D1.3 System Architecture and KPIs

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D1.3

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Executive Summary

This deliverable discusses the identification of key performance indicators and the development of Waternomics system architecture. Key performance indicators (KPIs) are needed for future evaluation purposes in order to report on the success of the Waternomics platform or the identification of potential improvements. The system architecture is the conceptual model to define the structure and behaviour of Waternomics platform consisting of three layers: hardware, data and software. Designing high level system architecture is an important step towards providing a technical guidance to the development of Waternomics platform and each of the project pilots' solutions.

This deliverable starts by identifying the set of KPIs after a survey done among pilots' stakeholders. Then we analyze the usage case and initial exploitation scenarios as input from D1.1 in order to determine relevant functional and non-functional usage requirements. These requirements are analyzed in order to define architectural requirements that the project needs to cover in terms of hardware, data and software requirements. These architectural requirements are mapped to a set of technologies that were identified in D1.2. A high level system architecture is also proposed in this deliverable.

The main contribution of this report is the definition of system architecture tailored to Waternomics platform and the key performance indicators for evaluating the performance of activities in Waternomics project. The system architecture plays the role as a guideline for the future work to build up the Waternomics platform carried out in other work packages (WP2, WP3 and WP5). KPIs run through the whole project to provide criteria on assessment and reporting on the Waternomics platform.

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1. Introduction

The goal of Waternomics is to explore how ICT can help households, businesses and municipalities with reducing their consumption and losses of water. Two important assets are required for properly design the Waternomics platform: Key Performance Indicators (KPIs) and System Architecture. These assets are part of the WP1 objectives.

KPIs are relevant for evaluating the Waternomics platform with respect to the stakeholders' requirements. The system architecture and requirements constitute a guideline towards designing a water management system.

1.1. Work Package 1 Objectives

The work of this WP relies on the expertise and field experience of the consortium partners as well as input elicited through the key stakeholder water workshop. This WP objective is to produce as output, the requirements, constraints, business strategies, use cases, and high level architecture that form the baseline for the development of the project foreground. In order to achieve this objective, the WP is aims to carry out the following actions:

- Business models applicable in the water management environment will be studied and monitored.
- Current needs, opportunities, barriers, policies, standards, challenges, and solutions will be documented.
- The business and collaboration opportunities identified will be structured in a way to ensure the maximum flexibility of the system architecture to provide different benefits for each targeted stakeholder/customer and across various European regions.
- The usage and exploitation scenarios related to the project base technologies, their integrated solution sets, and global project approach will be defined and detailed.
- Water ICT technologies, policies decision makers should be aware of, and standards that must be complied with will be captured and documented.
- Overall system architecture and its main functional blocks and their relations will be identified.
- Key performance indicators (KPIs) to be measured, calculated, and reported by the Waternomics Platform and by the pilot activities will be documented.

Results of these actions are captured in three deliverables including the current one. More specifically, this deliverable report on the efforts carried out towards achieving the last two action items: Overall system architecture and KPIs.

1.2. Purpose and Target Group of the Deliverable

The objective of this particular deliverable (D1.3) is to provide a technical guidance to other work packages (WP2, WP3 and WP5) in Waternomics by providing KPIs, functional and non-functional requirements together with high level system architecture.

More specifically, in this document we report on a survey carried out in order to identify relevant KPIs to the different stakeholders of the project. Then we use usage case and initial exploitation scenarios from D1.1 as input for functional and non-functional requirements analysis that leads to the identification the architectural requirements that the project needs to fulfil in terms of hardware requirements, dataspace requirements and software requirements. We further map these architecture requirements to the set of technologies discussed in D1.2. Finally, the deliverable defines a high level system architecture that constitutes a technical guideline towards designing a water management system.

The main target groups for this deliverable are designers of water management systems.

1.3. Relations to other Activities in the Project

Figure 1 illustrates the relations of this deliverable to other activities in the Waternomics project. These relations are represented as links numbered from 1 to 7 and are described as follows:

Link 1: D1.1 precedes this deliverable (D1.3) and it establishes all possible case scenarios and usability's of the tools to be developed within this project. This deliverable (D1.3) analyses these case scenarios in order to identify relevant KPI and usage requirements.

Link 2: This deliverable (D1.3) defines how the technology under Waternomics will be developed (system architecture and KPIs), as well as its key functionalities. It (D1.3) is informed by the key gaps in technology or requirements of existing (or indeed proposed) standards and policies listed in D1.2.

Link 3: Output from WP1 (D1.1, D1.2 and D1.3) will drive the identification of the Waternomics methodology captured in D2.1 and Pilot measurement frameworks in D2.2.

Link 4: Pilot planning in WP5 also uses output from WP1 (D1.1, D1.2 and D1.3). Particularly, this deliverable (D1.3) as it defines a high level architecture that will contribute to the design of each pilot solution.

Link 5: The development of the linked water dataspace in D3.1.1 requires the dataspace requirements as well as the high level system architecture identified in this deliverable (D1.3).

Link 6: The development of the support services in D3.2 requires the support services requirements as well as the high level system architecture identified in this deliverable (D1.3).

Link 7: The development of the Waternomics applications in D3.3 requires the applications requirements as well as the high level system architecture identified in this deliverable (D1.3).

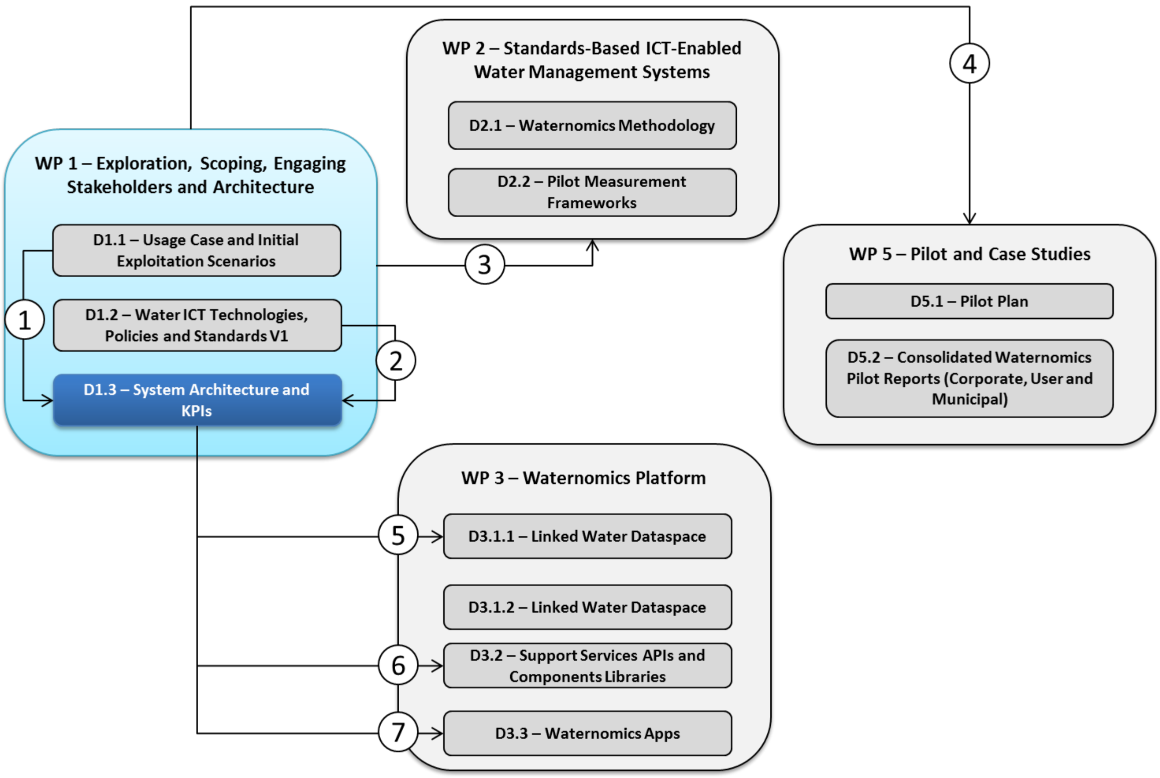

Figure 1: Relationships between D1.3 and other activities in Waternomics

1.4. Document Outline

The remainder of this document is organised as follows:

- Section 2: From KPIs and Usage Requirements to Architecture Requirements - This section defines the Key Performance Indicators (KPIs), functional and non-functional requirements, architecture requirements and related technologies.
- Section 3: System Architecture – A three-layer system architecture is proposed in this section. The proposed layers include: **Hardware**: Sensors and adaptors, **Data**: Linked Water Dataspace, and **Software**: Support Services and Applications.
- Section 4: Summary - concludes the deliverable.

The report also has a number of detailed appendices that provide further information on various aspects of each chapter; these are as follows:

- Appendix A: Sensor List – Lists the initial set of sensors that are used in Waternomics platform.
- Appendix B: Survey Feedback – This appendix reports on the surveys feedback that was gathered from representative stakeholders from each pilot site.
- Appendix C: Entity Relationship Model for Modelling Sensors and Readings – The object of this appendix is to define an Entity Relationship model for describing different components of the system.

1.5. About Waternomics

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 will explore the technologies and methodologies needed to successfully reduce water consumption and losses from households, companies and municipalities. Waternomics is a three year EU-funded project that started in February 2014 that will develop and introduce 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 CO_2 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 forecasting and fault detection diagnosis to the analysis of water consumption data.

