD method has been implemented for the verification of potable water freshness and the analysis of the water network in NUIG pilot [11]. This method identified important water saving opportunities related to the malfunctioning of the Rainwater Harvesting System. A model-based FDD has been implemented in Linate pilot [12] for the analysis of its water network. The results showed important leaks due to the imbalance between water pressures within the network. Finaly, a drought monitoring application has been implemented for the identification of drought periods for all the pilot sites. The application is set to make building managers aware of drought periods.

Business Models [13]: The Waternomics Platform is the collection of sensors, applications, data platform and the Waternomics methodology. Together they form a smart water system, aimed at industrial users, domestic users and water utilities. With such a diverse range of customer segments one cannot speak of a single business model for the Waternomics platform. It is more likely that multiple products and services offer parts of the smart water solution and that solutions for specific customer groups will be developed. Nevertheless, on a more abstract level, it is possible to aggregate these solutions and place them in a single business model canvas, as shown in Figure 7.

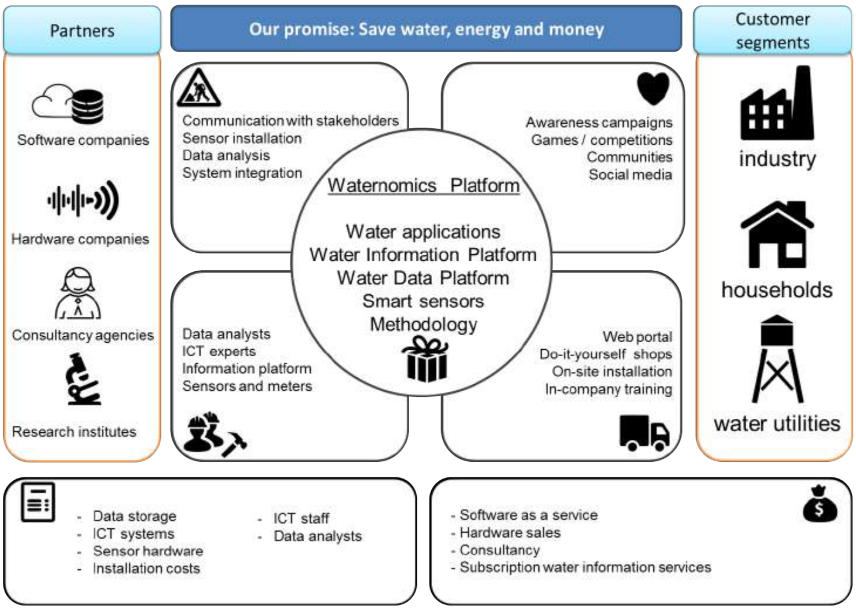


Figure 7: Business model Waternomics platform

Targeted dissemination and exploitation activities: One of the objectives of Waternomics is to maximise the business impact of the project and to prepare post-project exploitation of project results. To create a link with markets and target customers, business design activities have been defined who run in parallel with the research and development activities. The goal of the business design activities is to identify markets and customer segments who can benefit from solutions based on technologies or methods developed within Waternomics and to come to viable value propositions.

All of these key results will be detailed in the following sections.

2. Main Scientific and Technological Results

2.1. Overview

This section gives a summary of the key scientific and research results of the project and describes the main contributions to research and innovation in related domains. The main scientific and technological results include:

- The identification of **usage case and exploitation scenarios** took place in WP1. This contribution helped identify the key players for the exploitation of Waternomics results. Detailed in Section 2.2.
- The **inventory of technology, standards and policies** related to smart water management has been investigated as part of WP1. The inventory helped identify the required assets that needed to be considered in the project as well as gap where the project can guarantee a significant impact. Details are discussed in Section 2.3.
- A standard-based **methodology** for the development and implementation of ICT-enabled water management programs was proposed as part of WP2 efforts. The methodology was validated through the planning and execution of the four pilots. Details are discussed in Section 2.4.
- WP3 results are centred towards the Waternomics Information Platform, discussed in Section 2.5, that can been split into these contributions:
  - **Real-Time Linked Water Dataspace** that serves as one-stop-shop for relevant entities and data sources for the development of water data services and applications. Details are in Section 2.5.2.
  - **Support services and Component libraries** for accessing, analysing and visualising data from the linked water dataspace. Details are in Section 2.5.3.
  - Multiple **Waternomics apps** for serving a diverse range of end-users ranging from kids to adults, from casual to professional users, etc. Details are in Section 2.5.4.
- WP4 investigated techniques for the identification of water network issues. The results from this work are as follows:
  - A **Shazam-like leak detection** [10] approach has been proposed as an acoustic leak detection hardware and software for domestic environments. Details are in Section 2.6.1.
  - At the Linate Airport pilot, a **model-based fault detection and diagnosis** [12] approach has been implemented. It consists of analysing a complex water network for identifying potential leaks due to water pressure instability/incompatibility. Details are in Section 2.6.2.
  - At the NUIG university building pilot, a **rule-based fault detection and diagnosis** [11][14] approach has implemented to identify where underused drinking water fountains may require flushing due to long period of residency of water in pipes. Details are in Section 2.6.3.
  - In collaboration with the EU Joint Research Centre's European Drought Observatory (EDO), **drought-monitoring** data for the project pilots was exposed in the form of a service for notifying end-users about drought periods in their regions. Details are in Section 2.6.4.
- One of the results of WP7 concerns different **business models** [13] and **value propositions** that have been designed with the purpose to make commercialisation of the Waternomics Platform viable and sustainable. Details are in Section 2.7.
- Using the functionality of the Waternomics platform, WP7 proposed the concept of a customer-centric Water Bill. The idea was to explore which information should be presented to customers to support behavioural change towards optimal water consumption. Details are in Section 2.8.

Finally, Section 2.9 gives an overview of the execution of the fours pilots of the project with highlights on the results and impact of the project outcomes.

2.2. Usage case and Exploitation Scenarios

It is apparent that the lack of water information, management and decision support tools that present meaningful and personalized information about usage, price, and availability of water to end-users, hinders the efforts to manage water as a resource. Waternomics addresses these issues using innovative information, communication and technology (ICT) tools.

In the first phase of project and as part of WP1 activities, the consortium analysed the water information market in order to define a business strategy for successfully deploying a water information platform and to gain insight into customer needs. As water information services are targeted to public, domestic and corporate users, deliverable D1.1 analysed both public and commercial perspectives by engaging key stakeholders and employing **Value Network Analysis**, Business Modelling and Scenario & Storytelling techniques. The Value Network Analysis describes the relevant parties in a business ecosystem and their interrelations. Business Modelling was used to understand how key resources and activities ensure relevant value propositions are brought to customers and also how Waternomics impacts various stakeholders from a business point of view. **Scenarios and storytelling** were used effectively to understand and present the user context in which water information services are deployed. Figure 8 outlines the steps in creating the three scenarios. The specific pilot sites chosen for the Waternomics project are a subset of the generic scenarios described in Table 1.

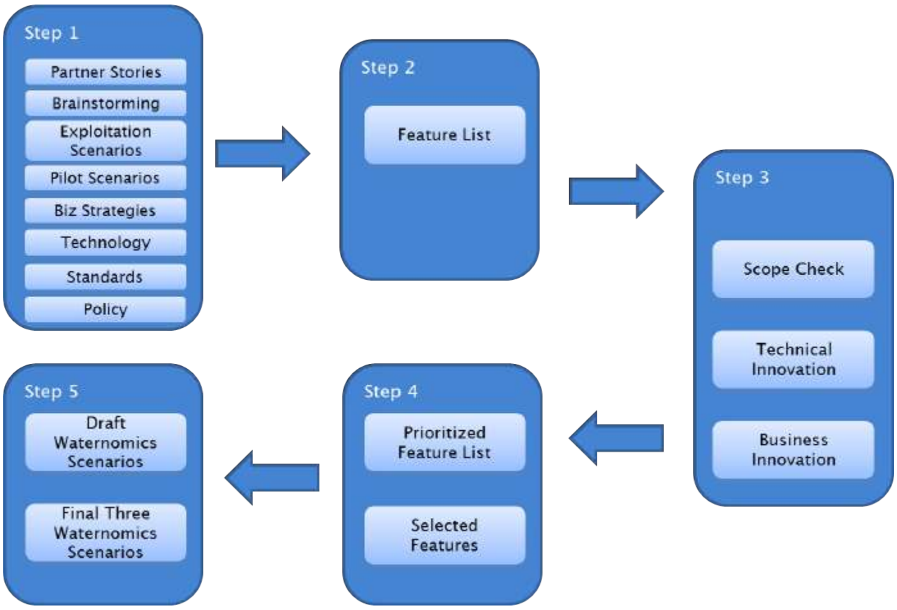


Figure 8: Graphical representation of the scenario development process

Table 1: Pilot Sites relevant to Exploitation Scenarios

Scenario	Relevant Pilot Site
Domestic and Public Users	Galway, Ireland & Thermi, Greece
Commercial operation/Industry	Linate Airport, Italy
Municipalities	Thermi, Greece

Secondly, Waternomics provided a template for specifying the features of an information platform, particularly one that engages a wide variety of users. Initially, based on desk research and stakeholder engagement, a long-list of **possible features** for water information services was developed. A methodology was developed to shortlist and rank potential features of Waternomics that addressed the key requirements of domestic and public users, corporate users and municipalities. After processing the shortlisted features in three usage scenarios it was observed that, while on a conceptual level water information services look similar across target user groups, the market is very fragmented and no single solution can serve all customer needs. The work in Waternomics demonstrated that a water information

platform should be designed to be modular, interoperable and scalable with considerable engagement with end-users necessary before defining the information platforms architecture and features.

The **market research** undertaken in Waternomics indicated increased uptake of water information services from water utilities, energy providers and suppliers of home automation. The risk of independent (non-interoperable) solutions and technologies is apparent. The consequence is that next generation water information services will face a fait accompli and cannot build on the first-generation services, delaying and increasing the cost of integrated water management systems. Thus, the consortium concluded that the Waternomics platform, and indeed any such platform, needs to be cognisant of developments in water information platforms in the home, energy and industry sector. It should be adaptable and be able to incorporate "new" data and forms of data and utilise these as required.

Finally, the role of **key players** in **exploiting** Waternomics is highlighted with actors vary from large companies that have internal skills to purchase and utilise Waternomics, to utilities and smaller business that may rely on consultants to advise on and provide such solutions. Thus, Waternomics tried to be adaptable to various business strategies and be an attractive addition to existing service offerings from engineering, management or sustainability consultants.

2.3. Inventory Technology, Standards and Policies

The project provided a review of releant **state-of-the-art technologies** and an assessment of **policies and standards** that govern the implementation and use of these technologies by utilities and water users. This work set the focus of Waternomics to ensure the innovations that derived were relevant to the industry. As such, in the context of Waternomics, and indeed with a view to a wider audience, deliverable D1.2 documents water ICT technologies, policies, and standards that decision makers should know.

The work in this area builds upon the 'Usage case scenarios and Initial Exploitation Scenarios'. The project partners discussed and agreed upon which uses and **stakeholders** should be considered, and agreed, with reference to numerous external stakeholders the project key outcomes (usage cases and exploitation scenarios).

Waternomics also provided a **technology inventory**, which compiles a set of technologies that complete the building phases of the Waternomics platform. A thorough technology inventory was developed for: i) hardware - which compiles different types of sensing technology (see Figure 9), ii) an inventory of data platforms, and iii) several technologies available to build the platform such as back and front-end application frameworks or mobile app development technologies.

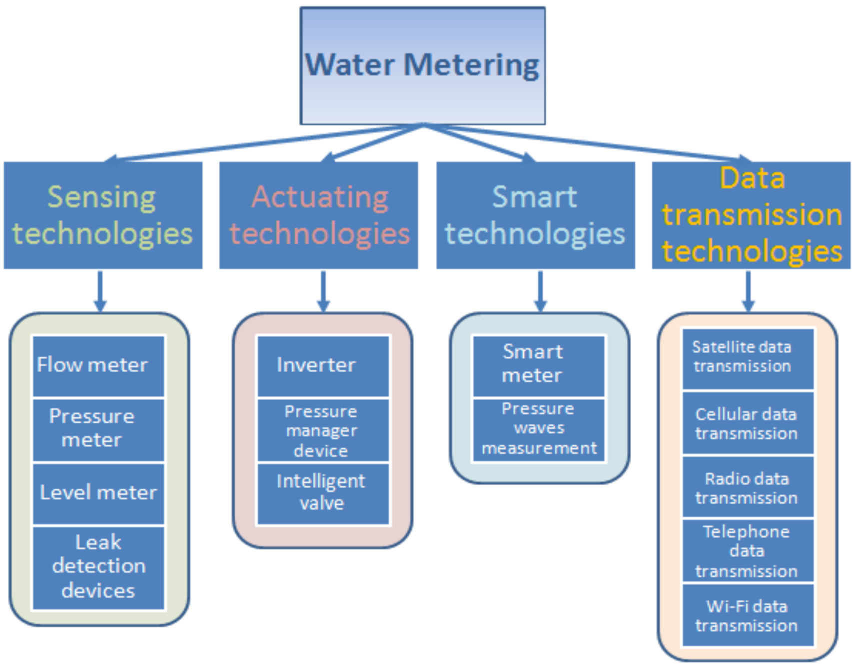


Figure 9: Organizational scheme of the reviewed technologies in "Water metering"

Finally, Waternomics elaborated how **policies and standards** can positively influence the adoption of 'smart' water technology and refers to different policies, standards and pointers of information including organizations and IT-driven initiatives. Table 2 highlights these organizations and initiatives.

Table 2: European influential groups on Smart Water Technology

Name	Description
European Innovation Partnerships on Water	The European Innovation Partnership on Water (EIP Water) was established in 2012. It aims to speed up development of water innovation, contribute to sustainable growth and employment, stimulate the uptake of water innovation by market and society and support the implementation of EU ICT developed technology
International Water Association (IWA)	IWA is a worldwide network for water professionals and companies. The IWA network is structured to promote multilevel collaboration among its diverse membership groups, and to share the benefits of knowledge on water science, technology and management worldwide
European Water Association (EWA)	EWA comprises of 25 European national associations representing professionals and technicians in the fields of wastewater and water utilities, as well as academics, consultants and contractors. In 2012, EWA published the third issue of the Water Manifesto, a document aiming to spotlight important current water issues in Europe, and to propose their resolution via the sustainable management and use of water resources
European Technology Platform for Water (WssTP)	Initiated by the European Commission in 2004, the WssTP strives to promote coordination and collaboration of research and innovation in the European water sector, while at the same time boosting its competitiveness. The WssTP comprises 101 members and has a network of more than700 individuals and 315 contributing organisations across 18 countries. The WssTP aims to actively facilitate and encourage members' involvement in research and innovation projects whose outcomes contribute to resolving the water-related challenges Europe is facing
European Federation of national Associations of Water Services (EUREAU)	EUREAU represents water and wastewater operators at EU level. EUREAU promotes the common interests of its members within EU institutions and keeps its members informed of relevant developments in the European arena

2.4. Waternomics Methodology

One of the main results of Waternomics project is the development of a standards-based methodology [4][5] for the development and implementation of ICT-enabled water management programs. The methodology points out constraints, standards, corporate preferences, key performance indicators (KPIs) and it provides decision makers and designers with a systematic way to select technologies, measurement points, data collection methods, and data management techniques for ICT-based water management systems. The methodology drives the implementation of a physical measurement framework to be applied in the four Waternomics pilot sites in order to achieve the project's results and implement a smart water management system. The developed methodology, which in itself is a new development for the water sector, has five phases: Assess, Plan, Do, Check, Act (as detailed in Figure 10). These phases are intentionally similar (with the exception of Assess being added as a first step to engage users) to those of ISO50001 (Energy Management Systems). In this way, environmental managers and the organizations, staff and service providers that work with them will immediately recognize the correlation between energy efficiency and the desired outcome of water efficiency.

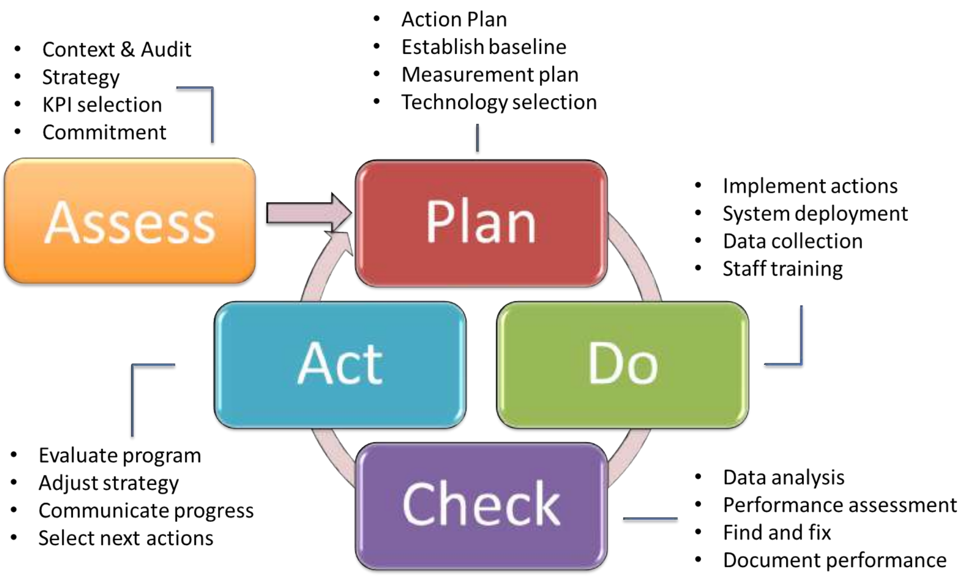


Figure 10: Waternomics Methodology Overview

Other standards that many stakeholders will recognize include ISO50002 (Energy Audit), IPMVP (measurement and verification planning), and ISO14046 (Water Footprint). In this way, a comprehensive and holistic standards-based approach is established. For each of the phases, the steps to carry out and implement the methodology are provided. The methodology is customised to the water sector in areas including energy-water relationships, water related KPIs, technology selection tools, rules to design physical measurement frameworks and assessment mechanisms.

The desired outcome of the Waternomics methodology is that decision makers and end-users at the community, corporate or home levels have a framework, set of tools, and references that enable them to take action towards water efficiency measures and to enact water management programs. The methodology is customizable to the needs of different end-users and as such the report packages phases and activities to carry out the methodology into a number of discreet, concise and accessible summary briefs. The initial methodology is defined in D2.1, it was then implemented in the four pilots and the refined version of the methodology that incorporates lessons learned from pilot activities was detailed in D6.2 at the conclusion of the project.

2.5. Waternomics Platform

2.5.1 System Architecture

The system architecture is the conceptual model to define the structure and behaviour of Waternomics platform consisting of three layers: hardware, data and software (see Figure 11). Designing high-level system architecture was an important step towards providing a technical guidance to the development of Waternomics platform and each of the project pilots' solutions.

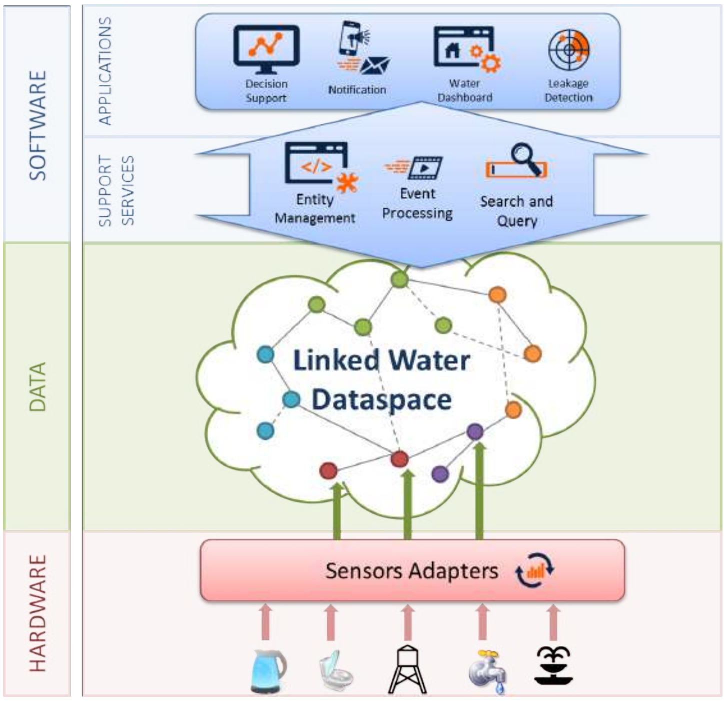


Figure 11: Overview of Waternomics System Architecture

The consortium analysed the usage case and initial exploitation scenarios in order to determine relevant **functional and non-functional usage requirements** to define the system architectural requirements that the project needs to cover in terms of hardware, data and software requirements. The project also identified **key performance indicators** for evaluation purposes in order to report on the success of the Waternomics platform and the identification of potential improvements. These architectural requirements were then mapped to a set of technologies. Finally, high-level **system architecture** tailored to Waternomics platform and the key performance indicators for evaluating the performance of activities in Waternomics project.

2.5.2 Real-Time Linked Water Dataspace

A dataspace is an emerging information management approach used to tackle heterogeneous data sources that support requirements such as standardization, enrichment, and linking of data in an incremental manner. The Real-Time Linked Water Dataspace [6][15] is a collection of water datasets along with a set of services that supports the dataspace. The dataspace is designed to be an incremental view of how water datasets join the computational space targeted by applications that has been experimented in different contexts [16][17][18][19][20]. In contrast to the classical one-time integration of datasets that causes a significant overhead, the Linked Water Dataspace adopts a pay-as-you-go paradigm. Water datasets join the space in an incremental manner: the more interfaces they expose, the more links they provide, and the more linked dataspace services they support, the more integrated into the dataspace they become.

In the approach adopted for the realisation of the Linked Water Dataspace, we considered the set of requirements identifiedin D1.3. By reviewing the current state of the art, the approaches listed in Table 3 were adopted for handling these requirements.

Table 3: Used Approaches for the Real-Time Linked Waster Dataspace

Requirement	Approach
Standardisation	Standard compliant ontologies such as SSN are used for describing sensors and their data. An entity management service that standardizes critical entities and maps their identifiers in different data sources. We extend CKAN data catalog for this purpose.
Consuming Open	One of the support services that are included in the dataspace consists of

Data	crawling weather data and integrating it in other services. Various open data can have various types/formats, and an app might not know which open dataset is relevant to a particular task. Users register each source in CKAN data catalog as an explicit indication of joining the dataspace. We provide custom adaptors for each data source to join the dataspace.
Publishing Linked Data	The produced data is published in RDF using linked data principles. We register each RDF source in CKAN data catalog as an explicit indication of joining the dataspace. Furthermore, we made the data available to query via an adapted version of OpenCube.
Data Linking	Relevant open data sources are integrated in the dataspace through explicit links between entities. We maintain high-level mappings in CKAN data catalog and low-level mappings maintained by each source.
Real-time data / events	The dataspace is designed with respect to the lambda architecture that covers real-time event processing. We use an event-processing engine for managing live sensor events, and deploy a scalable message oriented middleware for passing data between real-time sources and applications. We use middleware based on published/subscribe pattern, such as Apache Kafka, and Apache Spark Streaming for real-time aggregation jobs.
Real-time Analytics	Real-time analytics of data is considered in the platform as part of the speed layer of the lambda architecture. They seamlessly serve real-time and historical data in aggregated form to applications. We implement the serving layer of Lambda architecture using Metamarkets DRUID cluster.
Data integration	Lambda architecture in essence was used to deal with both historical and real-time data. This data integration is insured by relevant support services and follows a pay-as-you-go paradigm to ingest, integrate, and aggregate real-time data. We implement the speed and batch layers of Lambda architecture by employing Apache Spark for ingestion and aggregation of both real-time and historical data.
Heterogeneity of Sensor Data Events	The platform is designed to handle a variety of sensor types. Consequently, for each sensor type, a dedicated collector is designed for collecting data and make it available to query via DRUID. An event engine uses an approximate semantic matching model [21]–[28] to process sensor events.
Enrichment of Sensor Data Events with Open Data	Sensor readings are further enriched by dedicated support services using open data.

The Real-Time Linked Water Dataspace is a collection of water datasets such as weather data, water sensor data, building management system data, etc. Those form the actual content of the water dataspace. They are the basics for all the insights that can be drawn from the dataspace. Datasets can join and leave the dataspace. In fact, that can very dynamic such as in the case of dynamic sensor environments. Joining the dataspace requires some "cost" to be paid. This cost takes various forms: registration into a catalog so the dataset becomes visible by others, the conformance to a schema, or the mapping to other schema, the exposure of data into a set of formats such as the RDF serialization JSON-LD, etc. We adopt in the Linked Water Dataspace a pattern in which the publisher of the data is mainly responsible for paying this cost. This is a very pragmatic feature as it allows the dataspace to grow and enhance gradually.

While data is crucial for the dataspace, support services are the enablers that allow datasets to be visible, query-able, integratable, searchable, monitorable, and curatable. For instance, for a sensor to become visible to the dataspace, it must be registered in a catalog along with some information on how to get its data, how often and precise it is, etc. Other relevant services will be discussed in the following section. All the details of the Linked Water Dataspace are discussed in D3.1.1 and D3.1.2.

2.5.3 Support Services and Components' libraries

In order to facilitate the development of end-user applications using data from the Linked Water Dataspace, a number of services and component libraries are needed [20]. Support services and component libraries are key elements needed for effective analytics to drive decision-making: e.g., querying, entity management, and water usage analytics to raise user awareness of water consumption. Selecting, designing and implementing such support services and component libraries were an important step. Deliverable D3.2 detailes a number of support services component libraries that were either developed by the Waternomics team, or adapted from exiting open source projects. Services and libraries are classified in three categories:

- **Dataspace Services**: Represents the core services that the dataspace offers, including the search and query services, and the Catalog service that are detailed in Section 3 of D3.2.
- **Data Services**: Responsible for the analysis and maintenance of data within the dataspace. Services included in this category are: Data Analytics service, Entity Management Service and Event Processing Service that are detailed in Section 4 of D3.2.
- **Components and Libraries**: This category includes all components that help in the development of applications. They include the following components: Basic UI, Reporting and Graph, Notification, Social, Application Management and Dashboard Configuration that are detailed in Section 5 of D3.2.

<u>Dataspace Services</u>

The two core services of the Linked Water Dataspace are the Catalog and Query services. The Catalog service for the Linked Water Dataspace, also referred to as WKAN[1], is built on top of the CKAN[2] dataset portal. In essence CKAN is an open source data portal developed for storing datasets and their descriptions. Figure 12 shows the WKAN, a customized version of CKAN, with the added functionality to manage datasets and entities that are related to water management such as sensors, locations, and users.

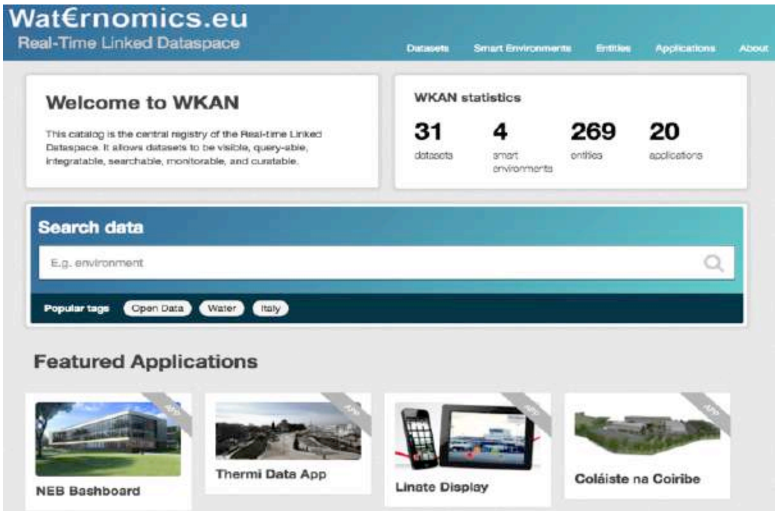


Figure 12: An overview of the WKAN: the CATALOG service for Linked Water Dataspace

The primary entities of the Waternomics dataspace are described in WKAN in a similar way to the datasets. Figure 13 shows some example entities in the WKAN. Some of these entities describe locations such as lecture rooms, while others describe water meters. Each entity has associated datasets that highlights that further information about the entity is available in the dataspace. This information can include, but is not limited to, raw sensor measurements, aggregated water usage stats, etc.

[1] Accessible at http://wkan.linkeddataspace.waternomics.eu:8001/
[2] Available at http://ckan.org/

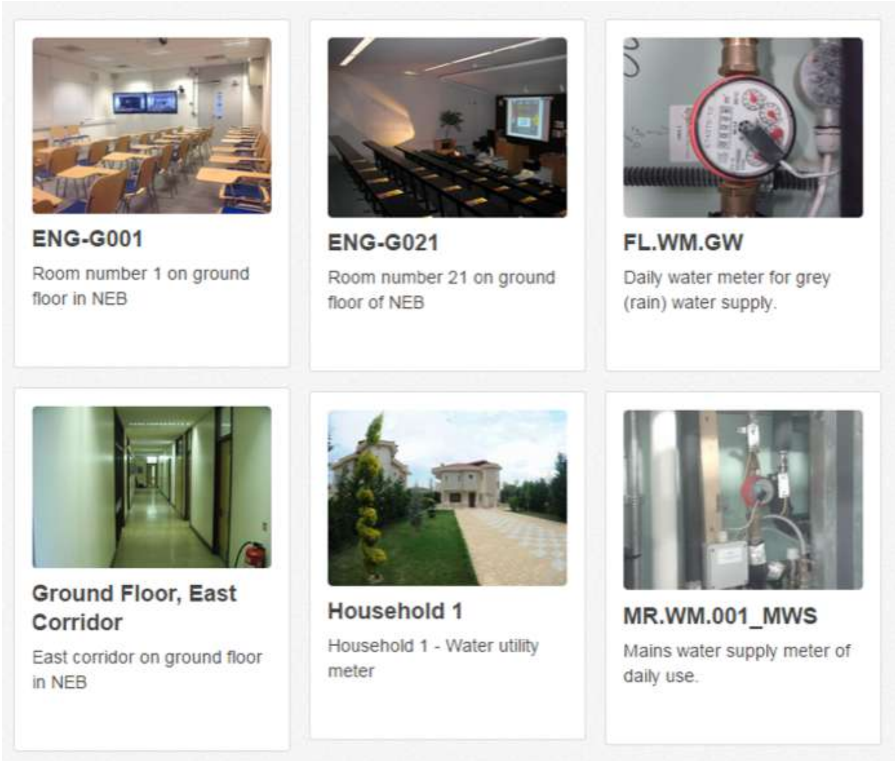


Figure 13: Entities for Waternomics defined in the WKAN

Registering a dataset with WKAN is the first step towards joining the dataspace. This enables applications and developers to access the dataset based on its description in the WKAN. In this regard, the WKAN serves a critical role in the management of the dataspace; therefore, it requires regular updates from dataset owners to ensure correctness of data descriptions.

The Query service is the second core service that concerns the technical aspects and processes of the dataspace that enable data access, through structured queries or RESTful API calls, to the applications. The Query service also addresses low latency and fault-tolerant data analysis. The used architecture to realize The Query service follows the Lambda Architecture recommendations [45]. The Lambda architecture [45] is a concept which is getting acceptance by Big Data researchers and practitioners. The Lambda architecture, as shown in Figure 14, realises the need for integrating water data within a data warehouse that is processed by batch processes and views that are pre-computed for fast access by applications. The Linked Data principles serve as a mediator to improve the integration within the batch layer for relatively not fresh data.

To provide applications with a single interface for data access, a serving layer is provided. This forms the query interface for the applications and is the visible facet of the dataspace QUERY service. This layer splits queries to the batch and speed layers to combine pre-computed results from the batch layer, with near-time fresh and maybe approximate results from the speed layer. In adition to the APIs and query endpoints provided by the individual data source, the Linked Water Dataspace also provides queries services over the WKAN catalog and integrated data sources.

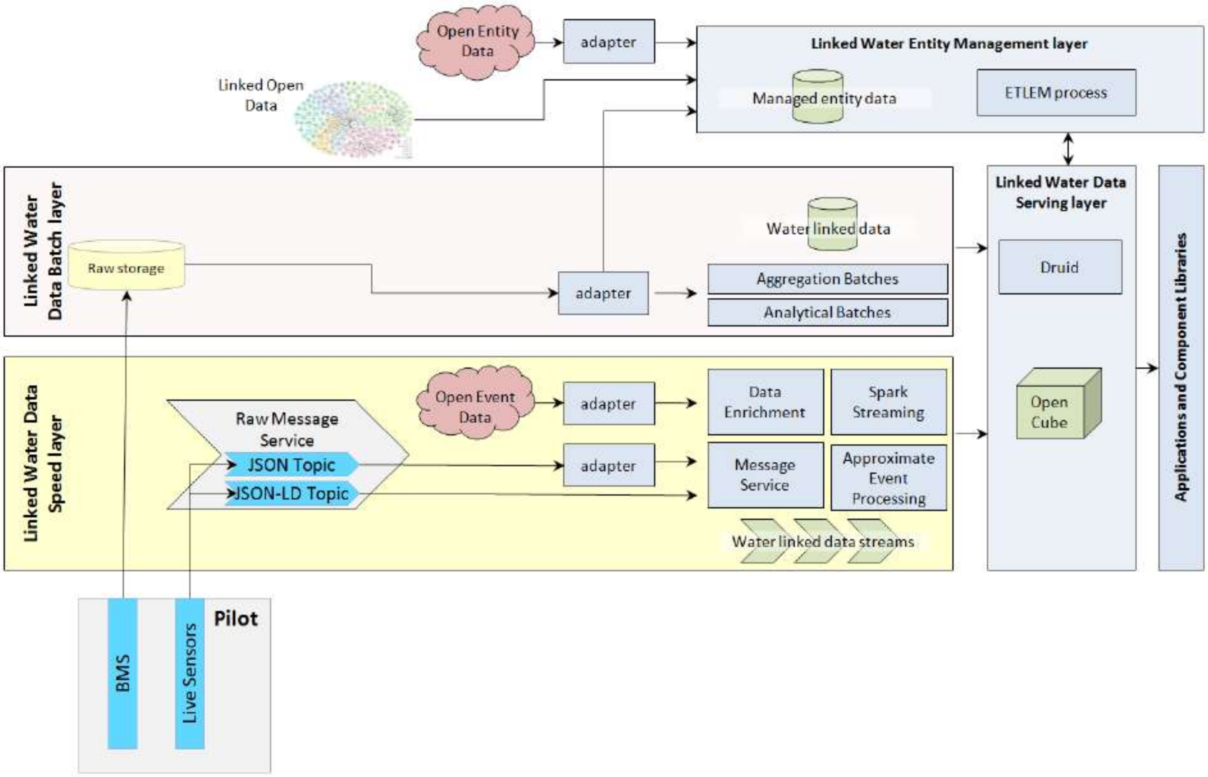


Figure 14: Linked Water Dataspace and the Lambda Architecture

Data Services

Two main services are considered in this category: event processing and data analytics services.

The **Event Processing Service** focuses on the semantic event processing and enrichment via the COLLIDER Engine [25]. The value of information coming from water flow sensors and other sensors increases when the latency of detection decreases. Thus, relying solely on batch processing jobs may cause a delay in the detection of a water leak.

The **Water Usage Analytics Service** allows analysing water consumption observed in a particular sensor or sensors and identifies potential problems such as unexpect over or under consumption of water, leaks or faults in the water network. The service uses statistical data analysis for identifying outliers. An outlier is an indication of an abnormal consumption that is notified to the end-users.

The steps that we follow for the Water Usage Analytics are depicted in Figure 15 and operate as follows:

1. The first step consists of classifying water usage readings while considering working and non-working days. Non-working days are either Saturdays and Sundays or public holidays that are retrieved from an Open Data source: Enrico Service[30].
2. For each set of readings, we compute its average and standard deviation. This is done while removing daily readings that contain 0 amounts.
3. For each value, its z-score is computed using the formula in Figure 15.
4. Filtering out outliers: an outlier is a reading which |z-score|>1.5

After filtering outliers from each set, the thresholds of the baseline are computed. A baseline thresholde value constitutes the decision points to evaluate whether a certain water usage is high or low.

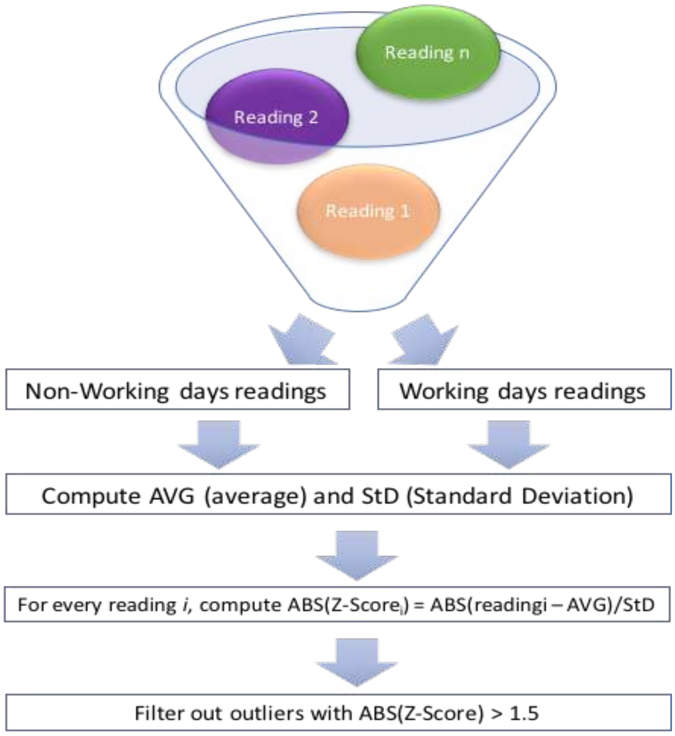


Figure 15: Water Usage Analytics: Filtering out Outliers

2.5.4 Waternomics Apps

Applications are the actual points of interaction between users with the data from in the Waternomics Platform. In total Wateromics developed 20 applications targeting 19 different user groups in the 4 pilot sites as highlighted in Figure 16. Dashboard applications are an example where users can easily adapt the platform to fit their needs (e.g. by customising or developing new views to meet their water information needs). This means that the actual individual application instances deployed is very high and quite dynamic since the same application is deployed multiple times for different user groups or even for the same user based on his/her individual needs. For this reason, the Waternomics Applications Platform is introduced as a flexible platform to make users create their own apps after a training session or following the video tutorials provided. Pilot-specific and device-specific applications developed as part of Waternomics are depicted in Figure 17 to Figure 21. All Waternomic apps are reported in detail in D3.3.

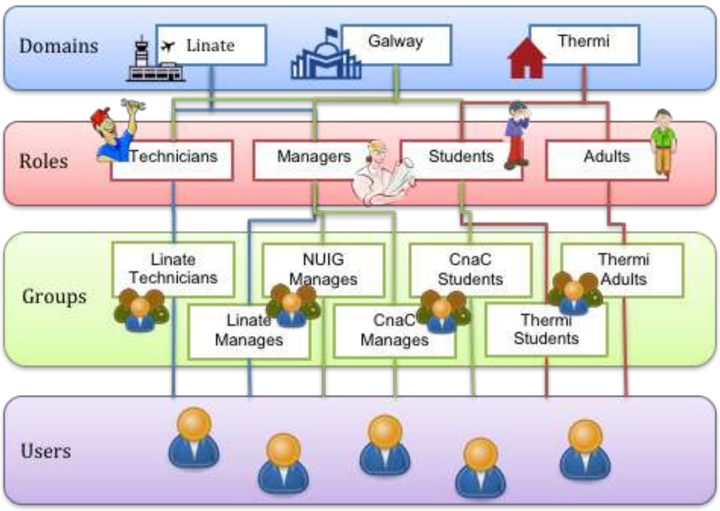


Figure 16: Sample of user management structure of Waternomics Applications Platform

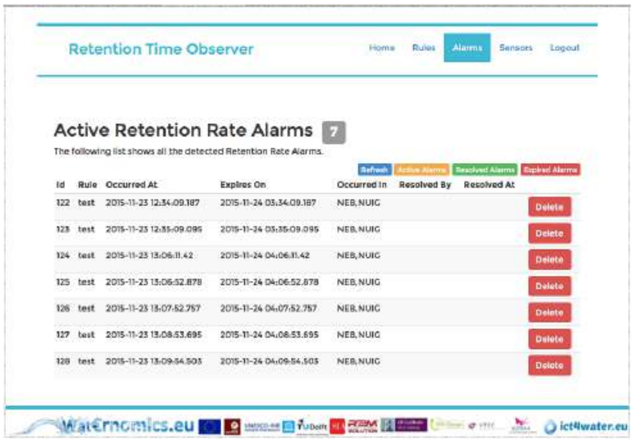


Figure 17: Retention Time Observer, Active Alarms

Figure 18: Goal-oriented Accessing water application

Figure 19: Public Display showing water data from the Engineering Building at the National University of Ireland

Figure 20: Wearable inforcentre, receiving notification from the water retention time observer

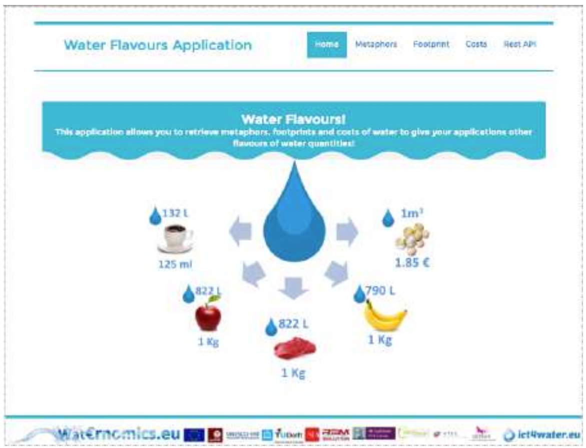


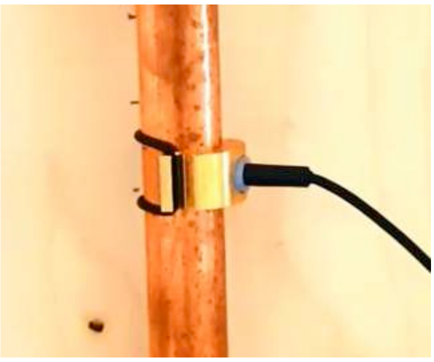
Figure 21: Screenshot of the landing page of the Water Flavours application

2.6. Leak and Fault Detection Diagnosis

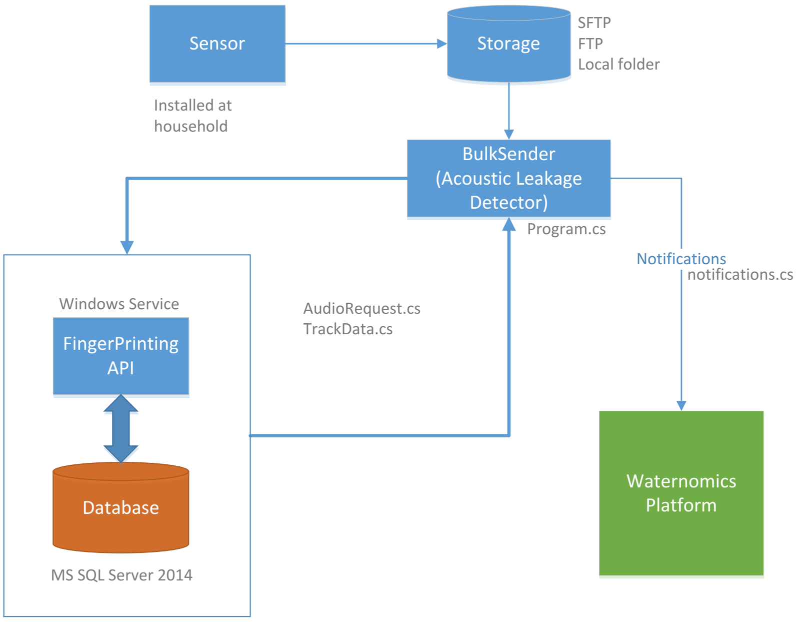
2.6.1 Shazam that Leak: Acoustic Leak Detection

Existing leakage detection methods are generally focused on scrutinising large diameter pipes in water supply distribution networks or transmission pipes. However, it has been estimated that the average household's leaks can be as much as 35 m^3 of water per year [10]. In order to solve the problem, analysis of different types of data in the household piping system is required. One conventional approach is to use flow sensors installed at several locations within the household piping system and perform a mass balance approach to detect leakage. However, this method is expensive and difficult to implement. Waternomics proposes a novel approach to household leakage detection by means of sound signal recordings. The approach consists of recording the sound signals that are produced by water fixtures and appliances, and then using these recordings to detect any abnormal situation that may be an indication of a leak.