WATERNOMICS will be demonstrated in three high impact pilots that target three different end users/stakeholders:

- Domestic users in Greece implemented by a water utility
- Corporate operator in Italy provided by a major EU airport
- Public and Mixed-use based demonstration in Ireland

Through these contributions, WATERNOMICS will pioneer a new dialogue between water stakeholders. It will enable the introduction of Demand Response principles and open business models through an innovative human centric approach that uses personalized water data, water availability based pricing, and gamification of water usage statistics. To maximize impact, the project highlights business development, exploitation planning, and outcome oriented dissemination.

2. From KPIs and Usage Requirements to Architecture Requirements

This section defines the Key Performance Indicators (KPIs), functional and non-functional requirements, architecture requirements and related technologies.

Section 2.1 presents the KPIs identified during surveys conducted with potential users of the Waternomics platform. Next, in Section 2.2 and 2.3, we summarise respectively the functional and non-functional requirements derived from D1.1. These usage requirements a then used to develop the architecture requirements for the Waternomics platform in Section 2.4. Finally, in Section 2.5, we map the architecture requirements to the technologies that are needed to fulfil them. These technologies are analysed in D1.2.

2.1. Key Performance Indicators

Key Performance Indicators (KPIs) define metrics to be used for conveying water data to various end-users/stakeholders. KPIs differ between stakeholders as they can have different requirements, preferences or interests towards water resources. In the context of Waternomics project, we find different KPIs among domestic users, corporate and municipalities.

In order to identify the relevant KPIs for this project, we surveyed potential users among project partners (internal stakeholders) in order to determine their 'wants and needs' from the platform. Participants in our survey were invited to project themselves as future users of the platform and to identify important questions that they would like to be able to answer when using Waternomics platform. Here are few examples of the types of questions posed:

- "I need to find a figure for our water usage per unit area/time/individual/group etc.? (e.g. m^3/student)" ,
- "I wonder what our leakage rate is per km of pipe" ;
- "I'd love to be able to pull up a graph on X and compare to Y"
- "Can I get a figure for our annual environmental report on consumption/emissions/leakage/waste, 2013 v 2014?"
- "What were the numbers of faults that were detected, which of these are currently open, and who are they assigned to?"
- "Am I on target to meet my water reduction goals based on projections?"

Each participant was then asked to complete a template document to identify specific KPIs they saw as being important to them, under the following headings:

KPI name / Description	Who is it for?	What will it be used for?	Units to be reported (if relevant)	Frequency	Reported by?

Feedback was gathered from representative stakeholders from each pilot site (see Appendix B: Survey Feedback). This information was then collated, and is summarised in Table 1 below. Key interests from various stakeholders can be categorised under the following headings:

- **Benchmarking / Footprinting:** This included methods for comparing building or site water footprint against peers or industry norms (i.e. benchmarking).
- **Budgeting / Forecasting / Planning:** The ability to use water pricing information to forecast spending under future scenarios, for the purpose of management and planning. This relates to forward projections, and the ability to forecast future consumption and cost based on past trends.
- **Consumption / Quantity / Volume:** The ability to display water consumption information for various periods (e.g. total water volume consumed this month).

- **Control / System Optimisation:** the ability to take historic water consumption data and system profile information to further optimise the overall system operation efficiency (e.g. pressure optimisation of water network).
- **Data Access:** Open access to water data (i.e. not proprietary 'closed' data models).
- **Economics / Costs:** the ability to relate water data to economics / cost information for the purpose of financial reporting.
- **Energy:** the ability to equate water consumption data to equivalent information pertaining to the energy costs/impacts of running the system (e.g. pumping and heating energy costs, kWh & €).
- **Environment:** the ability to infer environmental impact information from water consumption data (e.g. the carbon emissions related to water consumption, and thus the environmental impact of water/energy saving).
- **Infrastructure:** features related to planning and operation of physical water infrastructure (pipe networks, pumps, end-uses etc.).
- **Leaks / Faults:** the ability for the system to detect and alert the user to faults in the network automatically.
- **Sensors and Instrumentation:** the sensors and instrumentation used to enable data gathering, archiving and access.
- **Water Quality:** access to information pertaining to water quality (e.g. contaminants, pollutants).
- **Water Awareness:** general awareness of water consumption.

The feedback from this survey was used to describe and identify important indicators and the KPIs relevant to the stakeholders. The results of this survey are summarised in Table 1.

Table 1 -Internal Stakeholders KPIs summary

Internal Stakeholder KPI Summary																		
Country	Ireland												Greece		Italy			
Pilot	Engineering Building								Coláiste na Coirbe				Domestic Users		Linate Airport			
Stakeholders	President	Building Services Manager	Chief Technical Officer (CTO)	Consultants / Contractors	Technicians	Staff / Lecturers	Researchers (PG / PD)	Students	School Principal	Building Contractor	Teachers	Students	Parents	Children	Airport Manager	Consultant / Designer	Public Relations	Technicians
Key Interests																		
Benchmarking / Footprinting		X	X	X		X	X		X	X	X		X		X		X	X
Budgeting / Forecasting /		X	X						X				X		X			

Internal Stakeholder KPI Summary																		
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Planning																		
Consumption / Quantity / Volume	X	X	X						X		X	X	X	X	X		X	X
Control / System Optimisation										X								
Data Access			X			X	X		X	X	X	X	X					
Economics / Costs		X	X						X	X			X		X	X		X
Energy		X	X	X		X	X	X	X				X	X	X			
Environment		X				X		X	X	X	X	X	X	X	X			
Infrastructure		X								X					X	X		
Leaks / Faults		X	X	X	X				X	X			X					X
Sensors and Instrumentation																		
Water Quality			X			X		X	X		X	X	X	X				
Water Awareness		X	X			X		X	X		X	X	X	X				
Data Frequency / Reporting Intervals																		
Second							X											

Internal Stakeholder KPI Summary																		
Country	Ireland												Greece		Italy			
Pilot	Engineering Building								Coláiste na Coirbe				Domestic Users		Linate Airport			
Stakeholders	President	Building Services Manager	Chief Technical Officer (CTO)	Consultants / Contractors	Technicians	Staff / Lecturers	Researchers (PG / PD)	Students	School Principal	Building Contractor	Teachers	Students	Parents	Children	Airport Manager	Consultant / Designer	Public Relations	Technicians
Minute							X											
Hour		X	X	X	X		X				X	X						
Day		X	X	X	X	X	X	X	X		X	X		X				X
Week		X				X	X	X	X		X	X	X	X				
Month		X	X			X	X	X	X		X	X	X	X	X			X
Quarterly	X	X							X						X	X	X	
Year		X	X				X	X	X	X	X		X	X	X	X	X	X
Other / Custom	X	X	X															

Entries of Table 1 will be used as a set of metrics for the evaluation of the Waternomics platform for each pilot and validate the overall methodology of the Waternomics project.

2.2. Functional Requirements Analysis

This section is going to derive the functional requirements from usage scenarios depicted in Section 3 of D1.1. The functional requirements [1] specify how the Waternomics platform deals with input data, what operations it performs and what are the outputs. In D1.1, three fictional scenarios were developed for description of the usage of a possible Waternomics platform from the perspective of user, business and technology. Here we are going to extract the functional requirements according to the technical perspective of each scenario.

Scenario 1: Domestic and public users–describing how the Waternomics platform is used by ordinary citizens to strengthen their awareness about water consumption and conservation. And the storyline describes how a pair of brothers interacts with the Waternomics platform in their everyday activities at home, at school and at University.

Under the background of this scenario, the system should allow for:

1. Collection of water usage with identification of each specific sensor from each separate tap in the network.
2. Connection to the user's account on the Waternomics platform for ranking water consumption in leader board locally and globally.
3. Tracking personal water usage through various smart devices.

4. Inferring water usage based on patterns.
5. Presenting personal water consumption information through a variety of customized diagrams and statistics.
6. Simulation water distribution over water networks based on historical data.
7. Simulation water usage of various appliances based on the appliance profile created from their data sheets in the Waternomics platform.
8. Delivery of personalized suggestions for devices based on analysis of usage characteristics, location and budgetary conditions of a specific machine.
9. Providing games in different levels for simulating water management at various types of households with awards for good practices and penalty for bad ones.
10. Group and community creation among users.
11. Linking Waternomics application to the social network to disseminate the water conservation.

Scenario 2: Fiction Factory – focusing on how a medium sized factory uses Waternomics platform to get a better understanding of their water consumption and their business partners in other parts of the value chain.

Under the background of this scenario, the system should allow for:

1. Monitoring water usage and water-related energy consumption in production levels.
2. Customization of presenting the information on the display screen with personalized predefinition.
3. Presenting the comparison results within the same graph in the dashboard to enable users to visualize anomalies and trends.
4. Correlation between the information of existing production line and Waternomics platform to produce a pro-active mechanism for operators.
5. Identification of anomalies in the data.
6. Historic data storage with different levels of granularity.
7. Containing different scenarios for analysis of the cost of equipment deterioration or malfunction and the cost of replacement.
8. Enabling Waternomics Linked Dataspace to collect specifications of machines once published.
9. Simulation of water usage of the machines, prediction water consumption and cost estimation.
10. Real time tracking, detection and notification of flow anomalies in the form of alarming and sending messages to end-users.
11. Linkage between historic water consumption data and leader board to verify the efficacy of water reduction strategies and simulate the potential impact of future strategies.
12. Personalization of information by users and sending alert to personal devices when needed.
13. Publication of good performance via social media.
14. Identification of flow and energy signatures of each water-consuming device.
15. Collection and report of peak load pattern and period.

Scenario 3: Municipalities - describing how water utility companies or municipalities use the Waternomics platform to better manage and improve their existing water network which often involving aging infrastructure, deteriorating equipment and sub-optimal network configuration.

Under the background of this scenario, the system should allow for:

1. Collection of real time data from sensor points and nodes and monitoring the status of water distribution network.
2. Identification, indication and notification of presence and severity of faults / anomalies with colour-coded alerts on any single sensor `of the water system network.
3. Remotely controlling over pumps and valves to switch on/off.

4. Enabling Waternomics platform to send work orders to operatives.
5. Utilization of acoustic leak detection sensors to locate the position of suspected leaks in branches of the water distribution network.
6. Log of information about the progress of fault and leakage reports.
7. Combination of physical and economic data with historic data for analysis of strategies.
8. Calculation of the costs of repairs and the turnover over different periods and customization of results.
9. Combination of weather data and usage pattern data to predict and indicate water availability and possible periods of expected drought.

2.3. Non-Functional Requirements Analysis

This section is going to derive the non-functional requirements from usage scenarios depicted in Section 3 of D1.1. The non-functional requirements are about constraints or perquisites in terms of infrastructure (e.g. power and Wi-Fi present on the sensor installation site), hardware (e.g. mobile devices available) and software installations (e.g. web browsers) and users' abilities and capabilities (e.g. users can use web browsers, should understand easily diagrams, etc.).

Each scenario was briefly described in previous section and here we are going to extract non-functional requirements from them.

Scenario 1: Domestic and public users

1. Each sensor node needs to be equipped with water flow sensor (or pressure sensor if needed) and data transmission module.
2. Wi-Fi and power source work as a precondition for each sensor node.
3. User devices (e.g. smart phones, tablets, PCs, display screen, etc.) should be available as a precondition to conduct Waternomics platform activities.
4. When it comes to the results assessment, the user needs to make a reasonable and proper analysis for the next step to contribute to improving Waternomics platform.
5. Extra information of water distribution network, electric appliances and user type should be available for creating profiles in Waternomics platform.
6. Rewards and penalty mechanism should be made fairly to motivate the users.
7. Users have control over the exposure of shared information.
8. Users' ability to use the website and understand the information displayed is also an influential factor.

Scenario 2: Fiction Factory

1. The first three non-functional requirements are the same as stated in scenario 1.
2. Cost of equipment and replacement needs to be available as input of economic information for Waternomics platform.
3. Users' reaction and interaction is an influential factor for driving the workflow utmost.
4. Group participants control the information shared within the group.
5. The leader board is operated by a leading organization in the group.
6. Information about water-consuming devices should be available as input for creating appliance profile in Waternomics platform.
7. Knowledge about initializing the pattern discovery process is available for users.

Scenario 3: Municipalities

1. The first three non-functional requirements are the same as stated in scenario 1.
2. Each single sensor can indicate when there is an abnormality detected.
3. For fault detection and diagnosis, pressure sensor should be installed in the water network system.

4. Standard communication channels are available for notification.
5. Users at municipality are allowed to share news with specific users.
6. Remote communication devices should be available for remote control over the pumps and valves.
7. For critical parts of the network, a specific set of sensors should be available.
8. Replacement cost of network and tariff of water consumptionshould be available.
9. Weather information should be available for drought prediction.

2.4. Architecture Requirements

In section 0 and 2.3 functional and non-functional requirements were defined for specific scenarios of D1.1. In this section, we use them to define the architecture requirements in terms of sensor and adapter's requirements, dataspace requirements, support services requirements and applications requirements. The specific usage scenarios are mapped to functional and non-functional requirements, and then we develop the architecture requirements as depicted in Figure 2.

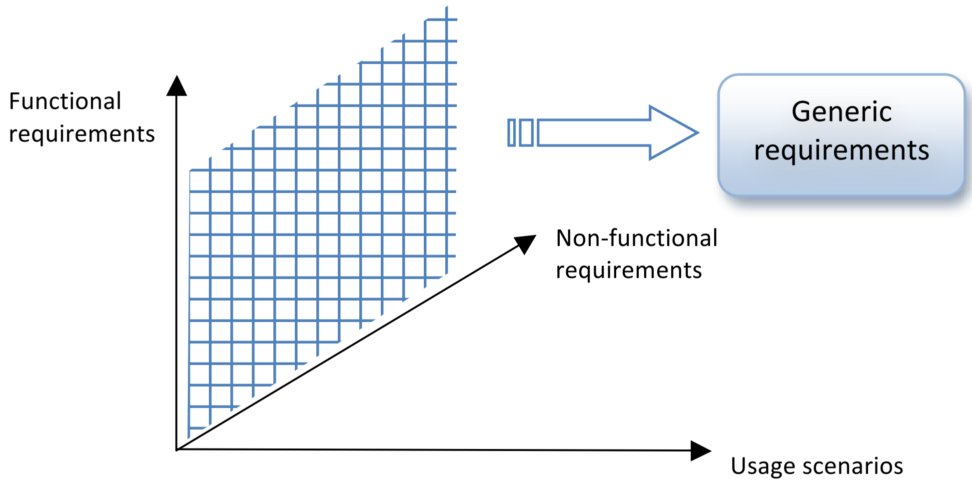


Figure 2: From functional and non-functional requirements to architecture requirements

2.4.1 Sensors and Adapters Requirements

SAR1. **Sensor networks deployment:** Water sensor networks will be developed as sources respectively for household, commercial and city. All the sensors should have electrical output. This is the most basic requirement all the pilots.

SAR2. **Household-level water flow sensor:** For household users, we define a household-level sensor as a sensor measures the total amount of water consumption in a household.

SAR3. **Building-level water flow sensor:** For commercial and city users, we define a building-level sensor as a sensor measures the total amount of water consumption in one main water supply in a building.

SAR4. **Fixture-level water flow sensor**: For all types of users, we require water meters for fixture-level disaggregation of water consumption. Therefore the sensor should be small-sized and waterproof.

SAR5. **Other sensors:** We define other sensors as pressure sensor, level sensor, etc. when the specific pilot needs extra functionalities. A technology inventory about other sensors is reported in D1.2.

SAR6. **Hardware adapter:** To transmit data from sensors to dataspace, we require data collection, data process and data transmission unit as adapters in hardware level.

SAR7. **Software adapter:** Software adapters will perform the 'RDFization' process, which transforms multiple formats and legacy data and lifts it to the data space.

SAR8. **Robust system:** The system must be robust to external factors. The system should remain operational and provide high availability even in the event of external factors such as transmission pauses, power failure or crucial environment.

SAR9. **Modular system:** Due to a large scale of sensor deployment, the system should be as simple as possible. Especially for householders, the system should be in 'one-box' concept which means integrate the sensor and data transmission module in one waterproof box to avoid complex situation for habitants.

2.4.2 Dataspace Requirements

DR1. **Consuming and Publishing Open Data:** By definition Open Data *"can be freely used, modified, and shared by anyone for any purpose*". The system should be able to make use of relevant **open data** assets for proper analytics. Possible scenarios for consuming open data include the prediction of water consumption using open weather data. Consuming open data requires a proper **selection and evaluation of data source** in order to select the most suitable one for proper decision support. The system is also producing data that needs to be **published** in a **standard format** in order to be (re)used by relevant support services and applications.

DR2. **Data Linking:** When **publishing** water data to the dataspace, it has to be **linked** to other data sets. This linking is very useful for ensuring an optimal data management and **integration**. It helps enhancing their (re)use and **discovering new knowledge** from water data put into a wider context. It is important to assess and determine what data sets are relevant to be linked with water data. Data linking is also useful for **enriching** data items with additional information for further analytics.

DR3. **Real-time data / events:** The system will be handling continuous **streams of data** coming from multiple sensors and data sources. The system should be able to manage **large quantities** of data in real-time. **Real-time** processing of data requires the development of algorithms and tools for parallel processing of simple and complex events in order to provide **real-time data analytics**.

DR4. **Heterogeneity of Sensor Data Events:** The system will be handling data from **a wide variety of sensors** and consequently a wide variety of **data formats**. The dataspace needs to be able to handle applications' queries across data formats with respect to their **semantic similarity**. Additionally, the dataspace should manage data produced by developed services from other work packages such as leakage detection data.

DR5. **Publishing Linked Data:** The data produced by adapters or support services should be published in the dataspace with respect to linked data principles : available on the web, structured, not using a proprietary format, using URIs to denote entities and linked to other data sets. Therefore applications and services should be able to publish in linked data format.

DR6. **Standardization:** The system will serve as a common dataspace for different stakeholders. Consequently, the data exchanged and published by the system should be standardized. The same data and support services will be available similarly to all applications which should be able both to publish and consume them.

DR7. **Data storage:** All the data should be **stored** in dataspace for the purpose of historical data retrieve or **data analytics**.

2.4.3 Software Requirements

SR1. **Water usage tracking**: Applications in all scenarios require some kind of identifying, tracking and inference of water usage. Applications should be able to identify and know what the purpose of the consumed water is in order to later provide meaningful results.

SR2. **Sensors management:** In order to identify water usage, track consumption and provide all related information smart sensors will need a mechanism in order to be identified and configured in terms of additional information such as what type of sensors are, where are they installed, if they are connected with other sensors etc.

SR3. **Leaderboards:** Leaderboard is a feature found in many different ways in all scenarios. They should be able to be used for a variety of purposes (comparing consumption, water footprint, consumption for a specific type of usage etc.) and a variety of groups (students in a class, family, airports of a country, etc.)

SR4. **Information Graphs:** Water related information should be presented in customized (and predefined) graphs for monitoring and reporting, supporting various levels of granularity and different periods of time. Users should be able (depending on their profile) to configure and control different parameters of graphs in such the period reported, the sensor focused, the interval granularity level, etc. Graphs will be the main part of dashboard applications developed for different users.