The proposed method has two components, hardware and software. The hardware is the acoustic leak detection sensor (LDS), see Figure 22a, which is used to periodically record the sounds produced by household water fixtures and appliances when in use. The main feature of this sensor is high sensitivity, fast detection, low cost, easy-to-install, and non-intrusive which is suitable for easy detection of leakages in households. Detailed technical characteristics of the LDS are in D4.1.



(a)



(b)

Figure 22: Hardware (a) and software (b) components of the LDS

The software used consists of components that access the recorded files from different sources and store it in a database that is used to generate audio fingerprinting. The Fingerprinting algorithm can detect similarity between audio signals. The algorithm's principle is similar to the one used by the Shazam app to identify songs from music recordings. Details on the fingerprinting algorithm are presented in D4.1. Other additional algorithms have been created to facilitate the communication with the server storing the recordings, to communicate with the fingerprinting software and to create notifications. The most components are shown in Figure 22b.

The leak detection method has been validated in two different conditions, namely the lab and a household. The lab setup was made in order to design the sensor and to validate the complete information cycle sensor – server – fingerprinting – notification. The household setup was made in order to evaluate the performance of the method in real conditions.

Due to the nature of the method, it was validated in two stages, namely feed mode and detection mode. In feed mode, the software creates fingerprints of each sound recording and builds the database; in detection

mode, once the database is complete, the ALD software works like the Shazam app[1]: listen to new recordings, check if they exist in the database and retrieve the message found / not found. If not found, an abnormal situation is likely to be occurring, e.g., a leak. This process is shown in Figure 23.

The detection mode has been tested in the household with controlled conditions. The setup consists of installing the sensor between the water meter of the house and the first pipe ramification going to all appliances in the house. The sensor was connected to a Raspberry Pi, which in turn was connected to Internet by means of a wired connection.

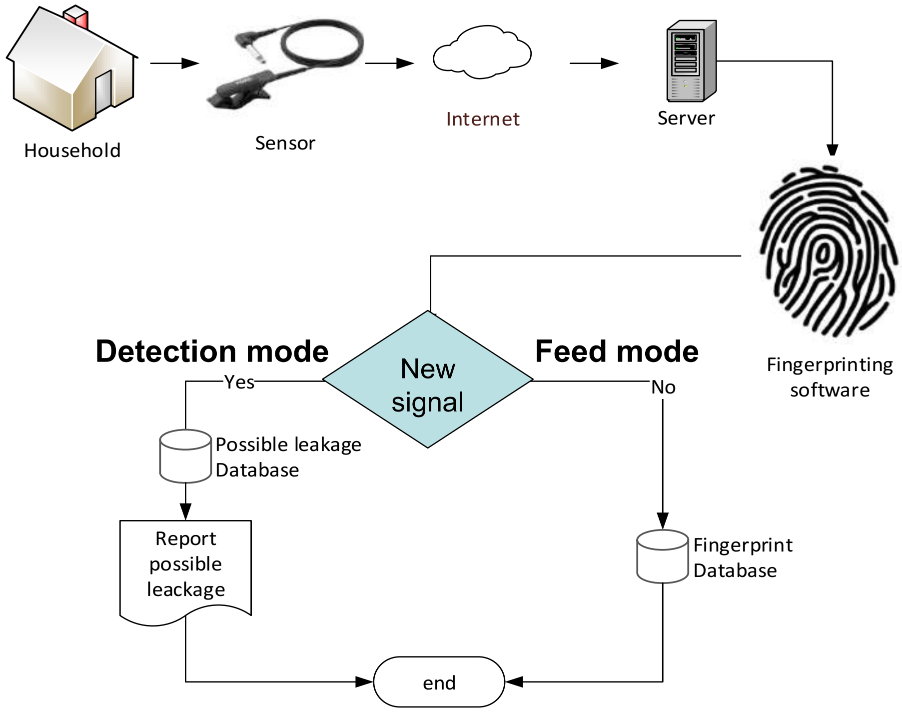


Figure 23: General approach for household leak detection using fingerprinting signals

Figure 24: Setup at household for detection mode

2.6.2 Model-based Fault Detection and Diagnosis

A model based Fault Detection and Diagnosis (FDD) method consists of modelling a water network and appling an anomaly detection algorithm over that network to identify if it contains any faults.

Within the Waternomics project, the Linate pilot water network was chosen to implement the model based FDD because it has a large water distribution system. We focused on the development of a

[1] Copyright Shazam Entertainment Limited. More info: www.shazam.com

hydraulic model of the water network of this pilot site by using the EPANET software coupled with an anomaly detection algorithm (ADWICE [12]) that is able to get data both from the Hydraulic model and the meters installed to find whether there is a leakage in the water network. The principle behind the model-based FDD is the following: the software model simulates the hydraulic dynamics (in terms of pressures at nodes and flows through pipes) of the water network in normal conditions (i.e. assuming no leakages are present). By comparing the outputs of the hydraulic model (pressure and flow data) with the real-time data gathered from the pressure and flowmeters installed in place, the algorithm (ADWICE) will point out whether abnormal conditions are occurring in the Water Distribution System (WDS) arising an alert that will be shown in the Waternomics Platform. The outputs of the hydraulic model performed both in the scenario without and with leakages in the water network are summarized in Figure 25, Figure 26, and Figure 27. Figure 25 shows the pressure set points in the water network when no leakages are introduced in the water network. As we can see no junction has the pressure under the value of 1 bar (10 m H2O).

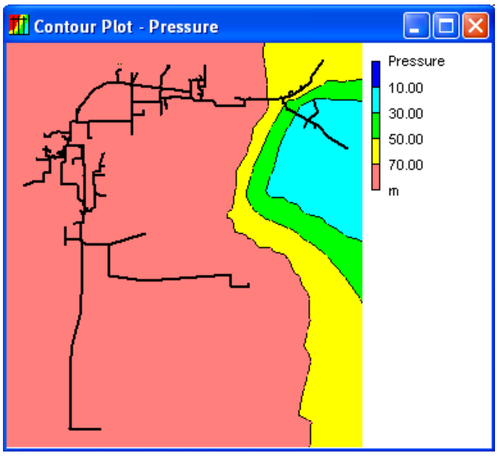


Figure 25: Pressure for the water distribution system model without leakages

Figure 26 shows how the pressure operational values change in the water distribution system after the introduction of a virtual leakage in one of the junctions. The leakage, as expected produces a drop in the pressure located to the area where the leakage is established. We can highlight how the pressure in the main part of the water network is not affected by the local leakage. Figure 27 shows the pressure operational values change in the water distribution system after the introduction of many virtual leakages. The operational conditions of the water distribution system change in every single junction of the water network.

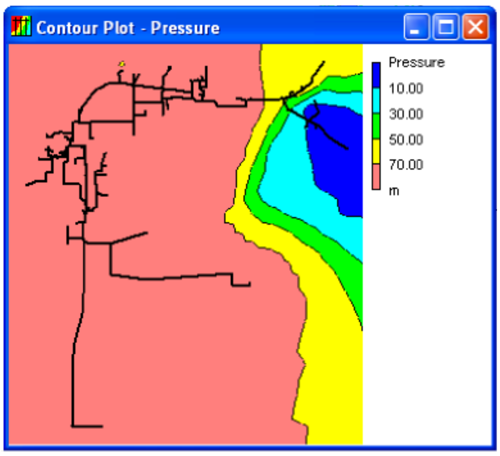


Figure 26: Pressure for the water distribution system model with one leakage scenario

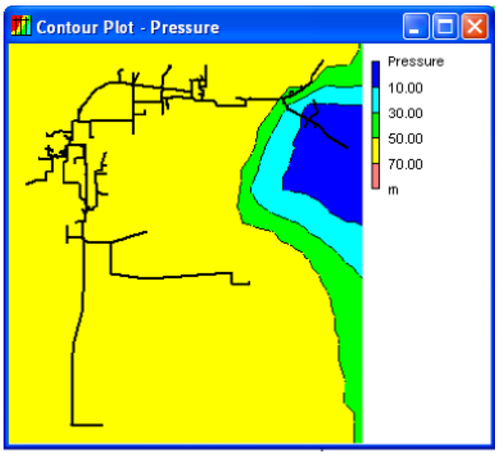


Figure 27: Pressure for the water distribution system model with multiple leakages scenario

As described in D4.2 we evaluated the effectiveness of the algorithm in terms of False Positive Rate FPR (the percentage of good data wrongly classified as anomalies), Detection Rate DR (percentage of bad data

correctly classified as alarm) and accuracy (the ration of the instances correctly classified either as alarms or normal observations). Our goal was to reach the highest Detection Rate at the cost of the lowest False Positive Rate possible.

The leakages scenarios have been implemented and the resulting data fed to ADWICE algorithm to evaluate if the FDD method works fine by recognizing that the scenario effectively shows anomalies in the usual operational values of functioning of the WDS. D4.2 gives the full details of the ADWICE implementation.

2.6.3 Rule-based Fault Detection and Diagnosis

A rule-based methodology to identify and diagnose faults in the potable water and rainwater-harvesting systems at the NUI Galway Pilot is presented detail in D4.2. The FDD methodology for the potable water system was developed as an application available on the Building Managers Dashboard. D4.2 presented the details of the rule-based FDD methodology developed for the potable system as an idealised decision tree specific to the water network at the NUIG Pilot that are subject to the FDD monitoring.

The rule-based FDD pilot was implemented as a "Water Retention Time Observer" application and is discussed in Section 6.4 in D3.3. Figure 28 shows the rules view of this application.

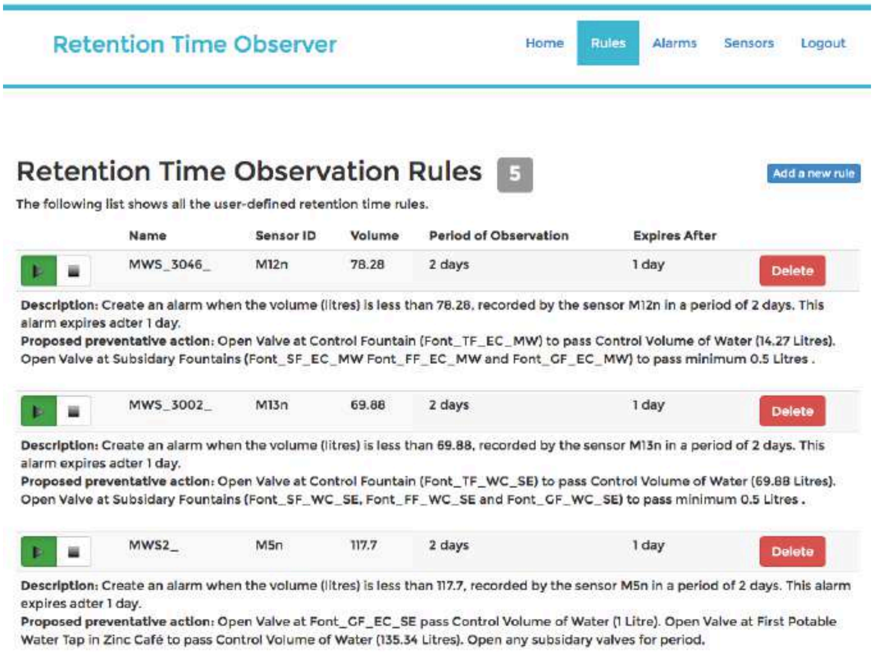


Figure 28: Water Retention Time Observer application - Rules View

The rules identified in this approach have not been hard-coded as a back-end application. Indeed, the Water Retention Time Observer allows building managers to create rules by entering the related parameters such as the reading values of a particular sensor that trigger an alarm as well as the required remedial action. Figure 29 shows the form that needs to be filled for creating rules of the FDD approach.

The building manager is notified by this application each time a rule has been violated. Several feedback sessions helped adjust some parameters of the application to make it send prompt and reduced number of notifications. Full details of the tests carried out with this application can be found in D4.3 and D5.2.

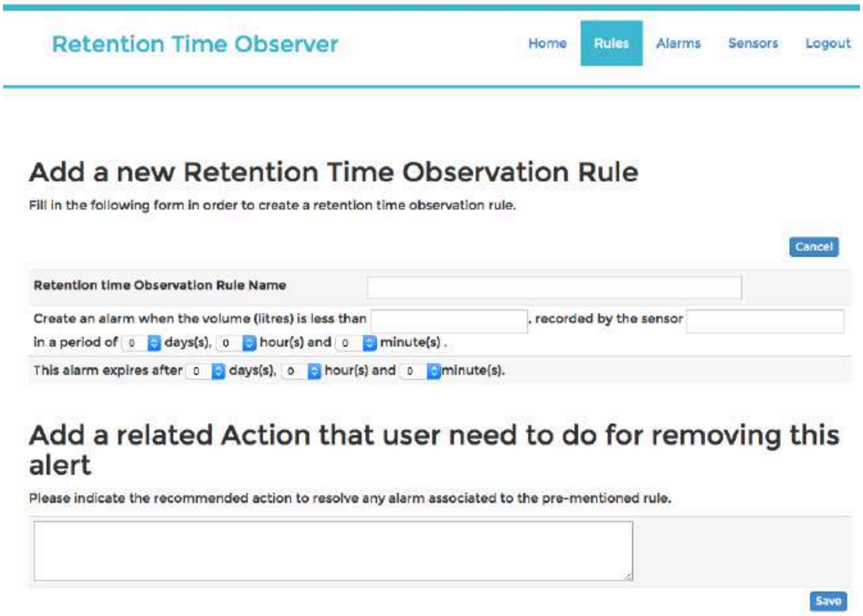


Figure 29: Adding a new rule to the Retention Time Observer

2.6.4 Drought Monitoring

The operational drought monitoring service of the EU Joint Research Centre's European Drought Observatory (EDO) provides to Waternomics the drought condition per country. By monitoring present precipitation, soil moisture, and vegetation conditions, EDO processes a Combined Drought Indicator on a 0.04 degree lat/lon resolution (edo.jrc.ec.europa.eu). Waternomics retrieves the EDO drought status for each pilot-site country (Greece, Italy, and Ireland) and sends a drought notification using the following steps (full details are provided in D4.2):

1. Download recent files from the European Drought Observatory web service for the countries Greece, Ireland and Italy
2. Extract the CDI for Thermi, Milan Airport and Galway (the four pilot areas of Waternomics project)
3. The CDI numeric values for each pilot area are then translated into a description of the drought condition.
4. A notification is pushed to the Waternomics platform.

The notification can be seen in Figure 30. A link is provided with the notification to allow users to go to the map-views in the EDO-website and see the extent of the drought, and how it developed over time. The user can then choose through the standard buttons of the Waternomics platform notification, whether to Take Action, ask for a Reminder, or Ignore the alert.

Figure 30: Sample drought notification on the Waternomics platform

The drought monitoring data from EDO for pilot sites Thermi, Linate airport, and NUIG Galway, are analysed for two reasons:

1. To assess how many alerts will be received by potential users, depending on the rules for triggering a notification. Too few alerts would reduce the effect of awareness raising of water being a limited resource, but too many alerts may lead to the service being perceived as a nuisance, and inaccurate if many of these notifications turn out to be false alarms. The number of alarms is expected to differ depending on the target area. If an alarm is given based on drought reaching the very point-location of the pilot-sites, this would raise fewer alarms as compared to giving out alarms based on a drought monitored anywhere in a wider area. Therefore, the number of droughts for the pilot sites is compared to the droughts on country level.

2. To assess the reported temporal evolutions of droughts, to find whether a long period of drought could cause a serious rain deficit, that might cause soil moisture anomaly, to vegetation damage, or follow more dynamic development paths. This would inform the project whether to forward every subsequent alert with interpretation, or whether select for example only the beginning and end of a drought.

2.7. Business Models and Value Propositions

One of the results of Waternomics concerns different **business models** and **value propositions** that have been designed with the purpose to make commercialisation of the Waternomics Platform viable and sustainable. The Waternomics Platform is the collection of sensors, applications, data platform and the Waternomics methodology. Together they form a smart water system, aimed at industrial users, domestic users and water utilities. On an abstract level the business model of the Waternomics Platform includes all customer segments, partners and necessary technology, as shown in Figure 31.

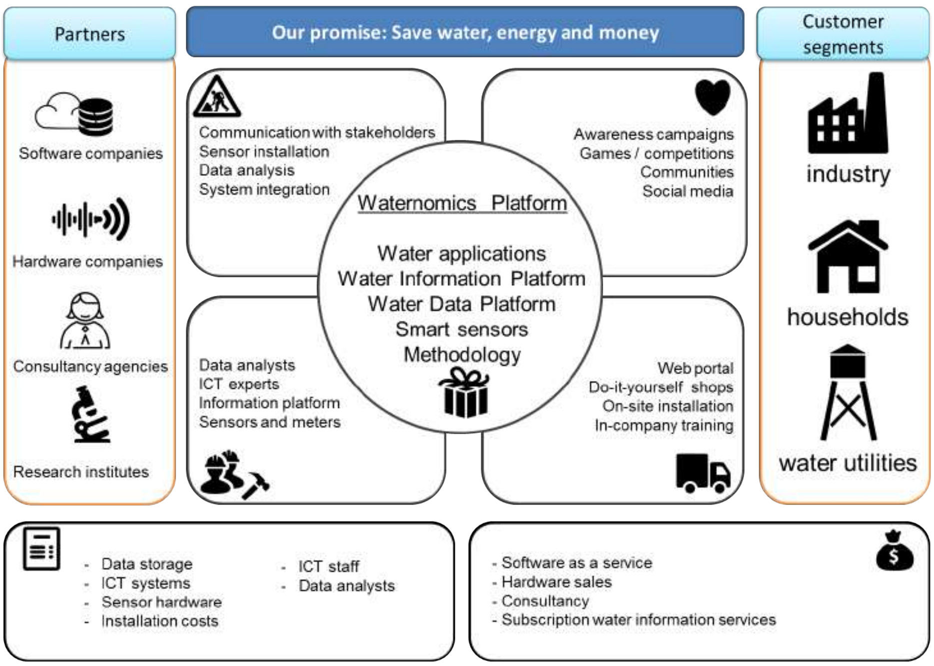


Figure 31: Business model for Waternomics platform

With such a diverse range of customer segments one cannot speak of a single business model for the Waternomics platform. Instead, Waternomics enables a broad range of business models and value propositions. For project foreground, multiple value propositions have been designed (see Table 4).