SR5. **Simulations:** A range of different simulation should be able to run and present their results in meaningful and actionable way. Depending on the user simulations needed might include those of network distribution, appliances consumption, etc. combined with financial projections

SR6. **Personalized advices:** A main mean for raising awareness is through educating people. However education in an age of overload needs to be smart, easy to consume, easy to act on and more importantly personalized so that people actually engage with it instead of being tired.

SR7. **Water management simulation game:** Another mean of learning in through gaming. For that purpose an application simulating various water management situations in many different entities such a household, enterprise, municipality etc. can help in raising awareness and educating people in all ranges of age and roles.

SR8. **Community formation:** An important aspect of Waternomics is that it brings social interaction as an additional mean of raising awareness. To achieve that Waternomics users should be able to form communities and groups in order to participate in contests, leader boards, exchange information, etc.

SR9. **Social media for social interaction:** Apart from the community formation and exchange of information between participants in them, social media will also enable this social interaction to extend beyond tight Waternomics user groups and communities and affect a broader range of users.

SR10. **Comparison graphs:** Users should be able to see comparisons between different periods, sensors, usages and other similar users in meaningful graphs to understand the effects of his behaviour changes and benchmark changes in infrastructure.

SR11. **Contextualization of information:** In order for information to be more meaningful connections of water information with other types of contextual data (e.g. weather, factory variables, domestic variables, etc.) should be made and presented to user.

SR12. **Problems detection:** Anomalies, faults and leak detection and identification with appropriate alarm and notification mechanisms customized by user

SR13. **Peak reporting:** Tools should be available for reporting of peak load periods

SR14. **Remote sensor control:** Users should be able to remote control of pumps and valves n the network

SR15. **Water availability and drought reporting:** Users should be able to check water availability in their region together with drought monitoring information in order to be aware of drought periods and adjust their consumption accordingly.

SR16. **Privacy:** In some scenarios, data should be subject to stringent **privacy** concerns. When it is needed, such sensor data should be anonymized. In other cases, data provision should permit limitation to the sensor data.

2.5. Architecture Requirements to Technology Mapping

2.5.1 Hardware

In section 2.1 of D1.2, a technology inventory of hardware called water metering related to Waternomics was developed. The hardware technology provides the basic characteristics of each technology along with advantages and disadvantages. The technologies are structured as follows:

- **Sensing technologies** are technologies used in devices that measure flow, and pressure of water and detect leakages.

- **Flow meters** are instruments that measure the liquid flow for a closed-piping system and are generally classified as; (i) differential pressure, (ii) positive displacement, (iii) velocity, and (iv) mass meters.
- **Pressure meters** are devices that can measure the pressure (the force per unit area that a fluid exerts on its surroundings) and are usually packaged with a scale that provides a method to convert to engineering units.
- **Leak detection devices** are devices that can detect and locate leaks or bursts on a water network.
- **Microphones** are devices that record sound signals which in Waternomics are going to be used as the basis for leak detection devices.
- **Actuating devices** is a group of water network control technologies that can control a variety of factors such as level measurements in wells, water flow, pumps and motors electrical data signals/alarms, alert levels, the lack of power supply, the status of start-stop, action protections and controls etc.
- **Smart water sensor technologies** are technologies used in devices that collect and transmit data about a water network on a real-time basis. Such technologies are used in smart water grid systems, where various parameters would be collected, stored, and transmitted to a computer by meters themselves.
- **Data transmission and power:** Data transmission includes network technologies that can be used for transmitting data from the sensor to the computer such as Ethernet cables, Wi-Fi, etc. Power includes various options for providing power to the sensor such as batteries, solar panels, energy grids, etc.

In the following table for each of the Sensors and adapters requirements (shown in the rows of the table) an 'X' is drawn in the technologies that will be needed for fulfilling that requirement.

Table 2 - Mapping of Sensors and adapters requirements to Hardware technology

	Hardware technologies						
Sensors and adapters requirements	**Flow meter**	**Pressure meter**	**Leak detection device**	**Microphone**	**Actuating devices**	**Smart water sensor technologies**	**Data transmission and power**
SAR1. **Sensor networks deployment**	x	x	x	x	x	x	X
SAR2. **Household-level water flow sensor**	x					x	x
SAR3. **Building-level water flow sensor**	x					x	
SAR4. **Fixture-level water flow sensor**						x	
SAR5. **Other sensors**		x	x	x	x		
SAR6. **Hardware adapter**							x
SAR7. **Software adapter**							x
SAR8. **Robust system**	x	x	x	x	x	x	x
SAR9. **Modular system**	x	x	x	x	x	x	x

2.5.2 Data Platform

As mentioned in section 2.2 of D1.2, a dataspace platform has been proposed to centrally collect, integrate, and analyse water consumption data from the various pilot sites. The platform also facilitates integration of contextual data for front-end applications and analytics. The design objectives of the platform are to 1) facilitate linkage between data entities across heterogeneous data sources, 2) enable real-time data processing and analytics, and 3) reduce the need for on-site data storage. Each of these objectives is facilitated by the following technologies discussed in details in Section 2.2 of D1.2:

- **Linked Data** is a recommended W3C best practice for exposing, sharing and connecting pieces of data, information and knowledge [2]. A piece of information is the Web document which may contain text, images, videos and other multimedia content. Typically, a web page can be abstracted and looked as a resource or entity. These entities are created with respect to the linked data principles[1]: available on the web, structured, not using a proprietary format, using Uniform Resource Identifiers (URIs) to denote entities and linked to other data sets [2]. In this context, we are particularly interested in *Entity Linking* and using *Standardised data format*.
    - **Entity Linking** is concerned by using *URIs* as names for entities: where entity here can refer to sensors monitoring water flow, locations where water is generated, spaces where water is consumed, people dealing with water lifecycle, taps, pipes, buildings, etc. URIs will be later used for interlinking these entities by capturing meaningful relations between them: a sensor is observing a location; a user is occupying a building/location; etc. This makes the dataspace seen as an entity-centric platform [3] for water data management.
    - **Standard Data Format**: Using structured data presented in a standard formats is part of the recommendations from linked data principles. Using non-proprietary formats such as CSV [4], JSON [5] or RDF [6] is a plus.
- **Real-Time Data processing** is usually required when data is continuously input and timely processing and output is needed. Multiple real-time data processing techniques are proposed depending on the data type, context, frequency, etc. [7] [8] [9] [10]. We are particularly interested in two main techniques used in this area: *event processing,* as a dataspace needs to process sensor and open data events in real-time, and event matching for covering the heterogeneous aspect of data.
    - **Event Processing** is a technique for tracking, analysing a stream of data or events [11] [12] [13]. Event processing and complex event processing are required for real-time management of sensor data streams.
    - **Event Matching**: In general, events are described by different stakeholders and with the absence of an agreement on event schema or a conceptual model, an event matching technique is required [14] [15].
- **Cloud Storage**: The proposed off-site technology is Infrastructure as a Service (IaaS). Such technology is useful primarily for storing sensor data as well as publishing it [16].

In the following table, for each of the dataspace requirements (shown in the rows of the table) an 'X' is drawn in the technologies that will facilitate fulfilling that requirement.

Table 3 - Mapping of Dataspace requirements to Data platform technologies

	Data platform technologies				
Dataspace requirements	**Linked Data**		**Real-Time Data processing**		**Infrastructure as a Service**
	Entity Linking	**Standard Data Format**	**Event Processing**	**Event Matching**	**Storage**
DR1. Consuming Open Data		x	x		
DR2. Data Linking	x	x			
DR3. Real-time data / events		x	x	x	
DR4. Heterogeneity of Sensor Data Events		x	x	x	
DR5. Publishing Linked Data	x	x			x
DR6. Standardization		x			
DR7. Data storage		x			x

[1]http://5stardata.info/

2.5.3 Software

In Section of D1.2 a number of specific technologies for the software development in general are reported. In particular Section 2.3 starts by presenting a number of already existing water information platforms already available in the market and then proceeds by describing technologies related with software development in Waternomics. The technologies reported are grouped in to the following categories which are here used as columns in the mapping table:

- **Back-end web application development frameworks** are development frameworks for developing the core part of web applications dealing with data modelling and handling according to users actions.
- **Front-end web application development frameworks** provide a set of user interface elements using CSS and JavaScript technologies. Such frameworks are used by developers to easily develop the front-end of a web application using a specific consistent and in some cases widely used design languages that are easy for the users to understand.
- **Mobile app development platforms and technologies** are development platforms that can be used for developing mobile applications. In general, there are three main approaches for mobile development a) based on responsive web design practices, b) native mobile application development and c) hybrid development which uses native applications that utilise parts of responsive web pages.
- **Charting technologies** are libraries and technologies that can easily produce charts and graphs for visualizing data.
- **Notification and alerting technologies** are technologies that allow applications to notify and alert users in different ways and with different levels of obtrusiveness and emergency (e.g., SMS, Email, push notifications etc.).
- **Web service technologies** allow software functions to be provided at a network address over the Web with the service always on as in the concept of utility computing.

In the following table for each of the Application requirements (shown in the rows of the table) an X is drawn in the technologies that will be needed for fulfilling that requirement.

Table 4 - Mapping of Application requirements to Software technology

	Software technologies					
Application requirements	**Back-end frameworks**	**Front-end frameworks**	**Mobile app**	**Charting technologies**	**Notification and alerting**	**Web service**
SR1. **Water usage tracking**	X		X			X
SR2. **Sensors management**	X	X	X			X
SR3. **Leader boards**	X	X				X
SR4. **Information graphs**	X	X		X		X
SR5. **Simulations**	X	X		X		X
SR6. **Personalized advices**	X	X			X	X
SR7. **Water management simulation game**	X	X				
SR8. **Communities formation**	X	X				X
SR9. **Social media for social interaction**		X			X	
SR10. **Comparison graphs**	X	X		X		X
SR11. **Contextualization of information**	X	X	X	X	X	X
SR12. **Problems detection**	X		X	X	X	X
SR13. **Peak reporting**	X	X		X		X
SR14. **Remote sensors control**	X	X				

SR15. **Water availability and drought prediction**	X	X			X	X
SR16. **Privacy**	X					X

2.6. Conclusion

The object of this section is twofold: First, by identifying KPIs for each pilot stakeholder, we will be later able to properly evaluate the Waternomics platform with respect to these KPIs. Second, the set of architectural requirements will be later used for the development of the various components of the Waternomics platform and more specifically the development of the dataspace, support services and applications.

3. System Architecture

This section describes the main components of the system architecture in three layers: hardware, data and software as depicted in Figure 3:

- **Hardware layer:** defines the sensors being considered in the Waternomics platform. This layer includes also the appropriate sensor adapters that are developed within WP3. Details about this layer are given in Section 3.1.
- **Data layer:** takes care of modelling of the different components of the Waternomics platform. The primary focus in this version of the proposed data model is centred towards sensors and sensor data. The data model is captured as an entity relationship model and detailed in Section 3.2.
- **Software layer**: introduces the set of support services and applications that will be developed as part of the Waternomics platform. This layer is discussed in Section 3.3.

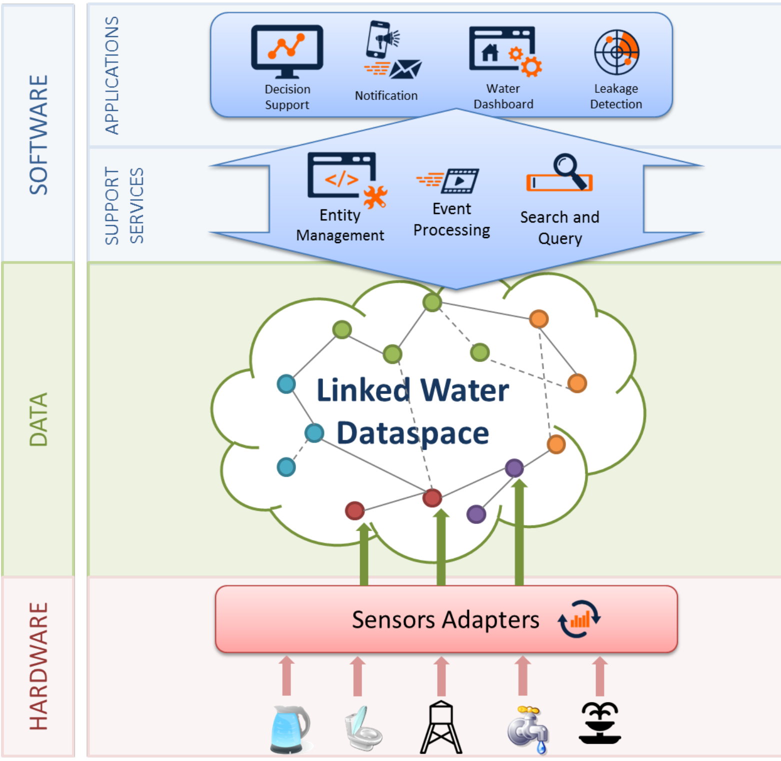


Figure 3 - Overview of system architecture

3.1. Hardware: Sensors and Adaptors

The lowest layer of the system architecture (see Figure 3) identifies two main components:

- Sensors: these are the main data sources for water information system. We list the sensors considered in Waternomics in Section 3.1.1.
- Adapters: these are responsible for collecting, filtering, and converting sensor data into a predefined format. Sensor adapters are described in Section 3.1.2.

3.1.1 Sensors

The primary sources of data in Waternomics are sensors. They are used for detecting events or changes in the properties they observe (e.g., temperature, humidity, pressure, etc.). In this project, we are mainly interested in water sensors: sensors that observe water properties such as flow rate, pressure, etc. An initial set of sensors that are used in Waternomics platform is presented in Table 5. More details about these sensors can be found in Appendix A: Sensor List.

Table 5 - Water sensor list

Sensor type	Characteristics	Example
Ultrasonic flow meter	The ultrasonic flow meter is a non-intrusive flow meter which normally contains a pair of clamp-on transducers and a main control unit. The basic measuring principle is based on the difference of the transit time of ultrasonic signals. The ultrasonic signals are transmitted between two transducers which work as both a sound transmitter and a sound receiver. The difference of transit time occurs when the fluid moves and is directly proportional to the flow velocity.	• ProlineProsonic Flow 91W(Endress + Hauser) • OPTISONIC 6300 (Krohne) • VTEC Ultrasonic Flow Meter (VTEC Engineering)
Mag meter	The measuring principle of Mag meter is based on Faraday's Law. When a conductor moves through a magnetic field, an electrical voltage is induced across it. And this voltage is proportional to the velocity of the conductor. The most common types of Mag meter are insertion and in-line.	• Magphant(Endress+Hauser) • ProlinePromag 50W, 53W(Endress+Hauser)
Water meter	The measuring principle of regular water meter is quite simple. Usually they have impeller inside which will rotate when the water flows. The output of this kind of meter is traditionally not electrical. In some cases, they have a pulse reader to add on top of the meter to get electrical signals.	• Woltman meters （ZENNER） • Smart meter (Elster) • VTEC Mini water meter (VTEC Engineering)

3.1.2 Adapters

With respect to the requirements identified previously in Section 2.4.1, sensor data needs to be collected in real-time, filtered and converted into a standard format before being transmitted to the dataspace. As shown in Figure 4 components of this process include:

- **Raw data collectors**: Sensors deployed within the considered environment are continuously sending sensed data into streams. The sensed data streams are retrieved by the collectors with respect to the protocols used by the actual sensors.
- **Filters**: The event-data retrieved by listeners is forwarded to the Filter component. As incoming event data may contain some irrelevant or unnecessary information in the form of noise, for example: empty values, repeating characters, unknown characters, etc. The filter component uses string processing techniques (string or character elimination or replacement) for cleaning this event-data and filtering irrelevant information. Please note that this component can be ignored in some contexts (e.g., high quality sensor readings).
- **Converters**: Raw sensor data is presented with respect to the manufacturer data model. As we are dealing with heterogeneous sensors, we have to convert raw data into a standardised format that will be later integrated into the water dataspace.
- **Transmission units**: After conversion, sensor data needs to be transmitted to the dataspace for further processing. Multiple communication techniques can be used for this purpose depending on the dataspace services.

It is important to note that for each sensor/sensor type, a dedicated adapter needs to be developed. Converters for the different sensors are developed within WP3.

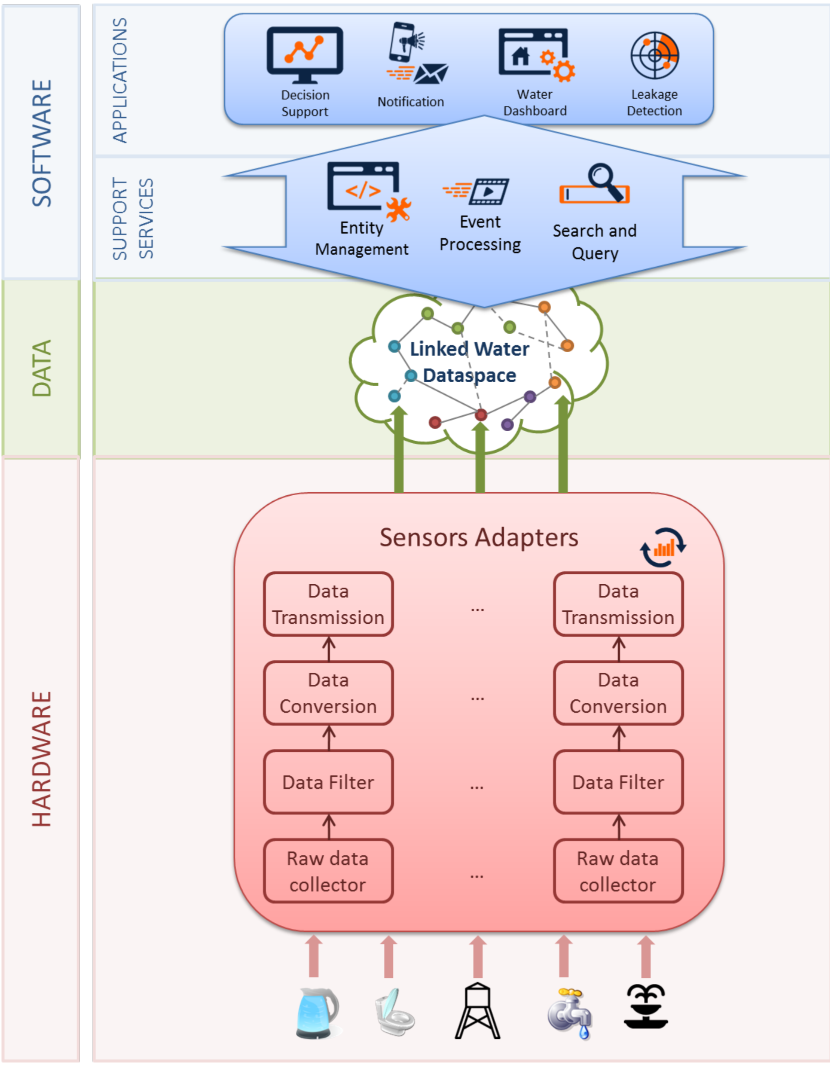


Figure 4 – Hardware Layer Overview

3.2. Data: Linked Water Dataspace

A dataspace, as it is understood in this project, is data integration architecture. It allows integrating data from multiple sources into a single space. A dataspace for Waternomics is not only hosting sensor data but also other relevant data for decision analytics. As it is highlighted in Figure 5, relevant data includes: sensor and location meta-data, weather data as well as other relevant data sources that will be identified later in this project.