Table 4: Overview of value propositions based on Waternomics project's foreground

Exploitable result	Description	Value proposition
Waternomics Platform	Smart water platform, including sensor hardware, data platform, applications and methodology	Consultancy services, Smart Building services

Flow Data analyser	Low cost non-intrusive flow meter	Ambient Assisted Living, Mobile Flow Meter
Acoustic Leakage Detector	Low cost acoustic sensor with leakage detection software for application in domestic environment	Leakage detector for industry, leakage detector for irrigation systems, earthquake detector,
Fault Diagnostic rules	Method to identify and rectify faults in water infrastructure in buildings	Water Network Fault Detection, Smart Building Monitor
Linked Dataspace	Data aggregation platform which collects real-time data about water consumption and availability and makes information services available to applications	Water Data Aggregator for utilities, Water Data Platform for industry
Waternomics Methodology	Standards based methodology for the implementation of a water information system	Consultancy services
Water Management Training	Introduction training on hydro-informatics and smart water systems, aimed at college students	Smart water training module for college students, water awareness course for industry
Drought Monitor	Notification system for droughts in specific geographical areas	Business Risk Monitor
Water Application Market	An online portal through which water-related software applications are made available for procurement and download	Smart water services portal for utilities, Water monitor for airport operators

2.8. Customer-centric Water Billing

Water billing is one of the instruments water utilities have to communicate with their customers. Despite the large variation in consumer profiles, most water utilities have only one uniform billing method for all their customers. This doesn't do justice to the differences in attitude, motivations, capabilities, knowledge and resources amongst their customers, which causes them to act and respond in different ways on enhanced billing information. For the Waternomics water bill, customers have been segmented based on two attributes (i) willingness to change, indicated by pro-environmental behaviour, and (ii) readiness for change, indicated by the stage in the change cycle the customer is in. Both willingness to change and readiness for change can inform which information should be presented best to customers to support behavioural change. To help water utilities with the design of an informative water bill, the Water Bill toolbox has been created. The Water Bill Toolbox, shown in Figure 32, helps utilities with the design of tailored water bills that can comprise a combination of billing mechanism, design and feedback. The toolbox consists of building blocks that can be utilised as required. Each column represents the building blocks that can be chosen within various categories: billing mechanism, design and feedback. Any combination of selected building blocks creates a basic design for a tailored water bill aimed at a specific customer segment. Figure 33 shows an example of the resulting water bill. This example has been prepared by using the functionality of the Waternomics platform.

Figure 32: Toolbox for informative water bills

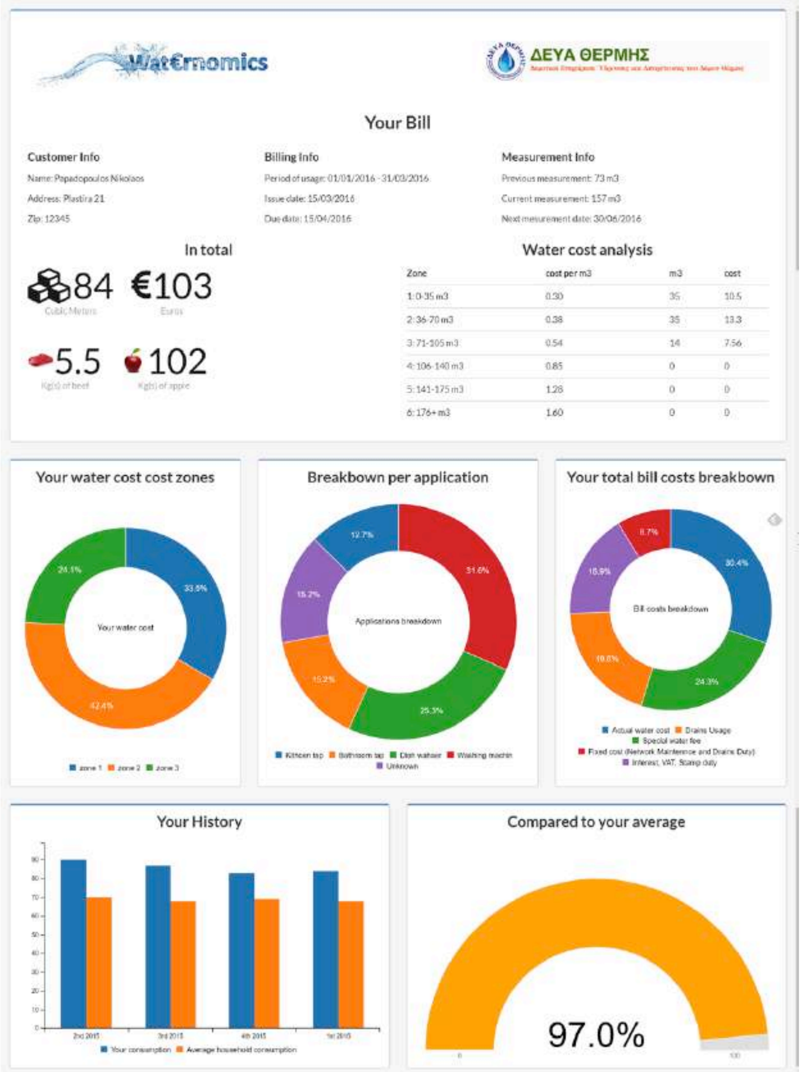


Figure 33: Waternomics water bill for Thermi

The Waternomics water bill was designed based on components used in apps of the water applications platform. Therefore, consumers were also involved in the design process although indirectly through the design of their custom applications.

The bill was evaluated with three professionals from the Water Utility in Thermi including its president and its financial manager. The evaluation run as a semi-structured interview that has been recorded with the consent of the participants.

Overall, the Waternomics water bill was considered as a major improvement in terms of the information presentation. They reacted positively to the possibility of adopting a more informative layout of their current bills. However, two main issues were discussed during the interview.

The first issue is the limitation of the current metering system. In fact, data is manually collected and the current state of data storage and processing facilities do not support such detailed billing layout. If the water utility decides to change to an automated metering system and an improved data storage infrastructure an improved new water bill design could be easily adopted.

The second issue is the metering strategy that is set to measure only the overall consumption of a building rather a detailed metering within the building itself. A detailed analysis of the water consummation within the household is difficult to achieve since it would require more extensive installation plans within

households. It was also commented that it might raise privacy issues with their consumers. However, given the new features offered by such new billing design, consumers could be convinced to accept having these installations taking place in their houses to put in context their usage and raise their awareness.

2.9. Pilots and Case Studies

2.9.1 Pilot 1 Linate Airport, Milan, Italy.

At Linate Airport, two totems were installed in order to interact with passengers by conveying information about the project and tips on improving personal water footprint. The installations were successful from the outset, with a strong involvement by users; recording in a single day approximately 100 interactions. In the final month of the project (M36) 2,250 passengers interacted with the touch screen displays.

Figure 34: Touch screen displays in Linate pilot

The Waternomics information platform interface created for the building management and maintenance staff at Linate includes a number of customized applications to visualize the water consumption for each meter and users can access the platform to review real-time measurements in the water network. Among the metered buildings within the Airport area, there are some operated only during the daytime. The Waternomics Application Platform allows us to point out the water savings that SEA corporate could get after having addressed the leakages or malfunctioning of the local water network. Table 5 provides a summary of this information and Figure 35 summarizes the saving that can be obtained by resolving water leakages detected.

Figure 35: Total water saving for the metered buildings

Table 5: Potential water saving for the metered building within the airport area

BUILDING METERED	NIGHT WATER CONSUMPTION	WATER SAVINGS
Mensa Building	The Mensa building works only during the daytime. In three months of observation of the Mensa building water consumption we have registered a total night consumption of 500 m^3. SEA maintenance staff is	The overall saving that we can get by solving the local water network leakages in 1 year time is 2000 m^3 of

	investigating the problem in the local water network to find leakages and malfunctioning	drinking water that correspond to 1000 €/year
Alitalia Building	The Alitalia building works only during the daytime. In three months of observation of the Alitalia building water consumption we have registered a total night consumption of 270 m^3. SEA maintenance staff is investigating the problem in the local water network to find leakages and malfunctioning	The overall saving that we can get by solving the local water network leakages in 1 year time is 1080 m^3 of drinking water
Purchase Building	The Purchase building works only during the daytime. In three months of observation of the Purchase building water consumption we have registered a total night consumption of 32 m^3. SEA maintenance staff is investigating the problem in the local water network to find leakages and malfunctioning	The overall saving that we can get by solving the local water network leakages in 1 year time is 384 m^3 of drinking water
General Direction (DG) Building	In three months of water consumption observation we have registered 0 m^3 of night consumption. There are no problems in the local water network to be addressed	The local water network works fine without leakages
CRAL Building	The CRAL building works only during the daytime. In one month of observation of the CRAL building water consumption we have registered a total night consumption of 700 m^3. SEA maintenance staff is investigating the problem in the local water network to find leakages and malfunctioning	The overall annual saving that we can get by solving the local water network leakages is 8400 m^3 of drinking water
Poste Building	The Poste building works only during the daytime. In three months of observation of the Poste building we have registered a total night consumption of 52 m^3. SEA maintenance staff is investigating the problem in the local water network to find leakages and malfunctioning	The overall saving that we can get by solving the local water network leakages in 1 year time is 208 m^3 of drinking water

Waternomics performed a Water balance in a selected area within the airport named DMA6 (District Metered Area n. 6). Within this area bidirectional and volumetric flow meters have been installed to virtually partialize the area from the overall water network. This allows us to point out the inflow cubic meters while an open channel flow meter installed in the sewage outlet that serves this specific area allows us to point out the water outflow. The comparison between inflow and outflow highlights the overall percentage of water leakages in the specific DMA6 area.

At the end of the project, despite the installation of the overall meters is finished, we are facing some problems with the calibration of the open channel flow meter. For this reason, the leakages analysis show very variable results in a range of 60-90%. The weekly consumption of the DMA6 area, in terms of inflow water is about 3,000 m^3 and if we assume that the lowest percentage of leakages registered so far in the DMA6 area is correct (60%) we have weekly water saving of 1,800 m^3. This means that the annual water saving for the DMA6 area will be, if the leakage problems will be solved, of about 86,400 m^3 of drinking water that correspond to about 42,000 €/year (Figure 36).

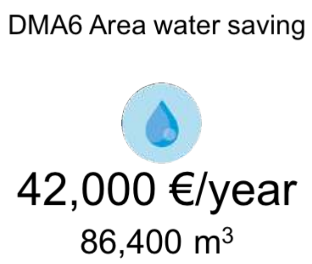


Figure 36: Total water saving for the DMA6 area

The information gathered from the WAP (Waternomics Application Platform) about the percentage of leakages within the DAM6 area could be extended to the entire airport water network due the similar conditions of the pipes in terms of age / materials. In this way, we can estimate the overall percentage of leakages in the entire airport water network and this will lead to renegotiate the agreement with the wastewater utility AMIACQUE to realize a payment for sewage based on the actual volumetric discharge, instead of the amount taken from the wells, with annual savings of approximately € 260,000 for the waste water treatment. The estimation assumes a percentage savings/leakages of approximately 60% and the current pricing of the cost of removal and purification of 0.5688 €/ m^3 (Figure 37). The average amount of water taken from the wells annually is about 770,000 m^3 consequently the amount of water effectively discharged is 308,400 m^3.

Figure 37: Total wastewater saving for the entire airport area

The water saving will reduce the operation time of the pumps system. We have estimated from the energy consumption meters installed in the Linate pilot that the energy consumption associated with the use of 1 m^3 of water withdrawn from a well is about 0.065 kWh. This means that in one year, if we save 462,600 + 12,000= 474,600 m^3 of drinking water we could get an overall energy consumption saving of 30,850 kWh that correspond (assuming an energy cost of 0.18 €/kWh) to about 5,500 € (Figure 38).

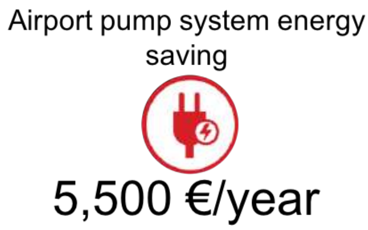


Figure 38: Total energy saving for pumping stations

2.9.2 Pilot 2 Thermi, Greece

At the start of the project (M7) the Municipality of Thermi sent out a press release to local media to gather interested participants' households and 3 months later (M10) a simple interface was created for participants to log their consumption on a monthly basis based on the existing water utility metering infrastructure.

After a short survey on the existing infrastructure of the interested households, in M20 6 sensors were installed in the first household. A workshop with the participants in the pilot was organized in order to introduce end- users to the hardware and gather feedback from the first installation in a household. One of the main outcomes of this session was the request from end-users to decrease the number of boxes to be used in the installation by merging the hardware of the two receiver boxes under a single box instead of two.

After the first installation, detailed metering plans were developed for all 10 households in October 2015 (M21) after visiting and documenting (photos and notations) in detail the requirements for each case. The sensors for were delivered to Thermi during M24 and a first round of firmware updates took place immediately after the first household installation (M25) to eliminate some initial software problems identified. The installations in the rest of the households continued during M26 and M27 while at the same time a new round of firmware update took place

In parallel with installations M26 saw the launch of the applications platform to end users with a set of initial dashboard applications for each household based on their needs and metering installation. End-users participated in the launch event of the applications platform and an initial round of feedback was gathered in this event.

After the launch event in users were gradually introduced to new applications with Learning and Exploration applications launched on M30 and Gaming application launched in M34. In addition, an interim evaluation of the applications through phone interviews was conducted During M32 with led to the development of additional apps and a slight change in the pilot plan described in D5.1. In particular,

the WEM of in school training was substituted by the release of a new application for daily, weekly and monthly digest emails to end-users that proved to have application and impact beyond Thermi's pilot.

The Themi pilot showed an increase in awareness of water consumption due to an increasing interest for the Platform, which has been ensured with the help of email newsletter campaigns and the exploration applications. Exploration applications also increased interest from users' side, which was also shown in the positive comments from many users. The main factor that contributed to the success of the digital email app was that it was providing users with information from the platform through communication channels they already use on their daily lives. For example, the effect of increasing the awareness of water consumption in the household enabled the users to discover that by consuming food that uses less water in its production they could reduce their overall water consumption.

Behavioural changes in water consumption were enabled with the exploration app of comparisons with other households. It showed potential based on preliminary results from interviews with some household owners. Unfortunately, no significant behavioural change was observed. A news aggregator app was also developed, but was not as helpful as expected. In many cases, it showed that, changing the behaviour in the household environment requires changing behaviour in all users of that household, and if all users are not interacting with the information this becomes more difficult.

Reduction of water consumption observations showed that for households, the economic incentive is too low. Water is relatively cheap and does not affect the household budget significantly, so the incentive for reducing water consumption is also low. Intervening into daily routines at homes for participants of the Thermi pilot seems to be more difficult than the other pilot sites. Personal and daily routines do not include checking water consumption on a frequent basis. Habits are not easily changed, especially in a home setting, and taking up new habits when you are not obliged (work or school often is) is difficult, especially because there are many other obligations and hobbies that require a person's time.

Pilot impact

- 15 users created in the platform
- 50+ personalized applications created
- 436 sessions of visits to the apps platform
- 10.032 page views to the apps platform (approx. 30% of total page views to apps platform)
- 19:48 minutes average time spend per session (higher than average time in total 15:00)
- Approx. 30% reduce of monthly and weekly consumption from September to November
- 10 Newsletter email campaigns sent to participants

2.9.3 Pilot 3 Engineering Building, NUI Galway, Ireland

Installation of 8 USF meters and associated enabling work was completed at the NUIG Pilot in M20 and testing and validation of the meters commenced immediately Intermittent Data Collection from the installed USF meters continued during the period M21 – M24. As a joint initiative with the Building Management at the NUIG Pilot and the Waternomics Team, a further 3 mechanical in line meters were installed during M21. The new mechanical meters were connected to the buildings existing BMS system in M22 and this brought to 14 the total number of inline water meters at the pilot site. A new data collection protocol was developed to gather data from 11 BMS connected water meters pre-dating the Waternomics Project and the additional 3 mechanical meters; this protocol was developed to resolve stability issues with the existing building BMS database. This system stabilized data collection from 14 water meters and a rain sensor at the Engineering Building and transfer of this data to the Waternomics dataspace.

The collection of data from the installed USF meters has been effected by some hardware, software and setup issues but data has been gathered from 7 of the meters since M21 and data collection and validation of the installed metering took place during the in M21 – M27. An extensive baselining analysis of existing water usage at the Engineering Building for the period M24 - M29 was finalized in M31.

In M24/25 a water awareness questionnaire developed by the NUIG team was completed by (70 no.) 1st Year Engineering Students (2015/2016) and a control group (40 no.) based in a separate part of the University campus. The surveys were used to baseline attitudes of students to water usage and conservation activities in advance of the launch of Waternomics WEM interventions.

Initial user trials and feedback cycle of Engineering Building Public Dashboard for the Waternomics Platform commenced in M27 and the Public Dashboard was launched in M31. Initial user trials and feedback cycle of Engineering Building Managers Dashboard for the Platform commenced in M27 and the launch event and training took place in M31.

In M36, post-intervention survey questionnaires were carried out in M36 with (70 no.) 1st Year Engineering Students (2016/2017) and a control group (40 no.), similar to that who took part in the pre-intervention surveys, based in a separate part of the University campus. The results of the analyses are included in D5.2. Post intervention water consumption analysis at the pilot is also included D5.2.

In M36 the acoustic sensor described in D4.3 developed by the TUD-IHE Waternomics Team was installed at the NUIG pilot site to assess its suitability for large diameter pipes, the sensor is installed on a 108mm OD pipe. Validation of the operation of the sensor is on-going and will continue post project.

Figure 39: WEMs at NUIG Pilot

A significant and readily measureable success of the Waternomics Project at the NUI Galway Pilot site is the availability of information regarding the operation of the water network at the site. This has allowed faults and other anomalies that would otherwise go undetected and unresolved to be identified. With timely and actionable information being provided to Building Managers regarding the operational anomalies, unexpected occurrences and predicted faults, the Waternomics Project has delivered a system that provides improved operation to the building water network at the NUI Galway Pilot Site. Prioritising corrective action with Building Management when faults are notified remains an issue due to staffing and budgetary constraints. However, the water residence time observer has been a very successful system with email alerts of simple resolutions sent to the building manager to take preventative action to avoid issues with water quality due to extended potable water residence times.

Any sustained engagement of building managers in the manager's dashboard applications has been difficult to achieve, primarily due to workloads and the necessity to prioritise critical faults in the University Building stock. However, identification of the fault in the rainwater harvesting system by the Waternomics Platform and its subsequent repair is considered a significant success of the project quantifiable by savings equivalent to the harvested rainwater used during the control period following the repair work (further details in Section 6.2.5 of D5.2). It should be noted that this approach is somewhat conservative and hidden faults could, without the intervention of the Waternomics platform, remain indefinitely. Extrapolating the timely identification and subsequent repair of the Rainwater harvesting system to an annual saving is detailed below.

The impact of the measures introduced at the pilot on water consumption could not be shown, due to system faults. No overall reduction in mains water usage was recorded but disappointingly an overall increase in water usage over the control period was noted due to the fault. The significant impact of system controlled water usage i.e. automatic flushing of urinals and persistent faults relative to any user controlled usage is a significant finding of the project in terms of controlling water usage in public/mixed used buildings. The overall effect on water consumption of even significant water use behaviour change

in end-users is limited due to the Operation/ System controlled water usage is more significant than User controlled usage.

In terms of user awareness, the pre intervention surveys indicate that the sample populations exhibit a moderately high level of water awareness. Post intervention awareness surveys were found to be statistically insignificant. Since pre intervention surveys already indicated a high level of awareness, small differences that might or might not have occurred would have been difficult to capture.

Based on the expected annual usage presented in Section 6.2.5 of D5.2 and an assumption (based on CnaC pilot site baselining data – see Section 2.9.5) that a minimum of 70% of total water usage can be accounted for by harvested rainwater. In addition, as described in D5.2, following the action planned by the Building Management to reduced water usage at the pilot on review of the information in the Waternomics platform, actual and a conservative estimate of the potential additional saving per annum is given in Figure 40.

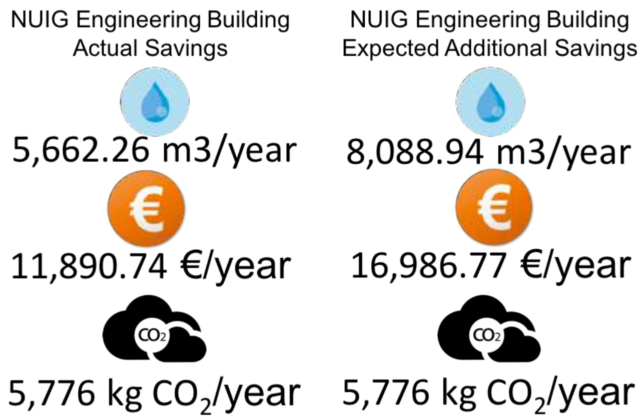


Figure 40: Actual and conservative estimate of water savings at NUIG

The Waternomics Project has been successful in promoting education regarding water usage as evidenced by new projects at the site. Post project initiatives as well as collaborations are ongoing, building on the work of Waternomics.

2.9.4 Pilot 4 Coláiste na Coiribe Secondary School, Galway.

Agreement was reached with the school authorities on the installation of 7 additional water meters and an interactive screen at the new school premises under construction bringing to 14 the total number of water meters to be installed at the school pilot. Installation of the all planned water metering at the pilot site was completed in M20 and the developed remote data collection protocol was implemented in M24 soon after the new school opened to students in M21. The collection of data from the connected water meters at the school pilot has continued without interruption since M24.

In M25/26 a water awareness questionnaire was completed by (~150 no.) students and a small number of teachers at the school. The surveys were used to baseline attitudes to water usage and conservation activities in advance of the launch of Waternomics WEM interventions. Stakeholder Engagement activities commenced in M26 and these are documented in D5.2.