The data needs to be standardised, interlinked and published in order to facilitate its reuse internally (i.e., support services: enrichment, aggregations, etc.) or externally (i.e., user or corporate applications). The Linked Water Dataspace design is detailed in D3.1.1.

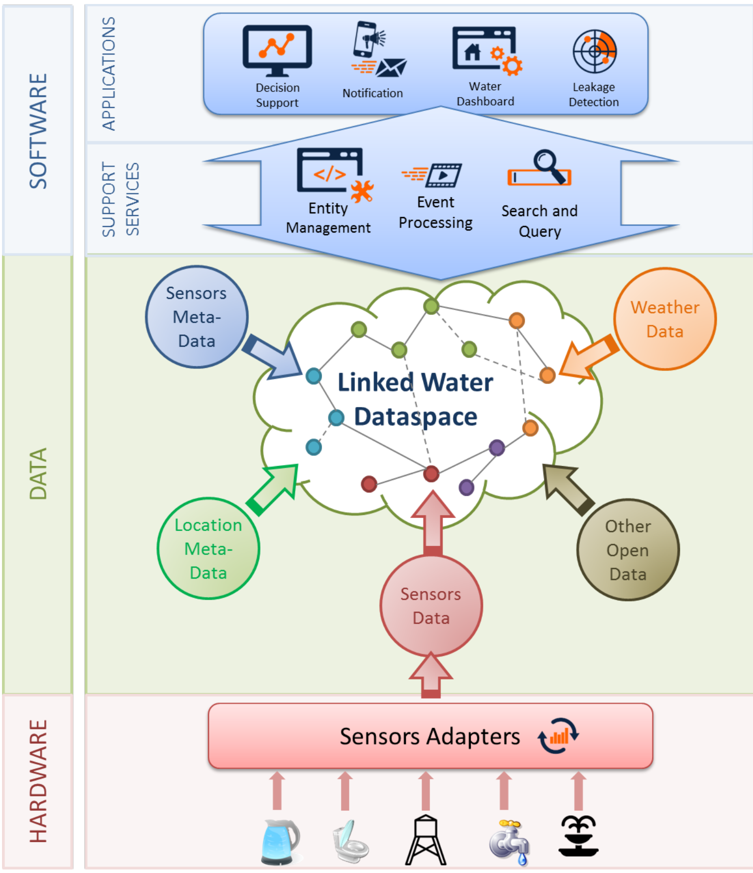


Figure 5 - Linked Water Dataspace

In this deliverable we are particularly interested in sensors and sensor data modelling. We propose for this purpose an entity relationship data model for representing them. Our model was created after several meetings with two pilots of the Waternomics project and full access to existing data models. The purpose of these meetings was to identify common and relevant data items required for describing sensors and their readings. The resulting data model is depicted in Figure 6 and featuring four entities:

- **Sensor**: describes a sensor via its identifier, name, location and a textual description.
- **Observation**: describes the actual readings from a particular sensor (captured via the relationship **observes**). It features an identifier, an observation time, and an observation value.
- **Observation_Type**: each observation has a pre-defined type represented via an identifier, an observed property and an associated unit of measurement.
- **Aggregated_Observation**: the model also captures aggregated observations that are described with an identifier, the used aggregation function, a name, a start and end time and a computed value.

Further details about this model together with examples are discussed in Appendix C: Entity Relationship Model for Modelling Sensors and Readings. Please note that this model can be tailored to local implementations of each pilot. It is actually used as a starting point for defining the meta-model to be used in the data space as detailed in deliverable D3.1.

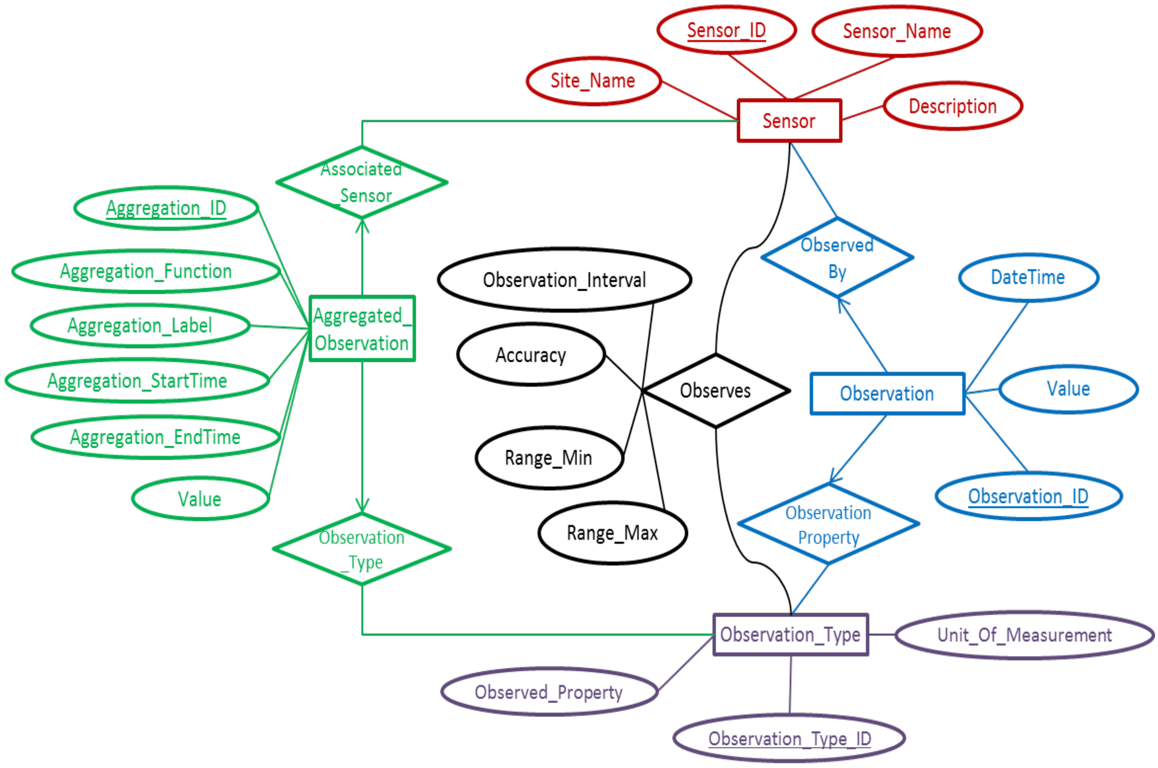


Figure 6 - Entity Relationship Data Model for Sensors and Sensor Readings

3.3. Software: Support Services

The top layer of the proposed architecture is the software layer. This is responsible for consuming data from the dataspace for proper decision making. This layer is split into two components:

- Support Services: represent the set of services required to simplify the exploitation of the data available in dataspace. Support services are further detailed in Section 3.3.1.
- Applications: a number of applications for covering the previously discussed functional requirements. A number of applications are discussed in Section 3.3.1 and are further detailed in deliverable D3.3.

3.3.1 Support Services

Given the linked water dataspace infrastructure a number of support services will be needed to simplify the exploitation and usage of the data. The services need to provide a standardised access to the dataspace and carry most of the data analytics.

Services as described here can include (but are not limited to) the following:

- **Entity Management Service**: The entity management service is concerned with the maintenance of information about entities critical to the Water data management and analysis. The expected outcome of this service is a database that severs as the canonical source of metadata for sensing data. In the case of Linked Water Dataspace, the primary set of entities includes the sensors and their physical locations. Besides these entities, the dataspace applications might also require information about the people, groups, buildings, and outlets. In short, all of the information that can help in understanding the water consumption, through association with real-world objects, is included in the entity management service.
- **Data Catalogue Service:** Cataloguing is a key feature for data exploration. This service implements a user interface that allows browsing through the collection of datasets. It should include browsing by categories and all type of sorting and filtering.

- **Search and Query Services**: Searching over the dataspace sets is another important exploration service. This includes full-text search over the data, as well as the metadata. Also it may include vocabulary search. This service can be either used internally by other support services such as the entity manager (e.g., searching for all sensors that do not have a well-defined location) or externally by the applications layer.
- **Prediction service**: Predicting water usage is a key feature for properly planning the consumption and optimising the cost of water. A prediction service uses water data together with other relevant sources such as weather condition and forecast for determining future water consumptions. Such service relies mainly on a machine learning algorithm that must be chosen for making reasonably accurate predictions.
- **Complex Event Processing Service**: The system should be able to manage large quantities of data in real-time. Real-time processing of data requires the development of algorithms and tools for parallel processing of simple and complex events. A complex event processing service helps to simplify the handling of data streams.

Support services developed for Waternomics platform is carried out within WP3. In Deliverable D3.2 support services will be further detailed. The final set of support services will be determined based on the requirements of the pilots and final linked water dataspace architecture.

3.3.2 Applications

At the top of the architecture are the water usage and management applications that consume the resulting data and events from the linked water data. Such applications will include personalized water dashboards presenting real-time actionable information on water usage, availability and pricing. They will also include a set of decision support systems in company and city levels facilitating the decision making process in terms of water usage related decisions and policies. For the household level such applications will also include serious games based on the real-time data encouraging good practices in water usage and management in household level.

An operational real-time forecasting system of water availability will be developed to increase awareness at the household level of periods of water scarcity. The forecast of water availability will be transformed into an indicator that shows to the household consumer, the current need for efficient water use. Visualisation and contextualisation focuses on non-technical users.

The temporal and spatial scale is case-study dependent and needs to balance locality, to be recognisable for the consumer, and hydrological relevance, to include the wider area that influences the water availability for society.

The part of the applications is further more separated into 3 layers that include a number of building blocks. Figure 7 show the architecture of Waternomics applications and the following paragraphs explain the functionality of each component and layer in general.

3.3.2.1 Web Browser Layer

Waternomics applications will be designed as web applications so the final end user level will be the web browser where through standard technologies such as HTML / CSS and JavaScript the end-user interface will be designed along with the basic interaction mechanisms

- **Technologies:** The technologies to be used for the web browser layer include standard web technologies that are widely used and allow the design of responsive applications that adapt their layout and interface based on the device being shown.
- **User Interface:** The user interface will be designed to be responsive for different devices and also adaptable and customizable based on a variety of parameters (user, time, location, etc.). It will also be designed to be as intuitive as possible so that users will not require much training in using it and the learning curve will be very steep.

The user interface will be using standard HTML-based UI components. Using event-driven programming these components will be triggering events that will enable communication with the presentation layer running on the server through HTTP and AJAX calls.

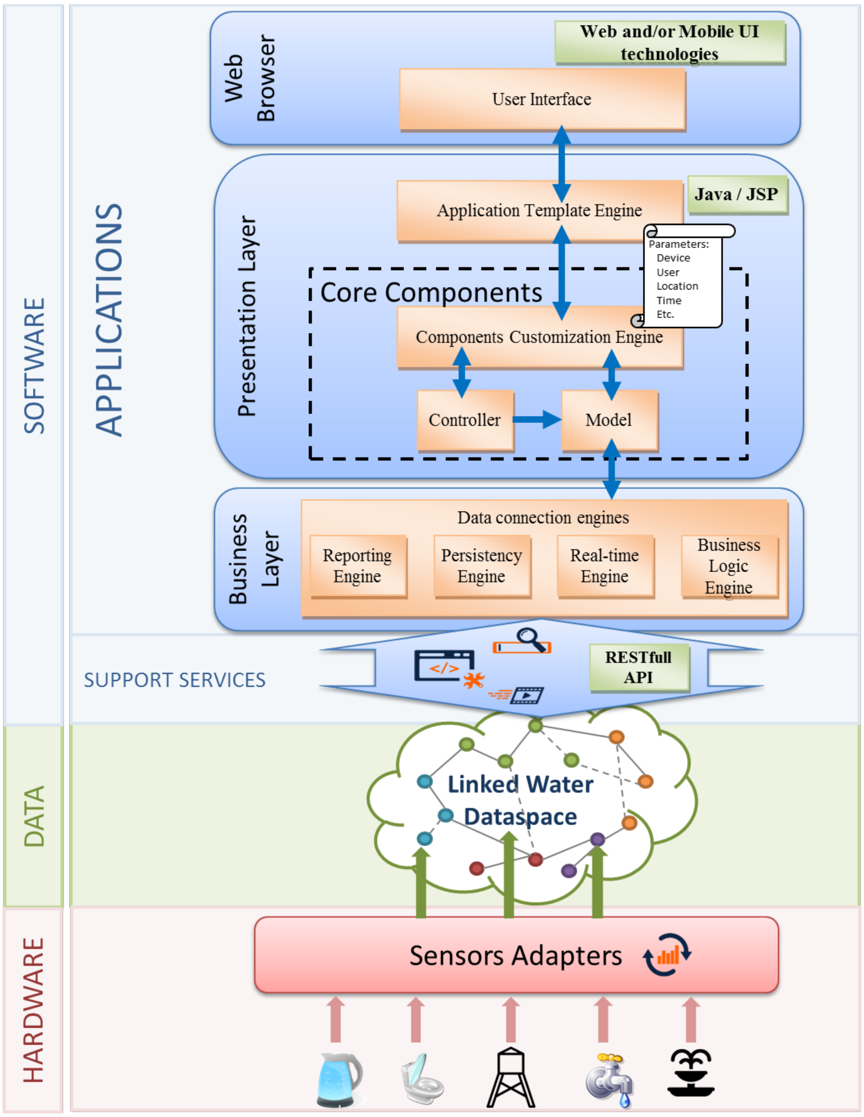


Figure 7 - Applications Layer Overview

3.3.2.2 Presentation Layer

The presentation layer is generally responsible for getting the required information from the business layer and presenting it to the user by constructing the appropriate user interface.

- **Technologies:** The technologies to be used in the presentation layer permits generating dynamic web pages such as Java and JSP.
- **Application Template Engine:** The application template engine will be responsible for making the decisions of which core components will be used on the application and general layout decisions based on a variety of parameters.
- **Components Customization Engine:** The components customization engine will be responsible for deciding what kind of information will be used for a component and how will those be presented based on a variety of parameters.
- **Parameters:** Waternomics apps will be customizable and personalized. To achieve that, a variety of parameters will be used on the customization of the user interface of applications. The type of user, the user himself, the device being used, the location where the device is, the time that the application is used and many other parameters (e.g. current weather conditions) might play a role in the adaptation that will happen on the application.

- **Core components:** The core components will be core parts of applications (e.g. dashboard) that will be developed to be customizable so that they can be used in different applications.
- **Controller:** Controllers are used for performing specific actions to the model based on what the user is requesting through the user interface (view).
- **Model:** Models are responsible for handling the information of an application in a way that fits the application's needs.

3.3.2.3 Business Layer

The business layer is the part that all applications will use as an intermediate to connect with the data layer on the data space. It will include components that have to do with the business logic of applications and consist of specific components / engines that are responsible for handling aspects of the connection and the data from the data space.

- **Technologies:** Technologies used for this layer will consider a general-purpose computer programming language such as Java.
- **Reporting Engine:** Reporting engine will be responsible for generating reports from the data gathered from the support services
- **Persistency Engine:** Persistency engine will be responsible for querying and storing locally information from the data space to handle possible connection problems with the data space and ensure the seamless functioning of applications.
- **Real Time Engine:** Real time engine will be responsible for handling the delivery and usage of real time information that will be used in applications

Business Logic Engine: Business logic engine will be responsible for transforming appropriately information from data space to fit the business logic of applications

3.4. Conclusion

This section described a high level architecture for the Waternomics platform. This architecture is composed of three layers: Hardware, Data and Software.

The hardware layer detailed the sensors used within the Waternomics platform in Section 3.1. Each sensor type needs a dedicated adapter for collecting, filtering, converting and transmitting sensor data. Sensor data is modelled with respect to the data model proposed in Section 3.2and hosted in a dataspace that is discussed in deliverable D3.1.

The data hosted in the dataspace is processed by the software layer presented in Section 3.3. This layer is also split into two layers: support services and applications.

Support services are used either internally or externally for further data processing. This deliverable listed few support service that Waternomics platform would host. Further details and services will be investigated in deliverable D3.2.

Applications are end users products that are used for displaying final result. Deliverable D3.3 will report of the developed application for each pilot within the Waternomics project.

4. Summary

This deliverable produced the technical requirements for the end-to-end Waternomics Platform. The usage scenarios defined in D1.1 are analysed and mapped in this deliverable towards a high-level system architecture. Indeed, Section 2.2 and 2.3 identify respectively the set of functional and non-functional requirements derived from D1.1. From these usage requirements we derive the architecture requirements that help identify the functional blocks of the Waternomics platform in Section 2.4.

Furthermore, taking into account the technology survey results of D1.2, this deliverable performed a preliminary mapping of related software towards the identified functional blocks in Section 2.5.

Additionally, a high level system architecture is proposed in Section 3. Within this architecture the main system functional blocks and their relations were identified.

Also in this deliverable and resultant from D1.1 and D1.2, this deliverable documented the key performance indicators to be measured, calculated, and reported by the Waternomics platform and by the pilot activities. The KPIs from Section 2 will provide an additional requirement for consideration and treatment in system design and analysis, and most importantly will help measure the success of the Waternomics platform and drive potential improvements.

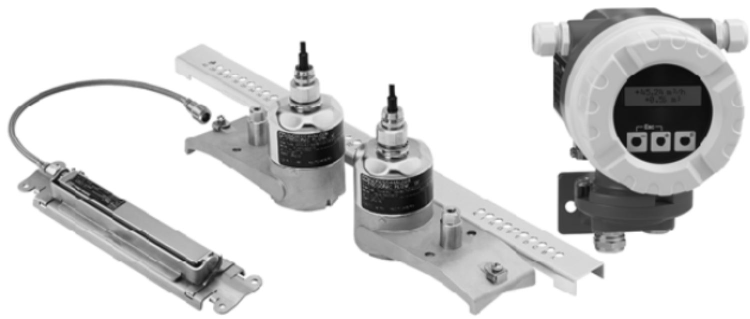
Appendix A: Sensor List

The primary sources of data in Waternomics are sensors. They are used for detecting events or changes in the properties they observe (e.g., temperature, humidity, pressure, etc.). In this project, we are mainly interested in water sensors: sensors that observe water properties such as flow rate, pressure, etc. An initial set of sensors that are used in Waternomics platform is presented in this appendix.