Initial user trials and feedback cycle of Coláiste na Coiribe Waternomics Public Dashboard and Managers Dashboard Applications commenced in M28 and M29 and the Managers Dashboard was launched at a training event in M31. The public Dashboard Application was launched in M32.

All planned WEMs as described in D5.1 and D 5.2 were in place at the Coláiste na Coiribe Pilot site prior to or by M32.

In M36, post-intervention survey questionnaires were carried out in M36 with (~70 no.) students at the school from both the junior and senior classes. The results of the analyses are included in D5.2. Post intervention water consumption analysis at the pilot is also included D5.2.

(a) Public display developped

(b) Public display developed by Cylon

Figure 41: WEMs at Coláiste na Coiribe

The analysis of water usage data from the CnaC Pilot Site, clearly demonstrates the value of the existing systems to minimize the use of mains water in a school environment, with per student daily water usage within recommended levels in both pre and post intervention. The pre-intervention surveys indicate that the sample populations exhibit a moderately high level of water awareness. The results of post intervention surveys carried out with similar groups at the end of the control period revealed an increase in awareness of 9% among the junior cycle students and 17% increase among the teachers. However, no change in awareness was recorded among sample students from the senior cycle of the school.

The Waternomics Project has been successful in promoting education regarding water usage and the Project Aims. The development of new projects within the school based on the findings of the Waternomics project and the project data was a significant aim of the project and discussions are underway. The results of the pre-intervention analysis of water consumption indicate that the school is very efficient in terms of its water usage with on average 4.42 m3 of water used per day with generally 70-90% of this provided by rainwater which dramatically reduces the requirement for treated water from the municipal mains

The availability and monitoring of water use data by Waternomics has proven to be a valuable addition to the existing systems in place at school allowing faults and other anomalies that would otherwise go undetected and unresolved to be identified. As described in D5.2, three significant faults have been identified using the Waternomics Platform at the CnaC pilot during the control period and their subsequent repair is quantified during the control period following the repair work and this is presented in Section 7.2.5 of D5.2. However, this approach is somewhat conservative and in reality, hidden faults could, without the intervention of the Waternomics Pplatform, remain indefinitely. Extrapolating the timely identification and subsequent repair of Fault 1 and Fault 2 as described in Section 7.2.4 of D5.2, the per annum savings associated are given in Figure 42 along with the potential savings for Fault 3 which is under investigation by the school authorities.

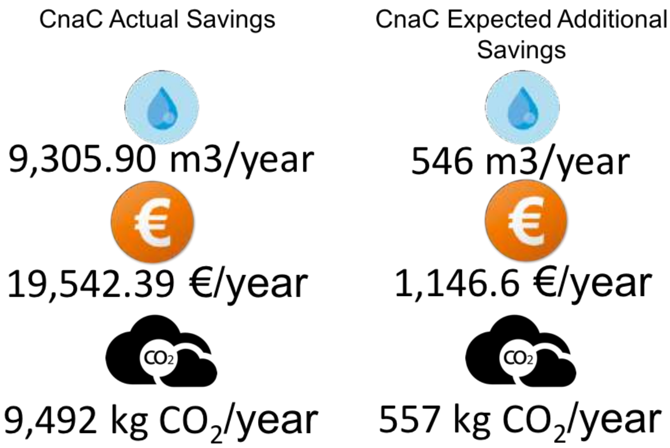


Figure 42: Savings relating to repair of faults at CnaC

3. Project Impact, Dissemination and Exploitation of Results

3.1. Overview

This Section details the impact, dissemination and exploitation of the project results. Section 3.2 discusses the impact of the project as summarised in Table 6. Section 3.3 presents an overview of the dissemination activities that have been carried out for communicating the project results with the different stakeholders as well as external, national and international audience. Finally, Section 3.4 lists the exploitation activities for maximising the business impact of the project and preparing for the post-project exploitation of project results.

Table 6: Summary of Waternomics Impact Areas

Impact Areas		Impact	Key Facts and Numbers
Increased Water Usage Awareness	1	Increased user awareness and introduction of a clear pathway to manage efficiently the water resource through a standard-based methodology	The methodology serves as a manual or guideline on how to get started in implementing a Water Management Plan.
	2	Increase awareness regarding water usage through tailored applications	More than 10 support services and 20 applications have been developed by Waternomics to serve all the user requirements identified within the project
	3	Increase awareness regarding water usage through education	Outputs generated from Waternomics have been transformed into teaching material at various levels: university and school teaching.
	4	Increased user awareness through online presence and dissemination activities	140 dissemination activities have been recorded in Appendix B: List of Dissemination Activities
Improved Operations	5	Improve the water management area through the introduction of new meters, new FDD and leakage detection methods	- New economic mini meters - Rule-based and model-based FDD identified potential water leaks and issues - New Shazam-like leak detection method
	6	Improved resource efficiency and business operations of water utilities due to ICT	Improved operation through: Smart metering and smart technologies
	8	Increased rate of ICT-innovation in water management companies	Developed business models and value propositions show benefit from smart water systems
Standardization	9	Reduce the gap between energy and water standardized sector	The proposed methodology is compliant with ISO50001-Energy Management Systems
	10	Reduce the gap between overarching procedural steps of a methodology and the actions required to accomplish them	The methodology has been tested successfully in 4 pilots with a visual support using Trello boards
	11	Prepare the groundwork for the development of new standards and certifications of excellence in the water sector	The methodology can help meet water consumption reduction excellence certification by being compliant with most recent EU directives

Open Source and Open Data Adoption	12	Reputation and leadership of Europe in the water management area through the adoption of an Open Source Strategy	The entire platform reuses existing Open Source Projects such as CKAN, OpenCube, Druid, Kafka, etc. And most of the developed Apps are released as Open Source
	13	Reputation and leadership of Europe in the water management area through promoting the use of Open Data	A wide adoption of Open data in the Waternomics apps such as: Weather data, Open Calendars, and Drought monitoring
Environmental Impact	14	Water Saving	Water saving opportunitites have been observed in all pilot sites. E.g., in CnaC more than 2,000 m^3 have been saved during the control period.
	15	Energy Saving	Energy and carbon footprint associated to water consumption is related to pumping, heating, etc. The more water is saved, the more energy is saved. More than 2,000 kg of CO_2 have been saved in CnaC pilot during the control period.
Scientific Impact	16	Number of publications jointly authored by researchers from ICT and the water domain	26 scientific publications are recorded in Appendix A: List of Scientific Publications
Economic Impact	17	Spin off company: iSENSIT	A spinoff established by VTEC in 2016 with 5 employees
	18	Commercial Water Efficiency Toolkit by partners Ultra4 and R2M	Using Waternomics Marketplace and Methodology, partners ULTRA4 and R2M are developing a water efficiency toolkit for industries in Southern Europe
	19	New smart building business opportunity for partners VTEC and BMC with Simaxx	VTEC and Simaxx plan over 400K on smart water/smart platform and BMC will provide business development support
	20	SEA plans to expand Waternomics to Malpensa airport	Results from Linate encourage managers to extend the work to Malpensa

3.2. Impact Areas

3.2.1 Increased Water Usage Awareness

In Waternomics, increasing water usage awareness has been one of its main objectives. Stakeholders from different environments and with different roles perceive information differently and thus multiple channels of communications are required to reach a maximum impact. Waternomics reached this objective with the following impacts:

Impact 1: "Increased user awareness and introduction of a clear pathway to manage efficiently the water resource through a standard-based methodology"

Use of the developed methodology provided a standards-based pathway that can lead to both organizational change (management procedures) and individual change (behaviour change) and serves as a manual or guideline on how to get started in implementing a Water Management Plan. The methodology was applied for the first time in the four pilot sites and it has been a reference in implementing the specific pilot activities and assessing the results. From the external point of view, the main target groups that can benefit from the developed methodology are:

- Organizational environmental/water managers
- Water consumers in various domains (domestic, community and corporate)
- Water services companies
- Water operational managers

Impact 2: "Increase awareness regarding water usage through tailored applications"

Services and Applications developed in Waternomics target a wide range of end-users as highlighted in D3.3: from school kids to adults, and from water management professionals to casual users/passengers of an airport. The tailored applications developed for each type of users is intended to increase users' awareness for building eco-friendly behaviours. Decisions regarding tailoring applications include:

- Giving the end-users the possibility to create their own apps using the developed Waternomics Platform
- A market place for Water Apps that users can include in their WApP space
- Translated apps to languages adopted in each of the pilot sites
- Use of metaphors and footprints to represent water volumes in different indicators
- Use of icons for kid's applications (especially in the school's dashboard)

Impact 3: "Increase awareness regarding water usage through education"

The data, services and applications generated in Waternomice have been transformed into teaching material at various levels. This has been facilitated by the nature of two project pilot sites: a university building and a secondary school. Training activities that were carried out by Waternomics team include:

- University teaching:
  - Waternomics data has been used for student projects for data visualisation while interacting with the Water Flavours App
  - Waternomics data from NUIG has been used for a data analytics class for master students
  - Multiple lectures have been given that discuss the use of ICT for sustainability

- School education:
  - Mobile applications development tutorials using Waternomics data and services
  - Water conservation workshops
  - Internship for secondary students at one of the pilot sites (NUIG)

Impact 4: "Increased user awareness through online presence and dissemination activities"

Training sessions and dissemination activities including the website, blog posts, social media, presence at events and conferences, and the Waternomics newsletters, all contribute to the increase of user awareness concerning water use. In addition, the developed dissemination and training material will remain available after the project has ended, reaching more people. Discussions with stakeholders from industry show an increase in awareness in water related business risks and a willingness to take action and consider adoption of smart water technology.

3.2.2 Improved Operations

Methodology, leakage detection method, Fault detection methods and the Waternomic Platform itself promote the smart management of the water network and help organizations to comply with the most recent directives and standards for reaching improved options. Waternomics impacts this are as follows:

Impact 5: "Improve the water management area through the introduction of new meters, new FDD and leakage detection methods"

New meters have been introduced and experimented within the project and new leakage detection method and hardware has been tested for the household environment, while for the public and corporate environments new FDD methods have been introduced. More effort will be needed to improve some of

these novel systems in order to introduce them in the market. They will be cheap meters/leakage and FDD detection methods for different environments and this represents their point of strength for market launch.

Impact 6: "Improved resource efficiency and business operations of water utilities due to ICT"

The Waternomics business model clearly shows that water utilities benefit in two ways from smart water systems. First utilities benefit through increased operational efficiency and secondly water utilities can benefit from new value added services enabled by smart water technology. The work on standards helps water utilities with selecting the appropriate compliant technologies and systems, thereby reducing the costs for integration of smart water technology with legacy ICT systems.

Impact 8: "Increased rate of ICT-innovation in water management companies"

The Water Bill toolbox helps water utilities with the adoption of informative billing and selecting the right technology and communication strategy for reaching their customers. The developed business models and value propositions show water utilities how they can benefit from smart water systems and help with defining the business rationale for adopting smart water technology. The post-project exploitation plans of the projects foreground have the potential to bring smart technology not only to water utilities but also to other domains like the chemical industry, leisure industry or airports.

3.2.3 Standardization

The Waternomics Methodology is intended to fill the gap existing in the water sector where not many standards are available. The methodology itself allows the end-users to comply with new standards (as for example ISO 14046: Water Footprint) and to improve their eco-sustainable image. This impact can be perceived from multiple perspectives:

Impact 9: "Reduce the gap between energy and water standardized sector"

The Waternomics Methodology introduced is targeted to fill the gap in the water sector where not many standards are available for implementing a Water Management Plan. The methodology provides a basis for water management improvement and effectively shows how different standards, also taken from energy sector (e.g., ISO50001-Energy Management Systems), can drive organizations and households to use water more efficiently.

Impact 10: "Reduce the gap between overarching procedural steps of a methodology and the actions required to accomplish them"

The Waternomics Methodology has been applied in the four Waternomics pilot sites and each pilot manager has followed it in order to create a water management plan, implement water efficiency measures and assess the results. Also, a visual graphic of the methodology has been introduced through the Trello Board application in order to assist implementation and eliminate the potential gap between overarching procedural steps and the actions required to accomplish them. A methodology may be as exhaustive as possible when listing the actions to be implemented, but without the accompanying tools will always be difficult to apply it to the real case. Through use of the Waternomics Methodology TRELLO Board, an organization can better ensure that a water management program is performed in a consistent way and have relevant information captured and communicated all in one place.

Impact 11: "Prepare the groundwork for the development of new standards and certifications of excellence in the water sector"

The standards background gives both a solid structure to the Waternomics Methodology and the possibility to include in it new standards to comply with organizations needs and governance. From the pilot sites feedback is clear that implementing the Waternomics methodology at the pilot sites executed many of the aspects that comply with new standards, e.g. water aspects of ISO 14001:2015 – Environmental Management Systems. In general, we can conclude that the methodology is a starting point for implementing a water management system and the Waternomics team and pilot managers found it very useful to achieve the pilot specific objectives. Moreover, it can support a water consumption reduction excellence certification by being compliant with the most recent EU directives.

3.2.4 Open Source and Open Data Adoption

The adoption of an open source strategy and use of open data in European projects contribute to the reputation of Europe in leading the smart water management area. This impact can be perceived as follows:

Impact 12: "Reputation and leadership of Europe in the water management area through the adoption of an Open Source Strategy"

The Linked Water Dataspace, related services and most of the applications are released as open source assets. The objective is to motivate the uptake and advancement of these assets by different interested stakeholders including academic communities as well as enterprising entities. An open source strategy is important for attracting potential customers not only in the water management area but also other sectors including the public sector.

Impact 13: "Reputation and leadership of Europe in the water management area through promoting the use of Open Data"

Pursuing the European strategy of promoting the use and release of open data, Waternomics used various sources of open data including: Open Calendars, Water Footprints, CO_2 emissions, etc. Waternomics used open data for enriching water data for enriched data analytics and visualisations.

3.2.5 Environmental Impact

Impact 14: "Water saving"

The most significant reduction in water consumption achieved at the pilot sites is quantified below in addition to the anticipated water savings that will result at the sites in the future as the effects of the measures implemented as part of the Waternomics Project are fully realized. The water saving effected by the Waternomics Project have a key positive environmental impact by saving water at all its pilot sites as shown in Table 7.

Table 7: Key water savings numbers

	Pilot		
	DMA6 at Linate	NUIG	CnaC
Actual Water Saving measured over control period (cubic metres)	2,954	174	2,179
Actual Water Saving measured over control period (cubic metres p.a.)	12,000	5,662	9,306
Expected Water Saving (cubic metres p.a.)	54,000	8,089	546

Impact 15: "Energy Saving"

The energy associated with water consumption is often underestimated by consumers, however such demands are a significant environmental issue in particular in terms of the high-energy requirement for water treatment and heating for domestic/commercial/industrial usage and the continued reliance on non-renewable electricity generation in many EU countries. The energy saving and associated carbon GHG saving effected by the water usage reductions achieved and those anticipated by the Waternomics Project are key positive environmental impacts. An estimate of the CO_2 savings associated with the water consumption reduction described in Impact 14 is given in Table 8 [31].

Table 8: Key CO2 emissions savings

	Pilot		
	DMA6 at Linate	NUIG	CnaC

Actual CO_2 Saving measured over control period (kg CO_2)	3,013	177	2,223
Actual CO_2 Saving measured over control period (kg CO_2 p.a.)	12,240	5,776	9,492
Expected CO_2 Saving (kg CO_2 p.a.)	55,080	8,251	557

3.2.6 Scientific Impact

Impact 16: "Number of publications jointly authored by researchers from ICT and the water domain"

Waternomics outcomes have been published in 26 international conferences and journals, presented and discussed in various international events. See Appendix A for the full list of scientific publications.

3.2.7 Economic Impact

Impact 17: "Spin off company: iSENSIT"

The connected sensor-platform, as developed in and for Waternomics, served as the technical starting point for a new company named iSENSIT, established by VTEC in 2016. By adding support for other sensor components, like accelerometers, gyroscopes, temperature, humidity etc., the platform has been prepared to serve other market segments. iSENSIT currently has five employees working on solutions for fitness centres and labour workforce health management services. A first commercial deployment of the system is planned for 2017 at an international fitness centre chain.

Impact 18: "Commercial Water Efficiency Toolkit by partners Ultra4 and R2M"

By combining the Waternomics Marketplace and the Waternomics Methodology, partners ULTRA4 and R2M are developing together a water efficiency toolkit for industries in Southern Europe. To bridge the gap to market and attract funding for productising this proposition, a collaborative project proposal is being prepared in the H2020 SME-Instrument program. Italian and Greece market parties (food industry and hospital) have shown interest and are willing to support pilots of the combined solution in their infrastructure.

Impact 19: "New smart building business opportunity for partners VTEC and BMC with Simaxx"

Simaxx is a Dutch provider of innovative smart building solutions, collecting, storing and analysing all available data from a building and returns actionable information to building owners and end-users. Over 200 office buildings are currently using their platform, and on average 20% energy reduction is achieved. A project proposal for the European program for regional development OP Zuid has been prepared and submitted, in which both VTEC and Simaxx together plan to spend over 400K euro for the further development and integration of a combined smart water/smart building platform and ask for co-funding from OP Zuid. BMC will provide business development support and help with the establishment of a new joint venture.

Impact 20: "SEA plans to expand Waternomics to Malpensa airport"

The results of the Waternomics pilot at Linate airport have been presented to senior management of the SEA organisation, owner of the airport. Their response was positive and management recognised the potential of the platform in helping them reaching their environmental goals and creating financial benefits. As a first action, it was decided to start an investigation on how to implement the Waternomics solution at their second and larger airport, Malpensa.

3.3. Dissemination

To disseminate the project results in the best possible manner, Waternomics implemented a multi-channel and multi-audience approach. We adopted a 3-phased dissemination approach that included:

1. *Planning* of a dissemination strategy,
2. *Execution* of the dissemination strategy, and
3. *Sustainability* of the dissemination activities.

The dissemination strategy adopted in Waternomics will be detailed in Section 4 and full dissemination activities are reported in deliverable D7.5.

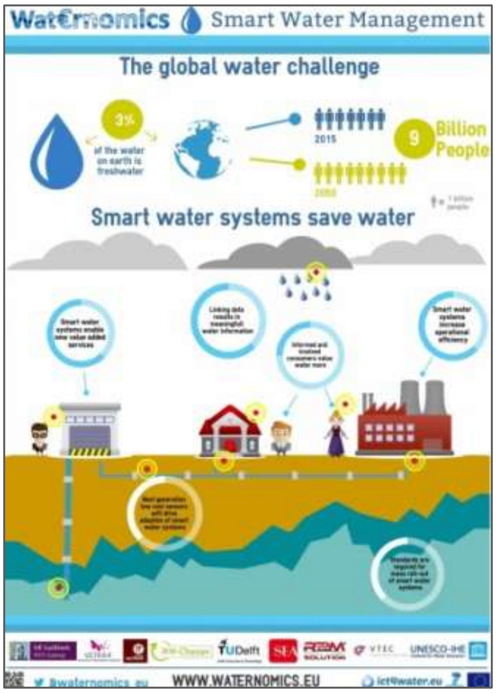
3.3.1 Brochures and Posters

Brochures and Posters made for disseminating Waternomics key ideas have been designed at an early stage of project. Multiple updates have been carried out for including new ideas. The brochure describes the key ideas in a generic way, avoiding jargon where possible. Target audience for the brochure are:

1. The Waternomics project members. To create a coherent message, the brochure guides project team members in their communication with external stakeholders. By capturing the key ideas and by making them explicit in a brochure, project partners are encouraged to exchange information and spread the ideas and results of the Waternomics project. Furthermore, this brochure will provide guidance in developing the key and supporting messages for specific communication activities, e.g. for specific project results or project milestones.
2. External stakeholders involved in the four pilots. With the brochure, pilot stakeholders like senior managers, water managers, policy makers and other decision makers will be informed about the rationale behind the Waternomics project. The brochure is deliberately designed in such a way that is visually appealing and easy to read and aims to inspire its readers to investigate and implement water efficiency measures in their immediate environment.

In the same format, two additional brochures have been prepared, being the "Waternomics Methodology"-brochure (D6.1) and the "Waternomics Results and Impact"-brochure (see Figure 43(a)).

(a) Key resulsts and impact brochure



(b) Key ideas poster

Figure 43: Waternomics brochure and poster

The poster (see Figure 43(b)) shows the global water challenge and Waternomics' idea of how information technology could contribute to resolving this challenge. The poster is targeted at the end-users of the four pilots and the general public in the immediate area around the pilots. The goal of the poster is to raise awareness about the global drinking water problem and to show how technology can be used in resolving this problem. The poster invites the interested reader to obtain further information about the pilot, Waternomics or the ICT4Water cluster by displaying the QR-code and links to the websites. Deliverable D7.2 and D7.5 reported on these dissemination materials.

3.3.2 Project Website and online presence

In order to facilitate Waternomics project dissemination the project has produced a public project website with a description of the project. The Waternomics website was designed and written by NUIG and supported by each partner with feedback and content. The project website has been updated regularly to include more content and reach an attractive design. The address of the website (see Figure 44) is www.waternomics.eu.

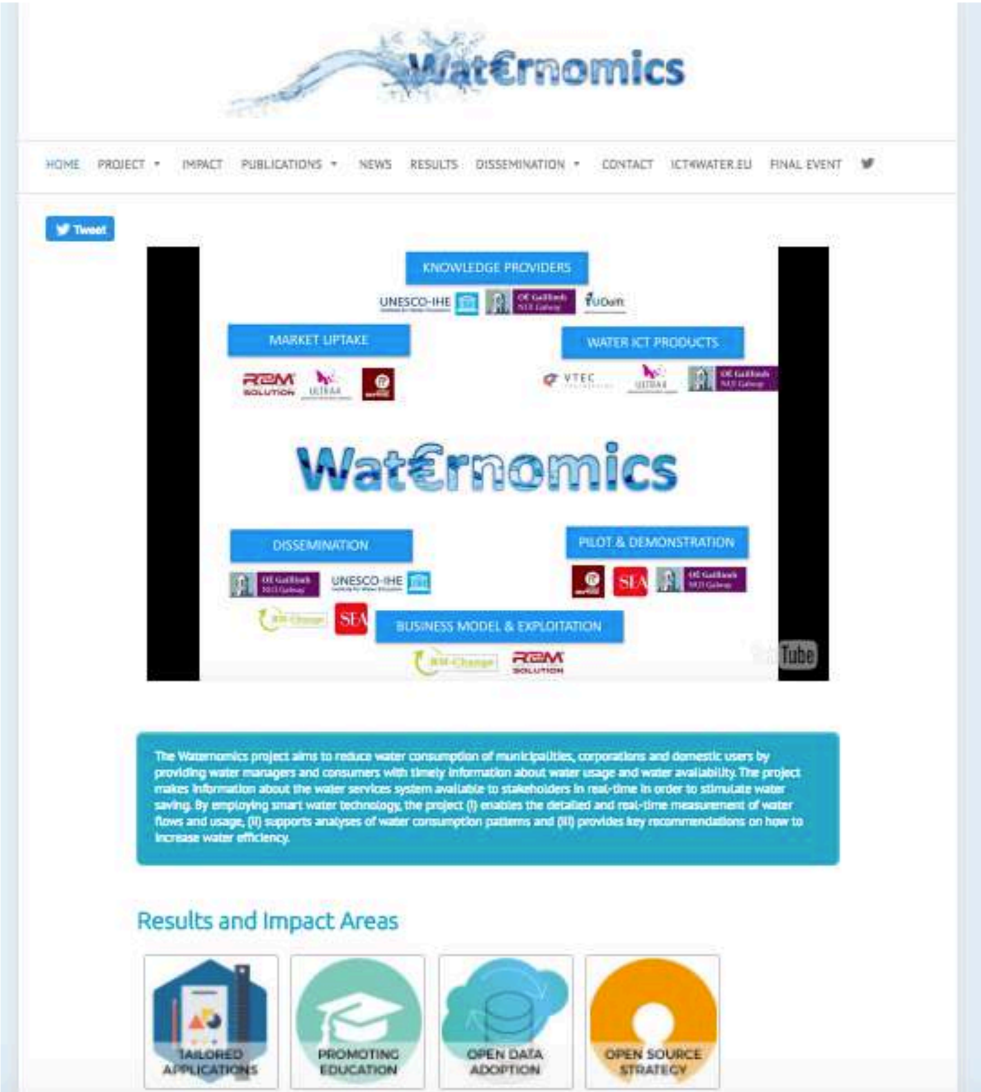


Figure 44: Home page of waternomics.eu

Regular monitoring of the website visitors' statistics has always been an active task in this Work package. Full details and statistics of the website are available in D7.5.

- Twitter Account @waternomics_eu (Status per 05-02-2017)
- Tweets: 632, Followers: 649, Following: 945

- Slideshare (Status per 05-02-2017)
- Shared presentations: 41, Total number of Views: 7741, Total number of Downloads: 155

Blogs and News

Appendix B: List of Dissemination Activities, lists the news articles that have been posted on the Waternomics website. These articles reflect the advancement of the project activities. For this reason, one can notice a relatively quiet period during the first year of the project. Starting from August 2015 the project results start to appear and consequently more articles become available.

YouTube

To make project ideas and results available to a wider audience and show the impact of a smart water system, videos have been prepared showing the pilot installation process and the value proposition design process. Together with the Ecomondo promotional video and the ICT4Water video, the videos were included in the Waternomics YouTube channel. Furthermore, the videos were embedded in the Waternomics project website and blog posts. Deliverable 7.5 lists the videos posted to the Waternomics Youtube channel.

ResearchGate

In November 2015, a project was created on ResearchGate to create more exposure for Waternomics amongst the broader scientific community. A total of fifteen papers and reports have been published resulting in 95 reads, 162 references and 26 followers (status 05-2-2017). The link to the ResearchGate project is https://www.researchgate.net/project/Waternomics-2

Newsletters

To actively inform water professionals and other stakeholders, Waternomics published 3 electronic newsletters. They contain articles about the progress of the project, project results and dissemination activities. As per 02/01/2017, the newsletter has 53 subscribers. The total number of recipients is: 150 with 158 as the total number of openings.

Next to the electronic newsletter, a paper newsletter has been prepared and distributed to a selected number of recipients from 10 different countries. The first issue was distributed in January 2015 to 66 recipients, the second in May 2016 to 73 recipients and the third in January 2017 to 84 recipients.

Interviews

Project members have given three interviews for online forums, as listed in the table below.

Table 9: Waternomics Interviews

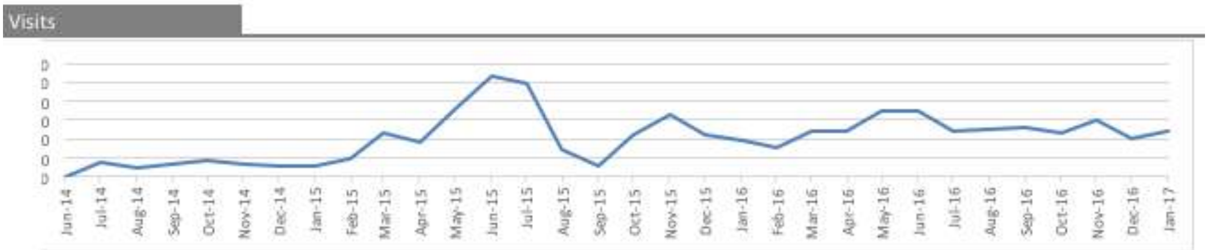
Platform	Interviewee	Title
Waterforum (Dutch)	S. Smit	Europees project Waternomics gaat met behulp van ICT water besparen
Vakblad H20 (Dutch)	S. Smit	ICT en flexibele beprijzing voor duurzamer waterverbruik
Delo (Slovenia)	W. Derguech	Znanost in prihodnost Evrope v digitalnem gospodarstvu

3.3.3 ICT4Water Cluster Dissemination Activities

The Waternomics project has taken leadership in setting up and maintaining dissemination activities for the ICT4Water cluster. To increase the visibility of the cluster and to increase the impact of the activities of the cluster projects, the NUIG team designed and is currently hosting and maintaining the ICT4Water website (see Figure 46). The content is continuously updated by the NUIG team in collaboration with

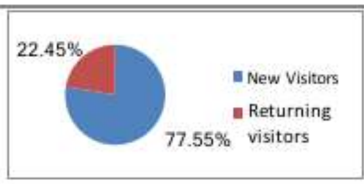
Sander Smit (BMC). The ICT4Water website displays the cluster members, latest news and project results. The website www.ict4water.eu has been on-line since July 1, 2014. Its usage statistics from its launch to January 31st,2017 is available in Figure 45.

ict4water.eu June 1, 2014 - January 31, 2017

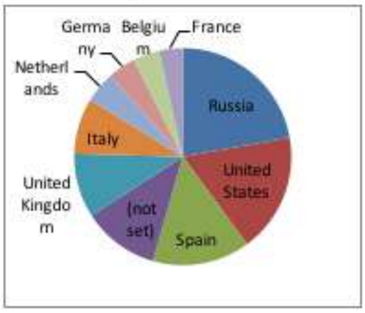


Site Usage Info

Sessions	Unique Visitors	Pageviews
13,143	10,033	19,807
Pages per Visit	**Avg. Visit Duration**	**% New Visitors**
1.51	0:01:05	77.55%



Country / Territory	
Russia	15.78%
United States	12.62%
Spain	10.34%
(not set)	8.13%
United Kingdom	6.81%
Italy	5.92%
Netherlands	3.29%
Germany	2.95%
Belgium	2.80%
France	2.50%



City	
(not set)	15.97%
Barcelona	2.71%
Saint Petersburg	2.05%
London	1.68%
Brussels	1.65%
Galway	1.63%
Lleida	1.59%
Milan	1.41%
Madrid	1.33%
Moscow	1.27%

Most Visited Pages	
Homepage	73.50%
Partners page	7.91%
Deliverables page	2.50%
Contact page	2.45%
News page	1.43%

Figure 45: Usage statistics of ict4water.eu from June 1, 2014 to January 31, 2017

The Waternomics team is also managing the twitter account of the cluster @ict4water_eu. The status of this account as per 05-02-17 is: Tweets: 1706, Followers: 550, Following: 653.

Waternomics has taken the initiative to generate and publish an electronic newsletter covering the activities of the ICT4Water cluster. The ICT4Water electronic newsletters are used to give an overview of the progress of the projects in the ICT4Water cluster. The source of its contents can be adapted from current activities, white papers, external communications, etc. Four newsletters are planned to be published each year. The first newsletter has been published in the 4th quarter of the year 2014. Post-project publication of the ICT4Water newsletter will be managed by BM-Change, member of the ICT4Water core team.

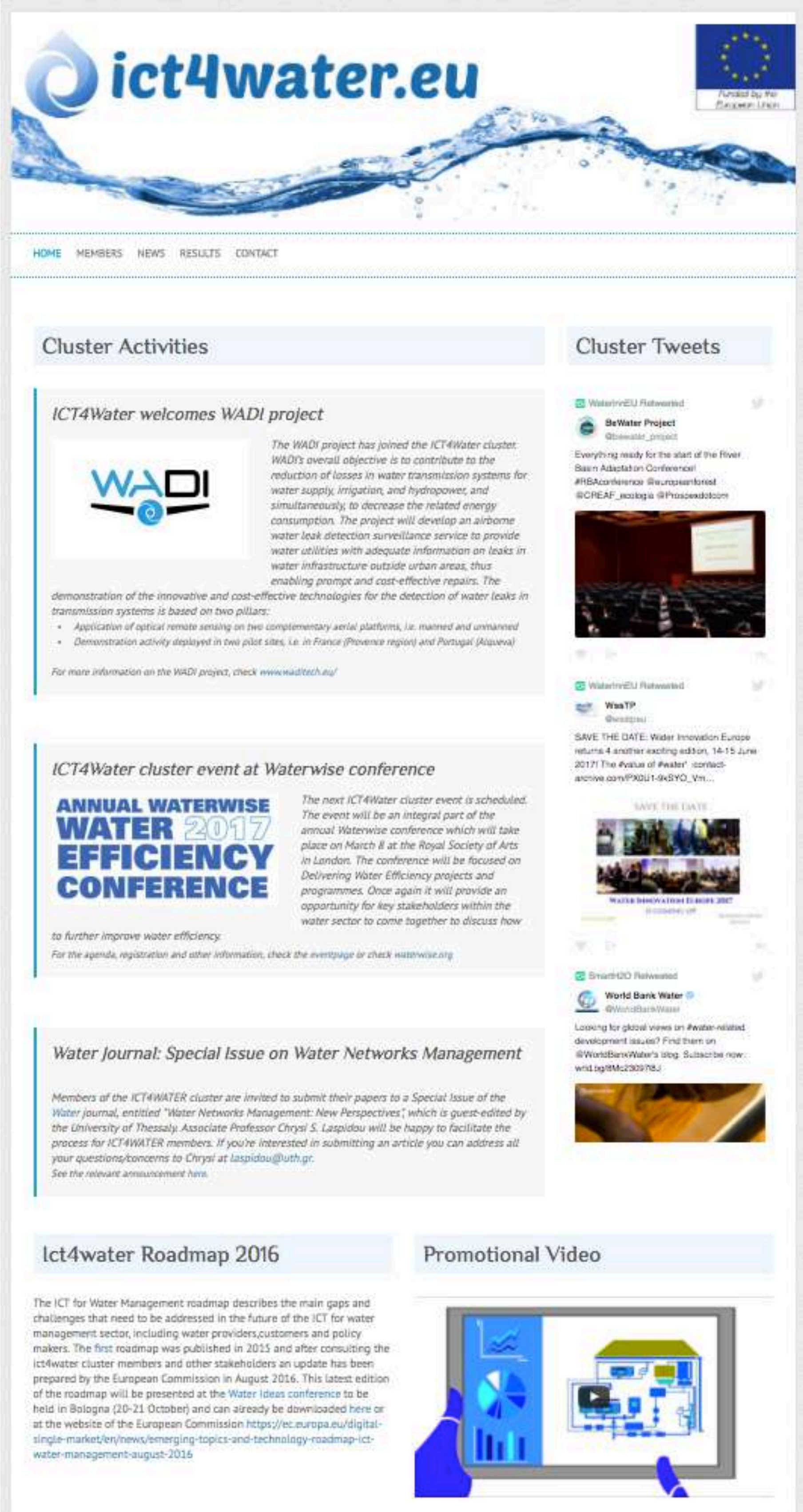


Figure 46: ICT4Water cluster website

Table 10: Overview ICT4Water electronic newsletters

1. Issue	Recipients	Total opens*	Clicks
#1 October 2014	28	897	14
#2 February 2015	66	450	12
#3 May 2015	78	479	39
#4 September 2015	116	475	40
#5 November 2015 (ICT2015 Special)	135	663	102
#6 January 2016	147	499	53
#7 May 2016	152	356	44
#8 September 2016	162	252	28
#9 January 2017	167	169	17

* No. of subscribers for the ICT4Water newsletter is 170 per 05-02-2017.

Finally, Waternomics has participated in various ICT4Water cluster meetings and events. During these meetings, project results and ideas have been shared with the European Commission and member projects from the ICT4Water cluster. Waternomics was present at the cluster meetings and events as listed as the following:

- February 2, 2014, Brussels, Belgium, European Commission, DG-Connect.
- July 15, 2014, Bari, Italy, 16th International Conference Water Distribution Systems Analysis
- August 17, 2014, New York, USA. Hydroinformatics conference 2014
- March 19, 2015, Brussels, Belgium. European Commission, DG-Connect. ICT4Water cluster meeting.
- September 22, 2015, Barcelona, Spain. ICT4Water Open Day
- October 19-22, 2015, Lisbon, Portugal. ICT2015, Waternomics has managed the design of the booth and provided staff for manning the booth.
- February 9, 2016, Leeuwarden, the Netherlands. EIP Water Conference
- June 17, 2016, Jerez, Spain, ICT4Water cluster meeting
- November 15-17, 2016, Barcelona, Spain, European Utility Week

3.4. Exploitation Activities

One of the objectives of Waternomics is to maximise the business impact of the project and to prepare post-project exploitation of project results. To create a link with markets and target customers, business design activities have been defined that run in parallel with the research and development activities. The goal of the business design activities is to identify markets and customer segments who can benefit from solutions based on technologies or methods developed within Waternomics and to come to viable value propositions. Before the start of the project, candidate results for exploitation had been identified. These exploitable results are listed in Table 11.

Table 11: Exploitable results from Waternomics project

Exploitable result	Description	TRL	Exploitation manager	Par.
Waternomics Platform	Smart water platform, including sensor hardware, data platform, applications and methodology	6/7	All	5.1
Flow Data analyser	Low cost non-intrusive flow meter	7	VTEC	5.2
Acoustic Leakage Detector	Low cost acoustic sensor with leakage detection software for application in domestic environment	4	IHE	5.3

Fault Diagnostic rules	Method to identify and rectify faults in water infrastructure in buildings	5	R2M	5.4
Linked Dataspace	Data aggregation platform which collects real-time data about water consumption and availability and makes information services available to applications	7	NUIG	5.5
Waternomics Methodology	Standards based methodology for the implementation of a water information system	NA	R2M	5.6
Water Management Training	Introduction training on hydro-informatics and smart water systems, aimed at college students	NA	IHE	5.7
Drought Monitor	Notification system for droughts in specific geographical areas	6	IHE	5.8
Water Application Market	An online portal through which water-related software applications are made available for procurement and download	6	ULTRA4	5.9

For each exploitable result, a broad set of ideas for value propositions has been generated and profiles of target customers have been defined. The real value of the business design activity was in the validation of the underlying assumptions with target customers, since the concepts and ideas are often generated by the project team, without involvement of these target customers.

The approach for business design used within the project was based on Osterwalder's value proposition design methodology (Osterwalder 2014). This methodology combines Steve Blank's customer development method with business model generation techniques. Underlying principles are the use of design methods, lean principles, visualisation, prototyping and experimentation for rapidly idea development and validate business hypotheses with target customers at an early stage.

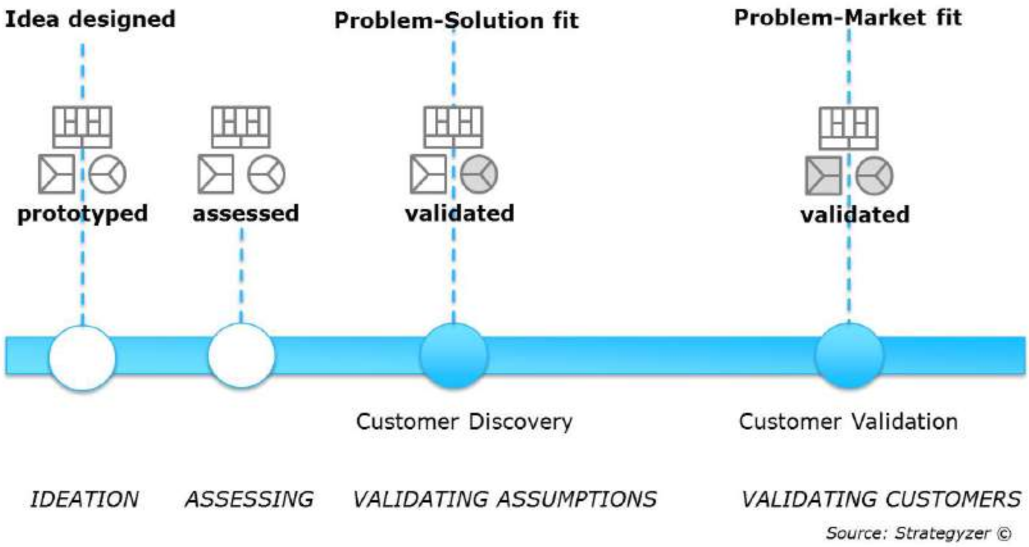


Figure 47: Value proposition design process used in Waternomics

Tools and techniques used were brainstorming, Adlibs, value proposition canvas, interview and experimentation. To facilitate collaboration between remote partners, the project used on-line tools like Deekit for on-line brainstorm and value proposition canvas sessions, or Trello for tracking tests for business hypotheses.

With the resulting output, being a validated business model, an organisational model and IPR arrangements, the foreseen exploitation partners are optimally prepared to bring Waternomics-based products or services to the market. Section **Error! Reference source not found.** provides an overview of the exploitation activities and their results for each of the aforementioned exploitable results. A full detail of the exploitation activities is discussed in Deliverable D7.4.

4. Use of Dissemination of Foreground

This section is split into two parts. The first part (Section A) discusses the dissemination measures and adopted approach for a targeted and efficient dissemination of the project foreground. The second part (Section B) lists the exploitable results of the project and describes the individual exploitation activities and plans of the project partners.

4.1. Section A: Dissemination Measures

To disseminate the project results in the best possible manner, Waternomics implemented a multi-channel and multi-audience approach. We adopted a 3-phased dissemination approach that included:

1. *Planning* of a dissemination strategy,
2. *Execution* of the dissemination strategy, and
3. *Sustainability* of the dissemination activities.

The first step included the definition of the overall dissemination strategy, identifying the objectives, target audiences, and channels for dissemination. This phase took place in the first 3 months of the project (Feb 2014 – April 2014).

The second phase included the dissemination activities based on the strategy created in the first phase, and using the channels already setup. This phase took place during the entire duration of the project with a stronger intensity from month 6 until the end of the project (June 2014 – January 2017).

Finally, the third phase focused on the sustainability of Waternomics dissemination activities. This phase took place in the last 12 months of the project (Feb 2016 – January 2017), with a special attention to standardization, training and the exploitable project results. The dissemination strategy and results of Waternomics described are described in details in D7.5.

4.1.1 Planning

The Waternomics dissemination strategy amounts to (i) circumscribing the target audience of Waternomics, (ii) understanding its particular needs, (iii) specifying the goals and objectives of this dissemination, (iv) introducing impact indicators that quantify the success of the dissemination, (v) determining dissemination tools and assigning impact factors to them as well and (vi) mapping these dissemination tools to different target groups. The dissemination strategy of Waternomics defined the organization profile and the methodology required to reach the target audience, considering the purpose, expectations and key arguments.

Figure 48: Dissemination strategy

4.1.2 Target Stakeholders

At the start of the project, some initial stakeholders were identified for dissemination of Waternomics results based on the subjects where the project was expected to advance the state of the art. This is based initially on the DOW and has been updated in the duration of the project, as well as populated by specific groups, organisations and individuals as and when they were identified. Target stakeholders were been split into five groups, as shown in Figure 49, being policy makers, water industry, consumers, pilot partners and the scientific community.

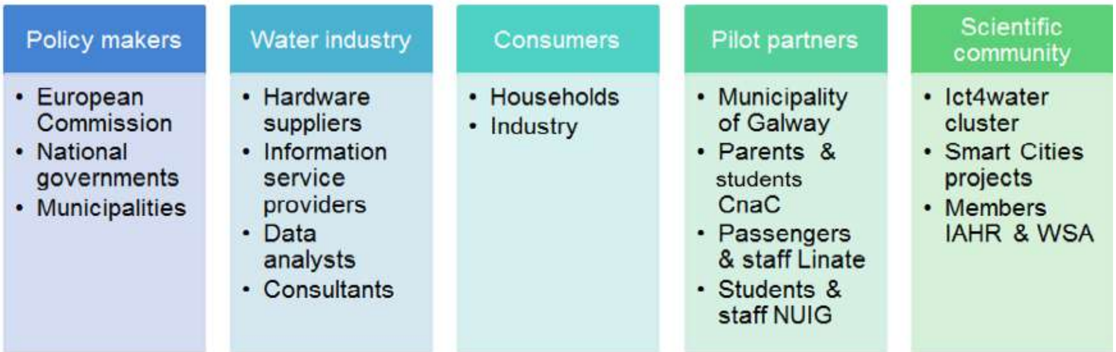


Figure 49: Waternomics target audience

Each stakeholders segment has a specific need or interest. Table 12 shows the stakeholder interests in relation to the Waternomics project.

Table 12: Stakeholder interests

No.	Stakeholder segment	Interest
1	Policy makers	Evidence based solutions for societal and environmental issues, economic growth and job creation.
2	Water industry	New technologies, products or services that can enhance or improve their operations. Case studies.
3	Consumers	Access to sufficient and affordable drinking water. Reduction of carbon footprint. Case studies.
4	Pilot partners	Ideas for solutions for environmental, organisational and/or economic issues.
5	Scientific community	Sharing of research results. New technologies, models and theories. Validated research. Applied research.

4.1.3 Dissemination channels

Table 13 shows the available dissemination channels and their target audience and objectives.

Table 13: Waternomics dissemination channels

Channel	Target audience	Objective
Project website	Water industry, scientific community, water consumers	Increase brand awareness, share key ideas and research results
Blog	Water industry, scientific community, water consumers	Share key ideas and research results
Electronic newsletter	Water industry, scientific community	Share research results, attract stakeholders

Workshops	Pilot stakeholders, policy makers	Validate research results, business validation
Presentations	Scientific community, policy makers	Share research results
Publications	Policy makers, scientific community, water industry	Share research results
Ict4water website	Scientific community	Sharing of research results, collaboration research projects
Stakeholder meetings	Policy makers	Shape smart water agenda
Flyer	Water industry, scientific community	Increase brand awareness
Training activities	Pilot stakeholders	Knowledge transfer, increase smart water awareness
Social media (Flipboard, Slideshare, Twitter, YouTube)	Water consumers, water industry	Increase impact research results, increase awareness hydroinformatics

4.1.4 Execution

Table 14 presents the dissemination plan containing details about the dissemination campaigns in Waternomics in terms of which audience they targetted, the main topics and focus, and how they were implemented with respect to particular channels and activities.

Table 14: Dissemination plan

No.	Campaign	Target audience	Goal	Channel(s)
1	Waternomics Kick-off (M1-M12)	Scientific community, water industry	Increase visibility of Waternomics project	• Waternomics website • Social media • Ict4water cluster • Papers on scientific conferences • Flyer
2	Waternomics policies (M6-M36)	Policy makers	Share ideas	• Roundtable sessions • Demonstration
3	Linate pilot (M18-M30)	Pilot stakeholders	Share Linate pilot results, increase water awareness	• Workshops • Training • Public display
4	Thermi pilot (M18-M30)	Pilot stakeholders	Share Thermi pilot results, increase water awareness	• Workshops • Training sessions
5	NUIG pilot (M18-M30)	Pilot stakeholders	Share NUIG NEB pilot results, educate in water management	• Workshops • Training sessions • Hackathon
6	CnaC pilot (M18-M30)	Pilot stakeholders	Share CnaC pilot results, increase water awareness	• Presentations • Training sessions • Hackathon • Public display
7	Waternomics exploitation (M24 - M36)	Water industry, water consumers	Share exploitable results, validate business models	• Presentation • Publications • Demonstrations • Interviews
8	Waternomics for	Scientific	Share scientific results	• Publications

	scientists (M13 – M36)	community		• Presentations • Newsletter • Website • Blog • Ict4water cluster
9	Waternomics results (M30- M36)	Scientific community, water industry, water consumers	Share final project results	• Website • Blog • Newsletter • Workshop • Presentations • Publications • Ict4water cluster • Social media

4.1.5 Sustainability

Dissemination in the final year of the project was covered by the “Waternomics Exploitation”-campaign and focused on impactful results and the support of sustainable use of project results. Examples of impactful results are: solutions to a problem, facts and data, tools and methods, recommendations and guidelines. The following table lists the expected and available results, origin from the work leading to the official deliverables.

Table 15: Sustainable project results

Result	Nature	Specific target audience
Linate pilot results	Case study, lessons learned	Airport operators
Thermi pilot results	Case study, lessons learned	Municipalities
NUIG NEB pilot results	Case study, lessons learned	Universities
CnaC pilot results	Case study, lessons learned	Schools
Flow Data Analyser	Low cost tool	Process industry
Acoustic Leakage Detector	Solution	Research projects
Fault Detection Diagnosis Rules	Method	Real estate owners
Water Application Market	Solution	Water utilities, municipalities
Waternomics Methodology	Method, guidelines	Consultancy agencies
Water Management Training	Training	Universities, schools
Drought Monitoring System	Tool	Municipalities

Next to that, scientific results will be transferred to the ICT4Water cluster, which will ensure continuous public availability of research results from all member projects.

4.1.6 Results

For full dissemination measures, refer to:

- Deliverable D7.5: Dissemination and Standards Work
- Appendix A: List of Scientific Publications
- Appendix B: List of Dissemination Activities

4.2. Waternomics Consortium

National University of Ireland, Galway

http://www.nuigalway.ie

http://www.insight-centre.org

Ultra4

http://www.ultra4.eu

TU Delft

http://www.tudelft.nl

IHE

https://www.un-ihe.org

BM-Change

http://www.bm-change.nu

R2M Solution

http://www.r2msolution.com

SEA

http://www.seamilano.eu

Municipality of Thermi

http://www.thermi.gov.gr

VTEC Engineering

http://www.vtec-engineering.nl

Appendix A: List of Scientific Publications

TEMPLATE A1: LIST OF SCIENTIFIC (PEER REVIEWED) PUBLICATIONS									
No	**Title**	**Main Author**	**Title of the periodical or the series**	**Number, date or frequency**	**Place of publication**	**Year of Publication**	**Relevant pages**	**Permanent identifier (if available)**	**Open access**
1	ACRyLIQ: Leveraging DBpedia for Adaptive Crowdsourcing in Linked Data Quality Assessment [32]	Umair Ul Hassan	20th International Conference on Knowledge Engineering and Knowledge Management	20	Italy	2016		doi:10.1007/978-3-319-49004-5_44	no
2	NoSym: Non-Symbolic Databases for Data Decoupling-abstract [33]	Souleiman Hasan	Conference on Innovative Data Systems Research (CIDR)		CA, USA	2017			yes
3	Water Analytics and Management with Real-time Linked Dataspaces	Umair Ul Hassan	Government 3.0 - Next Generation Government Technology Infrastructure and Services (Book)		Book Chapter	2017			
4	The ambiguity of innovation drivers: The adoption of information and communication technologies by public water utilities [34]	Mireia Tutusaus	Journal of Cleaner Production		Journal	2016		doi:10.1016/j.jclepro.2016.08.002	yes

5	Designing Next Generation Smart City Initiatives - Harnessing Findings And Lessons From A Study Of Ten Smart City Programs [35]	Adegboyega Ojo	European Conference on Information Systems	22	Tel Aviv, Israel	2014			yes
6	Tackling Variety in Event-Based Systems [21]	Souleiman Hasan	ACM International Conference on Distributed Event-Based Systems	9	New York, USA	2015	256-265	doi:10.1145/2675743.2774215	no
7	Linked Water Data For Water Information Management [36]	Edward Curry	International Conference on Hydroinformatics	11	New York, USA	2014			yes
8	Flag-Verify-Fix: Adaptive Spatial Crowdsourcing leveraging Location-based Social Networks [37]	Umair Ul Hassan	SIGSPATIAL International Conference on Advances in Geographic Information Systems	23	Seattle, Washington, USA	2015		doi:10.1145/2820783.2820870	no
9	Efficient task assignment for spatial crowdsourcing: A combinatorial fractional optimization approach with semi-bandit learning [38]	Umair Ul Hassan	Expert Systems with Applications	58	Journal	2016	36-56	doi:10.1016/j.eswa.2016.03.022	no

10	Interactive Water Services: The Waternomics Approach [20]	Eoghan Clifford	International Conference Water Distribution Systems Analysis	16	Bari, Italy	2014	1058-1065	doi:10.1016/j.proeng.2014.11.225	yes
11	Waternomics: a cross-site data collection to support the development of a water information platform [39]	Peter O'Donovan	Computing and Control for the Water Industry Conference	13	Leicester, UK	2015	458-463	doi:10.1016/j.proeng.2015.08.861	yes
12	The impact of adopting a Water Information Platform on a utilities business model [40]	Sander Smit	IWRA World Water Congress	15	Edinburgh, Scotland	2015			yes
13	Water Conservation with Novel Application of Fault Detection Diagnostics (FDD) Applied to a Rain Water Harvesting System in Ireland [11]	Niall Chambers	IWRA World Water Congress	15	Edinburgh, Scotland	2015			yes
14	NUIG lead EU funded project to increase water usage efficiency [41]	Daniel Coakley	http://www.engineersjournal.ie/		Online Journal	2015			yes
15	Waternomics (ICT for	Domenico Perfido	Procedia Environmental	4	Rimini Fiera, Italy	2015	285-293		yes

	waterresource management) methodology and water information platform [5]		Science, Engineering and Management						
16	Waternomics (ICT for water resource management) methodology for deployment of a water management system [4]	Domenico Perfido	Workshop at International Conference on Artificial Intelligence Application and Innovation		Bayonne Château-Neuf, France	2015			yes
17	Standards-based methodology for the design and implementation of a water management system [42]	Thomas Messervey	International Electronic Conference on Sensors and Applications, Sciforum Electronic Conference Series	2	Online Conference	2015		doi:10.3390/ecsa-2-S7003	yes
18	Modeling and Querying Sensor Services using Ontologies [16]	Sana Baccar	International Conference on Business Information Systems	18	Poznan, Poland	2015	90-101	doi:10.1007/978-3-319-19027-3_8	no
19	Engaging users in tracking their water usage behaviour [43]	Christos Kouroupetroglou	Computing and Control for the Water Industry Conference	13	Leicester, UK	2015	788-797	doi:10.1016/j.proeng.2015.08.937	yes
20	WATERNOMICS: Low cost sensors and systems for collecting water	Jan Mink	IAHR World Congress	36	The Hague, The Netherlands	2015			yes

	usage in three pilots [9]							
21	WATERNOMICS: Serving diverge user needs under a single water information platform [8]	Christos Kouroupetroglou	IAHR World Congress	36	The Hague, The Netherlands	2015		yes
22	Business drivers for adopting smart water technology [13]	Sander Smit	IAHR World Congress	36	The Hague, The Netherlands	2015		yes
23	Assessment and Planning for the Application of Fault Detection and Diagnosis (FDD) to Building Water Networks, A WATERNOMICS Approach [14]	Niall Chambers	IAHR World Congress	36	The Hague, The Netherlands	2015		yes
24	Sustainable water networks, an automated fault detection and diagnosis of water network systems [44]	Domenico Perfido	Sustainable Places	70	Anglet, France	2016		yes
25	WATERNOMICS: Development of a water information platform based on a linkesensor	Daniel Coakley	IIRC			2014		yes

	data framework [6]						
26	A Shazam-like household water leakage detection method [10]	Solomon Seyoum	WDSA	18	Cartagena, Colombia	2016	yes

Appendix B: List of Dissemination Activities

TEMPLATE A2: LIST OF DISSEMINATION ACTIVITIES

No.	Type of activities	Main leader	Title	Date/Period	Place	Type of audience	Size of audience	Countries addressed
1	presentations	Wassim Derguech	Waternomics - ICT for Water Resource Management	01/04/2015	Insight Centre for Data Analytics at NUIG	Scientific Community (higher education; Research)	60	Ireland
2	presentations	Wassim Derguech	(Big) Data Analytics for Environmental Sustainability	01/04/2016	The Mediterranean College of Thessaloniki, Greece	Scientific Community (higher education; Research)	30	Greece
3	presentations	Eoghan Clifford	Waternomics – ICT for Water Resources Management (Joint with Engineers Ireland West)	01/11/2014	ENG-G047, Engineering Building, NUIG	Scientific Community (higher education; Research)		Ireland
4	conferences	Souleiman Hasan	Tackling Variety in Event-Based Systems	29/06/2015	DEBS 2015, University of Oslo	Scientific Community (higher education; Research)	60	International
5	conferences	Wassim Derguech	Modeling and Querying Sensor Services using Ontologies	25/06/2015	BIS 2015, Poznan, Poland	Scientific Community (higher education; Research)	50	International
6	presentations	Souleiman Hasan	Water Management, Web of Things, and Enabling Technologies	20/04/2015	W3C Web of Things Interest Group, Siemens, Munich, Germany	Scientific Community (higher education; Research) and Industry	50	International
7	flyers	Souleiman Hasan	Waternomics Flyers	16/11/2015	European Data Forum, Luxembourg	Scientific Community (higher education;	200	Europe

						Research) and Industry		
8	presentations	Souleiman Hasan	Dealing with Variety in the Internet of Things	18/09/2015	EarthBias Summer School, University of the Aegean, Greece	Scientific Community (higher education; Research)	20	International
9	conferences	Andrea Costa	2nd Green session chapter Lombardia di GBC Italia	25/10/2016	Milan - Italy	Scientific Community (higher education; Research)	50	Europe
10	videos	Marcella Scuccimarra	Video segment for the touch screen displays / youtube	15/09/2016	Milan - Italy	Medias	> 2000	International
11	posters	Domenico Perfido	Ecomondo 2016: Waternomics - Model Based FDD	08/11/2016	Rimini - Italy	Other	200	Europe
12	videos	Domenico Perfido	Video segment for Ecomondo fair 2015 / youtube	15/10/2015	Milan - Italy	Medias	> 2000	Europe
13	conferences	Thomas Messervey	ECSA 2015 - Standards-based methodology for the design and implementation of a water management system	15/11/2015	Online conference session	Scientific Community (higher education; Research)		Europe
14	conferences	Thomas Messervey	ECSA 2016 - AUTOMATED LEAK DETECTION SYSTEM FOR THE IMPROVEMENT OF WATER NETWORK MANAGEMENT	15/10/2016	Online conference session	Scientific Community (higher education; Research)		Europe
15	workshops	Andrea Costa	IceWater Workshop	15/09/2015	Milan - Italy	Scientific Community (higher education; Research)	30	Europe
16	presentations	Federico Noris	Sustainable Places 2016: Waternomics - IModel Based FDD	30/06/2016	Anglet - France	Scientific Community (higher education; Research)	60	Europe

17	workshops	Louise Hannon	Water Awareness Workshop and Intro to App Design for Secondary School Students	01/03/2016	NUI Galway - Ireland	Other	37	Europe
18	workshops	Louise Hannon	Water Conservation Workshop for Primary School Students	04/03/2016	Local Primary School	Other	30	Europe
19	workshops	Louise Hannon	Water Awareness Workshop and Intro to App Design for Secondary School Students	15/03/2016	CnaC Pilot Site	Other	>85	Europe
20	workshops	Louise Hannon	Water Conservation and Awareness Workshop for Secondary School Students	26/04/2016	NUI Galway - Ireland	Other	30	Europe
21	workshops	Louise Hannon	1-Week Internship Scheme for Secondary School Students	07/06/2016	NUI Galway - Ireland	Other	2	Europe
22	presentations	Louise Hannon	Introducing Waternomics - Presentation to visiting Students and Academics from Purdue and Auburn Universities in USA	25/05/2016	NUI Galway - Ireland	Scientific Community (higher education; Research)	40	USA
23	presentations	Louise Hannon	Introducing Waternomics - Presentation to 1st Year Engineering Students at NUI Galway	12/09/2016	NUI Galway - Ireland	Scientific Community (higher education; Research)	200	Europe
24	presentations	Sander Smit	European Utility Week - The business aspects, perspectives and future for smart water	17/11/2016	Barcelona, Spain	Industry	30	Europe
25	flyers	Sander Smit	European Utility Week, Waternomics flyers and brochures	15-17/11/2016	Barcelona, Spain	Industry	>10000	International
26	exhibitions	Jan Mink	Domotica en slim wonen, Waternomics demo	26/05/2016	Eindhoven, Netherlands	Industry		
27	exhibitions	Wassim Derguech	ICT2015, Flyer, poster presetnation & video	18/10/2015	Lisbon, Portugal	Policy makers	>2000	Europe
28	posters	Sander Smit	ICT4Water Open Day	22/09/2015	Barcelona, Spain	Scientific Community (higher education;	50	Europe

						Research)		
29	conferences	Sander Smit	IAHR - Business drivers for adopting smart water technology	02/07/2015	the Hague, Netherlands	Scientific Community (higher education; Research)	30	Europe
30	conferences	Christos Kouroupetroglou	IAHR - WATERNOMICS: Serving diverge user needs under a single water information platform	02/07/2015	the Hague, Netherlands	Scientific Community (higher education; Research)	30	Europe
31	conferences	Niall Chambers	IAHR - Assessment and Planning for the Application of Fault Detection and Diagnosis (FDD) to Building Water Networks, A WATERNOMICS Approach	02/07/2015	the Hague, Netherlands	Scientific Community (higher education; Research)	30	Europe
32	conferences	Sander Smit	World Water Conference - The impact of adopting a water information platform on a water utilities business model	27/05/2015	Edinburgh, UK	Scientific Community (higher education; Research)	30	Europe
33	conferences	Niall Chambers	World Water Conference - The impact of adopting a water information platform on a water utilities business model	27/05/2015	Edinburgh, UK	Scientific Community (higher education; Research)	30	Europe
34	presentations	Wassim Derguech	Waternomics Results and Key Impacts	27/01/2017	Galway, IE	Scientific Community (higher education; Research)	50	Ireland
35	presentations	Shyam C. Jayakrishnan	Design Thinking: Experience from the Waternomics Project	26/01/2017	Galway, IE	Industry	20	International
36	presentations	Eoghan Clifford	Waternomics Key Impacts for Smart Water Management	31/01/2017	Galway, IE	Industry	25	International
37	presentations	Joanne Craven	Waternomics: Shazam that Water Leak! (Sensors and Faults)	31/01/2017	Galway, IE	Industry	25	International
38	presentations	Wassim Derguech	Waternomics: Making Sense of	31/01/2017	Galway, IE	Industry	25	International

			Water Data					
39	presentations	Christos Kouroupetroglou	Waternomics Applications Platform: Water apps for everyone	31/01/2017	Galway, IE	Industry	25	International
40	presentations	Sander Smit	Waternomics: Methodology	31/01/2017	Galway, IE	Industry	25	International
41	presentations	Louise Hannon	Waternomics: Overview of the Pilots Objectives, Measures and Outcomes	31/01/2017	Galway, IE	Industry	25	International
42	presentations	Sander Smit	Waternomics: Business Models and Exploitation	31/01/2017	Galway, IE	Industry	25	International
43	flyers	Wassim Derguech	Waternomics Flyers	31/01/2017	Galway, IE	Industry	25	International
44	flyers	Wassim Derguech	Waternomics Keys Results	31/01/2017	Galway, IE	Industry	25	International
45	thesis	Shyam C. Jayakrishnan	Waternomics Apps: Usability Testing and Re-design Recommendations	05/10/2016	TUE, Eindhoven, NL	Scientific Community (higher education; Research)	>2000	International
46	thesis	Maarten Piso	Waternomics: The quest for persuasive technology applications for sustainable water consumption	02/10/2015	TUE, Eindhoven, NL	Scientific Community (higher education; Research)	>2000	International
47	thesis	Zhiyuan Zheng	Rethink Accessing Water - A First Attempt in Goal-oriented Water Usage	02/10/2015	TUE, Eindhoven, NL	Scientific Community (higher education; Research)	>2000	International
48	workshops	Christos Kouroupetroglou	WATERNOMICS: ICT for Water Resource Management (EU Project Networking Session at ESWC 2015)	08/03/2015	Portoroz, Slovenia	Scientific Community (higher education; Research)	50	International
49	videos	Waternomics Youtube Channel	Waternomics – From application to value proposition	Apr 2015	Youtube	Other	>2000	International
50	videos	Waternomics Youtube Channel	Waternomics household installation smart water pilot Thermi	Oct 2015	Youtube	Other	>2000	International

51	videos	Waternomics Youtube Channel	R2M Solution SRL – ECOMONDO	Dec 2015	Youtube	Other	>2000	International
52	videos	Waternomics Youtube Channel	SEA video sustainability	Jun 2016	Youtube	Other	>2000	International
53	videos	Waternomics Youtube Channel	SEA public video	Sep 2016	Youtube	Other	>2000	International
54	videos	Waternomics Youtube Channel	Waternomics INSIGHT NUIG	Nov 2016	Youtube	Other	>2000	International
55	videos	Waternomics Youtube Channel	Retention time observer	Nov 2016	Youtube	Other	>2000	International
56	videos	Waternomics Youtube Channel	WKAN and OpenCube demo	Nov 2016	Youtube	Other	>2000	International
57	videos	Waternomics Youtube Channel	Waternomics platform real time pipeline	Nov 2016	Youtube	Other	>2000	International
58	videos	Waternomics Youtube Channel	Waternomics demo: Interactive display	Nov 2016	Youtube	Other	>2000	International
59	videos	Waternomics Youtube Channel	Demo QRcode app	Nov 2016	Youtube	Other	>2000	International
60	videos	Waternomics Youtube Channel	Waternomics demo secure query service	Nov 2016	Youtube	Other	>2000	International
61	videos	Waternomics Youtube Channel	Insight@NUIG partner in Waternomics	Dec 2016	Youtube	Other	>2000	International
62	videos	Waternomics Youtube Channel	Public display for school	Dec 2016	Youtube	Other	>2000	International
63	videos	Waternomics Youtube Channel	Engineering Building at NUIG, a pilot site of Waternomics project	Dec 2016	Youtube	Other	>2000	International
64	videos	Waternomics Youtube Channel	Coláiste na Coiribe - pilot site for the Waternomics project	Dec 2016	Youtube	Other	>2000	International
65	videos	Waternomics Youtube Channel	Department of Civil Engineering at NUIG partner in Waternomics	Jan 2017	Youtube	Other	>2000	International

66	videos	Waternomics Youtube Channel	Introducing Waternomics project	Jan 2017	Youtube	Other	>2000	International
67	videos	Waternomics Youtube Channel	Acoustic leak detection by Waternomics	Jan 2017	Youtube	Other	>2000	International
68	videos	Waternomics Youtube Channel	Acoustic leak detection by Waternomics	Jan 2017	Youtube	Other	>2000	International
69	videos	Waternomics Youtube Channel	Water conservation in Galway City	Jan 2017	Youtube	Other	>2000	International
70	videos	Waternomics Youtube Channel	Waternomics: Key Impacts for Smart Water Management	Jan 2017	Youtube	Other	>2000	International
71	videos	Waternomics Youtube Channel	Waternomics: Shazam that Water Leak	Jan 2017	Youtube	Other	>2000	International
72	videos	Waternomics Youtube Channel	Waternomics: Overview of the Pilots Objectives, Measure and Outcome	Jan 2017	Youtube	Other	>2000	International
73	videos	Waternomics Youtube Channel	Waternomics Business Models and Exploitation	Jan 2017	Youtube	Other	>2000	International
74	videos	Waternomics Youtube Channel	Waternomics Methodology	Jan 2017	Youtube	Other	>2000	International
75	videos	Waternomics Youtube Channel	Waternomics: Making sense of water data	Jan 2017	Youtube	Other	>2000	International
76	videos	Waternomics Youtube Channel	Key technologies for Smart Cities	Jan 2017	Youtube	Other	>2000	International
77	videos	Waternomics Youtube Channel	Africa Water	Jan 2017	Youtube	Other	>2000	International
78	videos	Waternomics Youtube Channel	Waternomics Application Platform: Applications for everyone	Jan 2017	Youtube	Other	>2000	International
79	videos	Waternomics Youtube Channel	Introducing Waternomics project	Jan 2017	Youtube	Other	>2000	International
80	web	Waternomics Blog	Kick off meeting	February	waternomics.eu	Other	>2000	International

		and News		2014				
81	web	Waternomics Blog and News	Deputy Mayor of Thermi visits Insight Galway	February 2014	waternomics.eu	Other	>2000	International
82	web	Waternomics Blog and News	From application to value proposition	April 2014	waternomics.eu	Other	>2000	International
83	web	Waternomics Blog and News	Saving water through better information	December 2014	waternomics.eu	Other	>2000	International
84	web	Waternomics Blog and News	Comics for Waternomics usage scenarios	December 2014	waternomics.eu	Other	>2000	International
85	web	Waternomics Blog and News	Planning for water savings at Linate airport	January 2015	waternomics.eu	Other	>2000	International
86	web	Waternomics Blog and News	Got leaks? – we can hear them!	January 2015	waternomics.eu	Other	>2000	International
87	web	Waternomics Blog and News	Preparing Waternomics pilot at Thermi	January 2015	waternomics.eu	Other	>2000	International
88	web	Waternomics Blog and News	Smart Water for Irish schools	January 2015	waternomics.eu	Other	>2000	International
89	web	Waternomics Blog and News	AFDD improves efficiency of water network	January 2015	waternomics.eu	Other	>2000	International
90	web	Waternomics Blog and News	Paper accepted at BIS 2015	March 2015	waternomics.eu	Other	>2000	International
91	web	Waternomics Blog and News	Six papers accepted at IAHR 2015	March 2015	waternomics.eu	Other	>2000	International
92	web	Waternomics Blog and News	Paper accepted at DEBS 2015	April 2015	waternomics.eu	Other	>2000	International
93	web	Waternomics Blog and News	Waternomics Water Value Map	May 2015	waternomics.eu	Other	>2000	International
94	web	Waternomics Blog and News	The W3C Interest Group on the Web of Things	May 2015	waternomics.eu	Other	>2000	International
95	web	Waternomics Blog	How to measure water flow	August 2015	waternomics.eu	Other	>2000	International

		and News						
96	web	Waternomics Blog and News	Waternomics and ICT4Water at Pint of Science Ireland – Galway	August 2015	waternomics.eu	Other	>2000	International
97	web	Waternomics Blog and News	Waternomics in Smartest House	August 2015	waternomics.eu	Other	>2000	International
98	web	Waternomics Blog and News	ICT4Water Open Day	September 2015	waternomics.eu	Other	>2000	International
99	web	Waternomics Blog and News	Waternomics at the Big Data Analysis in Earth Sciences Summer School	September 2015	waternomics.eu	Other	>2000	International
100	web	Waternomics Blog and News	ICT 2015 Innovate, Connect, Transform	October 2015	waternomics.eu	Other	>2000	International
101	web	Waternomics Blog and News	ECOMODO 2015 – "The Green Technologies Expo"	October 2015	waternomics.eu	Other	>2000	International
102	web	Waternomics Blog and News	Waternomics exhibits at ECOMODO	November 2015	waternomics.eu	Other	>2000	International
103	web	Waternomics Blog and News	Anytime, anywhere, the notifications will be delivered	November 2015	waternomics.eu	Other	>2000	International
104	web	Waternomics Blog and News	The story of a very successful sensors installation	December 2015	waternomics.eu	Other	>2000	International
105	web	Waternomics Blog and News	Introducing the Waternomics Applications Platform	December 2015	waternomics.eu	Other	>2000	International
106	web	Waternomics Blog and News	Why an Application Platform?	January 2016	waternomics.eu	Other	>2000	International
107	web	Waternomics Blog and News	Waternomics targets diverse user groups	January 2016	waternomics.eu	Other	>2000	International
108	web	Waternomics Blog and News	Making users feel like home	February 2016	waternomics.eu	Other	>2000	International
109	web	Waternomics Blog and News	EIP Water Conference 2016	February 2016	waternomics.eu	Other	>2000	International

110	web	Waternomics Blog and News	Waternomics Workshop for the Engineers Week	February 2016	waternomics.eu	Other	>2000	International
111	web	Waternomics Blog and News	Diverse users, multiple applications, one platform for all	February 2016	waternomics.eu	Other	>2000	International
112	web	Waternomics Blog and News	Apps Building for school kids using MIT App Inventor and Waternomics Data	March 2016	waternomics.eu	Other	>2000	International
113	web	Waternomics Blog and News	Waternomics at EIP Water Conference	March 2016	waternomics.eu	Other	>2000	International
114	web	Waternomics Blog and News	Water Conservation Workshop – Water Aware Event for Secondary School Students at NUI Galway	March 2016	waternomics.eu	Other	>2000	International
115	web	Waternomics Blog and News	From notifications, to actions and motivation	March 2016	waternomics.eu	Other	>2000	International
116	web	Waternomics Blog and News	Waternomics Workshop at Coláiste na Coiribe	March 2016	waternomics.eu	Other	>2000	International
117	web	Waternomics Blog and News	(Big) Data Analytics for Environmental Sustainability	April 2016	waternomics.eu	Other	>2000	International
118	web	Waternomics Blog and News	Water Flavours	April 2016	waternomics.eu	Other	>2000	International
119	web	Waternomics Blog and News	Ict4water cluster meeting at LET2016	April 2016	waternomics.eu	Other	>2000	International
120	web	Waternomics Blog and News	Altantec'16 Festival	April 2016	waternomics.eu	Other	>2000	International
121	web	Waternomics Blog and News	Waternomics at NUI Galway Civil Engineering TY Week	May 2016	waternomics.eu	Other	>2000	International
122	web	Waternomics Blog and News	Waternomics at Atlantec'16	June 2016	waternomics.eu	Other	>2000	International
123	web	Waternomics Blog and News	Waternomics hosts two interns at NUIG	June 2016	waternomics.eu	Other	>2000	International

124	web	Waternomics Blog and News	Research Toolbox – Data Analysis with Python : A Waternomics Case Study	June 2016	waternomics.eu	Other	>2000	International
125	web	Waternomics Blog and News	Waternomics installs public displays at Linate airport	July 2016	waternomics.eu	Other	>2000	International
126	web	Waternomics Blog and News	Inviting users to visualize details about water consumption in public spaces	August 2016	waternomics.eu	Other	>2000	International
127	web	Waternomics Blog and News	Waternomics installs a public display at the Engineering Building, National University of Ireland, Galway	August 2016	waternomics.eu	Other	>2000	International
128	web	Waternomics Blog and News	Linked Water Dataspace: Real-time pipeline	September 2016	waternomics.eu	Other	>2000	International
129	web	Waternomics Blog and News	WKAN and OpenCube demo – Catalog Service and Data Explorer	September 2016	waternomics.eu	Other	>2000	International
130	web	Waternomics Blog and News	Training and Feedback Session at Coláiste na Coiribe School	September 2016	waternomics.eu	Other	>2000	International
131	web	Waternomics Blog and News	A Shazam-like household water leakage detection method	October 2016	waternomics.eu	Other	>2000	International
132	web	Waternomics Blog and News	ECOMONDO 2016 – The Green Technology Expo	November 2016	waternomics.eu	Other	>2000	International
133	web	Waternomics Blog and News	Waternomics at ECOMONDO 2016	November 2016	waternomics.eu	Other	>2000	International
134	web	Waternomics Blog and News	Exploiting Hydraulic Model to Enhance Water Network Operation, Performance Monitoring and Control with FDD Algorithm	November 2016	waternomics.eu	Other	>2000	International
135	web	Waternomics Blog and News	Automated Leak Detection System for the Improvement of Water Network Management	November 2016	waternomics.eu	Other	>2000	International
136	web	Waternomics Blog	SEA will host a "Water Fair" in	November	waternomics.eu	Other	>2000	International

		and News	Linate Airport	2016				
137	web	Waternomics Blog and News	Launch of the Public Display App at Colaiste na Coiribe School in Galway, Ireland	January 2017	waternomics.eu	Other	>2000	International
138	web	Waternomics Blog and News	Design Thinking workshop	January 2017	waternomics.eu	Other	>2000	International
139	web	Waternomics Blog and News	Waternomics Final Event	January 2017	waternomics.eu	Other	>2000	International
140	web	Waternomics Blog and News	Waternomics events for January 2017	January 2017	waternomics.eu	Other	>2000	International

Bibliography

[1] European Commision, "Europe 2020 Flagship Initiative Innovation Union," 2010. [Online]. Available: http://ec.europa.eu/europe2020/europe-2020-in-a-nutshell/flagship-initiatives/index_en.htm. [Accessed: 14-Apr-2016].

[2] European Commision, "The European Innovation Partnership on Smart Cities and Communities," 2015. [Online]. Available: http://ec.europa.eu/eip/smartcities/. [Accessed: 16-Apr-2016].

[3] European Commision, "The European Innovation Partnership on Water," 2013. .

[4] D. Perfido, T. Messervey, F. Noris, R. Pugliesi, S. Smit, and C. Andrea, "{WATERNOMICS} {(ICT} for Water Resource Management) - Methodology for Deployment of a Water Management System," in *Proceedings of the Special Tracks and Workshops at the 11th International Conference on Artificial Intelligence Applications and Innovations {(AIAI} 2015), Bayonne, France, September 14-17, 2015.*, 2015, vol. 1539, pp. 83–96.

[5] D. Perfido, T. Messervey, C. Kouroupetroglou, and A. Costa, "Waternomics (ICT for water resource management) methodology and water information platform," *Procedia Environ. Sci. Eng. Manag.*, vol. 2, no. 4, pp. 285–293, 2015.

[6] D. Coakley, P. O'Donovan, J. Mink, E. Curry, and E. Clifford, "WATERNOMICS : Development of a water information platform based on a linked sensor data framework," in *Intel Ireland Research Conference, Novmeber 2014*, 2014.

[7] ckan.org, "CKAN - The Open Source Data Portal Software." .

[8] E. Kouroupetroglou, Christos Van Slooten, Jesse Clifford, Eoghan Coakley, Daniel Curry, "WATERNOMICS: Serving diverge user needs under a single water information platform."

[9] J. Mink and Y. Lu, "WATERNOMICS: Low cost sensors and systems for collecting water usage in three pilots," *36th IAHR World Congr. (IAHR 2015)*, 2015.

[10] S. Seyoum, L. Alfonso, S. J. van Andel, W. Koole, A. Groenewegenb, and N. van de Giesen, "A Shazam-like household water leakage detection method," in *Conference on Water Distribution System Analysis, WDSA 2016, At Cartagena, Colombia, 2016*, 2016.

[11] N. Chambers, D. Coakley, M. Keane, and E. Clifford, "Water conservation with novel application of fault detection diagnostics (FDD) applied to a rain water harvesting system in Ireland," in *Proceedings of World Water Congress XV*, 2015.

[12] D. Perfido, M. Raciti, C. Zanotti, S.-J. van Andel, and A. Costa, "EXPLOITING HYDRAULIC MODEL TO ENHANCE WATER NETWORK OPERATION, PERFORMANCE MONITORING AND CONTROL WITH FDD ALGORITHMS."

[13] S. Smit, M. Tutusaus, E. Curry, T. Messervey, and Z. D'Andrea, "Business drivers for adopting smart water technology," *36th IAHR World Congr. (IAHR 2015)*, 2015.

[14] N. Chambers *et al.*, "Assessment and Planning for the Application of Fault Detection and Diagnosis (FDD) to Building Water Networks, A WATERNOMICS Approach," *36th IAHR World Congr. (IAHR 2015)*, 2015.

[15] P. O'Donovan, D. Coakley, J. Mink, E. Curry, and E. Clifford, "Waternomics: A cross-site data collection to support the development of a water information platform," in *Procedia Engineering*, 2015.

[16] S. Baccar, W. Derguech, E. Curry, and M. Abid, "Modeling and Querying Sensor Services using Ontologies," in 18th International Conference on Business Information Systems (BIS 2015), 2015.

[17] W. Derguech, S. Hasan, S. Bhiri, and E. Curry, "Organizing capabilities using formal concept analysis," in *Proceedings of the Workshop on Enabling Technologies: Infrastructure for Collaborative Enterprises, WETICE*, 2013.

[18] W. Derguech, S. Bhiri, S. Hasan, and E. Curry, "Using Formal Concept Analysis for Organizing

and Discovering Sensor Capabilities," *Comput. J.*, vol. 58, no. 3, pp. 356–367, 2015.

[19] C. Kouroupetroglou *et al.*, "WATERNOMICS: Serving diverge user needs under a single water information platform," *36th IAHR World Congr. (IAHR 2015)*, 2015.

[20] E. Clifford *et al.*, "Interactive water services: The WATERNOMICS approach," in *Procedia Engineering*, 2014.

[21] S. Hasan and E. Curry, "Thingsonomy: Tackling Variety in Internet of Things Events," *IEEE Internet Comput.*, vol. 19, no. 2, pp. 10–18, 2015.

[22] S. Hasan and E. Curry, "Approximate Semantic Matching of Events for The Internet of Things," *ACM Trans. Internet Technol.*, vol. 14, no. 1, p. 2:1--2:23, 2014.

[23] S. Hasan and E. Curry, "Thematic event processing," in *Proceedings of the 15th International Middleware Conference*, 2014, pp. 109–120.

[24] S. Hasan, E. Curry, M. Banduk, and S. O'Riain, "Toward Situation Awareness for the Semantic Sensor Web: Complex Event Processing with Dynamic Linked Data Enrichment," in *The 4th International Workshop on Semantic Sensor Networks 2011 (SSN11), a Workshop of ISWC 2011*, 2011, pp. 60–72.

[25] S. Hasan, K. Gunaratna, Y. Qin, and E. Curry, "Approximate Semantic Matching in the COLLIDER Event Processing Engine (Demo)," in 7th ACM International Conference on Distributed Event-Based Systems (DEBS 2013), 2013, pp. 337–338.

[26] S. Hasan, S. O'Riain, and E. Curry, "Towards Unified and Native Enrichment in Event Processing Systems," in *The 7th ACM International Conference on Distributed Event-Based Systems (DEBS 2013)*, 2013.

[27] S. Hasan, S. O'Riain, and E. Curry, "Approximate Semantic Matching of Heterogeneous Events," in *6th ACM International Conference on Distributed Event-Based Systems (DEBS 2012)*, 2012, pp. 252--263.

[28] S. Hasan and E. Curry, "Tackling Variety in Event-based Systems," in *Proceedings of the 9th ACM International Conference on Distributed Event-Based Systems*, 2015, pp. 256–265.

[29] N. Marz and J. Warren, *Big Data: Principles and best practices of scalable realtime data systems*. O'Reilly Media, 2013.

[30] Kayaposoft, "Enrico Service." [Online]. Available: http://kayaposoft.com/enrico/.

[31] A. Clarke, N. Grant, and J. Thornton, "Quantifying the energy and carbon effects of water saving – Full technical report," *[Online]*, 2009.

[32] U. ul Hassan, A. Zaveri, E. Marx, E. Curry, and J. Lehmann, "ACRyLIQ: Leveraging DBpedia for adaptive crowdsourcing in linked data quality assessment," in *Lecture Notes in Computer Science (including subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics)*, 2016.

[33] S. Hasan, "NoSym: Non-Symbolic Databases for Data Decoupling," in *CIDR*, 2017.

[34] M. Tutusaus, K. Schwartz, and S. Smit, "The ambiguity of innovation drivers: The adoption of information and communication technologies by public water utilities," *J. Clean. Prod.*, 2016.

[35] A. Ojo, E. Curry, and T. Janowski, "Designing Next Generation Smart City Initiatives-Harnessing Findings And Lessons From A Study Of Ten Smart City Programs," *Proc. Eur. Conf. Inf. Syst. 2014*, vol. 2050, pp. 0–14, 2014.

[36] E. Curry, V. Degeler, E. Clifford, D. Coakley, A. Costa, S.-J. Van Andel, N. Van De Giesen, C. Kouroupetroglou, T. Messervey, J. Mink, and S. Smit, "Linked Water Data For Water Information Management," in 11th International Conference on Hydroinformatics (HIC 2014), 2014.

[37] U. ul Hassan and E. Curry, "Flag-Verify-Fix: Adaptive Spatial Crowdsourcing leveraging Location-based Social Networks," *23rd ACM SIGSPATIAL Int. Conf. Adv. Geogr. Inf. Syst. (ACM*

SIGSPATIAL 2015), 2015.

[38] U. ul Hassan and E. Curry, "Efficient task assignment for spatial crowdsourcing: A combinatorial fractional optimization approach with semi-bandit learning," *Expert Syst. Appl.*, vol. 58, pp. 36–56, 2016.

[39] P. O'Donovan, D. Coakley, J. Mink, E. Curry, and E. Clifford, "Waternomics: A Cross-site Data Collection to Support the Development of a Water Information Platform," *Procedia Eng.*, 2015.

[40] S. Smit, M. Tutusaus, K. Schwartz, E. Curry, T. Messervey, and R. Puglisi, "The impact of adopting a Water Information Platform on a utilities business model," in *Proceedings of World Water Congress XV*, 2015.

[41] D. Coakley, N. Chambers, L. Hannon, M. Keane, E. Curry, and E. Clifford, "NUIG lead EU funded project to increase water use efficiency," *Engineers Ireland Journal*, 2015.

[42] T. Messervey, D. Perfido, L. Hannon, and S. Smit, "Standards-based methodology for the design and implementation of a water management system," in *International Electronic Conference on Sensors and Applications, Sciforum Electronic Conference Series, November 2015*, 2015.

[43] C. Kouroupetroglou *et al.*, "Engaging users in tracking their water usage behavior," in *Procedia Engineering*, 2015, vol. 119, no. 1.

[44] D. Perfido *et al.*, "Sustainable water networks, an automated fault detection and diagnosis of water network systems," in *Sustainable Places 2016 International Conference (SP 2016), Anglet, France, 2016*, 2016.

[45] J. M. Cavanillas, E. Curry, and W. Wahlster, Eds., New Horizons for a Data-Driven Economy: A Roadmap for Usage and Exploitation of Big Data in Europe. Cham: Springer International Publishing, 2016.