<table>
<tr><th colspan="4">Part 1. Ultrasonic flow Meter</th></tr>
<tr><td colspan="4">Introduction</td></tr>
<tr><td colspan="4">The ultrasonic flow meter is a non-intrusive flow meter which normally contains a pair of clamp-on transducers and a main control unit. The basic measuring principle is based on the difference of the transit time of ultrasonic signals. The ultrasonic signals are transmitted between two transducers which work as both a sound transmitter and a sound receiver. The difference of transit time occurs when the fluid moves and is directly proportional to the flow velocity.</td></tr>
<tr><td colspan="2">1</td><td rowspan="2"></td><td rowspan="2"></td></tr>
<tr><td colspan="2">VTEC Ultrasonic Flow Meter[1]
(VTEC Engineering BV)</td></tr>
<tr><td colspan="4">Main features</td></tr>
<tr><td colspan="2">Measuring principle</td><td colspan="2">Ultrasonic</td></tr>
<tr><td colspan="2">Installation type</td><td colspan="2">Clamp-on</td></tr>
<tr><td colspan="2">Pipe size</td><td>DN50mm to DN700mm</td><td>DN15mm to DN100mm</td></tr>
<tr><td colspan="2">Pipe material</td><td colspan="2">Steel, stainless steel, cast iron, Glass Reinforced Plastic, PVC, copper, aluminium, concrete, etc. Allow pipe liner.</td></tr>
<tr><td colspan="2">Pipe liner</td><td colspan="2">Epoxy Asphalt, Rubber, mortar, polypropylene, polystyrene, polyester, polyethylene, hard rubber, Bakelite, Teflon</td></tr>
<tr><td colspan="2">Communication technology</td><td colspan="2">4-20mA current loop, RS485, relay, OCT</td></tr>
<tr><td colspan="2">Liquid temperature</td><td colspan="2">0˚C - 100˚C</td></tr>
<tr><td rowspan="2">Protection level</td><td>Main unit</td><td colspan="2">IP 65</td></tr>
<tr><td>Transducers</td><td colspan="2">IP68</td></tr>
<tr><td colspan="2">Velocity</td><td colspan="2">±0.03 to ±105 ft/s (±0.01 to ±30 m/s), bi-directional</td></tr>
<tr><td colspan="2">Measurement period</td><td colspan="2">0.5s</td></tr>
<tr><td colspan="2">Accuracy</td><td colspan="2">±1% at rates >0.6 ft/s (0.2m/s)</td></tr>
<tr><td colspan="2">Repeatability</td><td colspan="2">±0.2%</td></tr>
<tr><td colspan="2">Power</td><td colspan="2">110VAC, 220VAC and 8-36VDC.</td></tr>
</table>

[1] For more information on VTEC Ultrasonic Flow Meter, see VTEC Ultrasonic Flow Meter Specification.

Cost	Main unit	€800
	Transducers	€200
Comment		
Temperature and pressure can also be added to this device if user needs.		

2		
ProlineProsonic Flow 91W (Endress + Hauser)		
Main features		
Measuring principle		Ultrasonic
Installation type		Clamp-on
Pipe size		DN15mm to DN2000mm
Pipe material		Carbon steel, Ductile Iron, Stainless steel, Alloy C, PVC, PE, LDPE, HDPE, PVDF, PA, PP, PTFE, Glass pyrex.
Pipe liner		Mortar, Rubber, Tar Epoxy
Communication technology		4-20mA current loop, pulse/status output
Liquid temperature		–20 to +80 °C
Protection level	Main unit	IP 67
	Transducers	IP67
Velocity		0 to 15 m/s (0 to 50 ft/s)
Measurement period		
Accuracy		±2%
Repeatability		Max. ± 0.3 % for flow velocity > 0.3 m/s (1 ft/s)
Power		85 to 260 V AC, 45 to 65 Hz 20 to 55 V AC, 45 to 65 Hz 16 to 62 V DC
Cost		€3.000,00

3		
OPTISONIC 6300 (KROHNE)		
Main features		
Measuring principle		Ultrasonic
Installation type		Clamp-on
Pipe size		DN15mm to DN4000mm
Pipe material		Metal, plastic, ceramic, asbestos cement, internal / external coated pipes (coatings and liners fully bonded to pipe wall)
Pipe liner		
Communication technology		Current (incl. HART®), pulse, frequency and/or status output
Liquid temperature		-40...+120°C
Protection level	Converter	IP 65/66/67
	Transducers	IP 67
Velocity		0.5...20 m/s
Measurement period		
Accuracy		±1% of the measured value for DN⩾50 mm / 2" and v > 0.5 m/s / 1.5 ft/s
		±3% of the measured value for DN<50 mm / 2" and v > 0.5 m/s / 1.5 ft/s
Repeatability		<±0.2%
Power		Standard: 100…230 VAC (-15% / +10%), 50/60 Hz Option: 24 VAC/DC (AC: -15% / +10%; DC: -25% / +30%)
Cost	Signal converter	€1.925,87
	Transducers	€1.001,00

4		
OPTISONIC 6300 P (KROHNE)		
Main features		
Measuring principle		Ultrasonic
Installation type		Clamp-on
Pipe size		DN15mm to DN1500mm
Pipe material		Metal, plastic, ceramic, asbestos cement, internal / external coated pipes (coatings and liners fully bonded to pipe wall)
Pipe liner		
Communication technology		0(4)...20 mA, pulse, frequency and/or status output
Liquid temperature		-40...+120°C
Protection level	Converter	IP 65
	Transducers	IP 67
Velocity		0.5...20 m/s
Measurement period		
Accuracy		±1% of the measured value for DN⩾50 mm / 2" and v > 0.5 m/s / 1.5 ft/s
		±3% of the measured value for DN<50 mm / 2" and v > 0.5 m/s / 1.5 ft/s
Repeatability		<±0.2%
Power		Adapter for 100…240 VAC (-10% / +10%), 47...63 Hz Adapter voltage: 13.2 V battery
Cost	Signal converter	€4.733,75
	Transducers	€1.224,00

5	
TFX Ultra (BAR Instruments)	
Main features		
Measuring principle		Ultrasonic
Installation type		Clamp-on
Pipe size		<= DN50mm
Pipe material		
Pipe liner		
Communication technology		4-20 mA, frequency, RS485
Liquid temperature		0-100 °C
Protection level	Transmitter	IP 65
	Transducers	IP67
Velocity		Bi-directional to greater than 40 FPS (12 MPS)
Measurement period		
Accuracy		1%
Repeatability		0.5% of reading
Power		AC: 95-264 VAC 47-63 Hz @ 17 VA max. DC: 10-28 VDC @ 5 VA max.
Cost	Transmitter	€1.743,00
	Transducers	€800,00

Part 2. Mag meter	
Introduction	
The measuring principle of Mag meter is based on Faraday's Law. When a conductor moves through a magnetic field, an electrical voltage is induced across it. And this voltage is proportional to the velocity of the conductor. The most common types of Mag meter are insertion and in-line.	
1	
Magphant (Endress+Hauser)	
Main features	
Measuring principle	Electromagnetic
Installation type	Insertion
Pipe size	Union nut for DN 25...2000 For plastic pipes DN 15...1000
Communication technology	4-20mA current loop, relay
Liquid temperature	-20...100 °C
Protection level	IP 66
Flow rate range	1...5 m/s
Accuracy	±2% at flow velocities >1 m/s
Repeatability	±2%
Power	24 V DC (20...30 V DC)
Cost	€1.290,00

2	
ProlinePromag 50W, 53W (Endress+Hauser)	
Main features	
Measuring principle	Electromagnetic
Installation type	In-line
Pipe size	DN25mm to DN2000mm
Communication technology	current loop, Pulse/frequency, RS485
Liquid temperature	Polyurethane(liner): –20 to +50 °C (DN 25 to 1200) Hard rubber(liner): ±0 to +80 °C (DN 50 to 2000)
Protection level	IP 67/68
Flow rate range	0.01 to 10 m/s (0.03 to 33 ft/s)
Accuracy	
Repeatability	Max. ±0.1% of reading ± 0.5 mm/s
Power	85 to 260 V AC / 20 to 55 V AC / 16 to 62 V DC
Cost	€1.700,00

Part 3. Multi-Parameter Water Sensor	
Introduction	
The mutil-parameter water sensor can measure several water parameters such as flow, temperature and presussre and so on at the same timein one integrated sensor.	
1	
KAPTA™ 3000-AC4 In-line multi-parameter water sensor (VEOLIA)	
Main features	

<table>
<tr><td colspan="4">Detection of active chlorine(HOCl)
Measurement of conductivity, pressure and temperature
Miniaturized low power consumption sensor probe</td></tr>
<tr>
<td>Pressure
Range: 0 – 10 bar (145 psi)
Measurement accuracy at 25°C : ± 50mbar
Measurement accuracy over temperature
(0-40°C) : ± 100mbar
Sensor output resolution : 2 mbar
Output communication resolution: 50 mbar</td>
<td>Temperature
Range: 0 – 40°C
Measurement accuracy : ± 1.2°C
Sensor output resolution: 0.2°C
Communication output resolution: 0.3°C</td>
<td>Conductivity
Range: 50 – 1000 µScm-1
Measurement accuracy: ± 5 µScm-1; ± 5%
Sensor output resolution: 1 µScm-1
Output communication resolution:5 µScm-1</td>
<td>Chlorine HOCl (2X)
HOCl: 0.01mg/l – 2.0 mg/l
Measurement accuracy: ± 0.03 ppm; ± 5%
Sensor output resolution: 0.01 ppm
Output communication resolution: 0.01 ppm
Response time : < 30s</td>
</tr>
<tr><td colspan="2">Probe power supply</td><td colspan="2">3.2 – 5 V DC; Battery operated: Replaceable Battery Pack included</td></tr>
<tr><td colspan="2">Flow rate</td><td colspan="2">Minimum 0.03 m/s
Maximum 1.5 m/s</td></tr>
<tr><td colspan="2">Probe dimensions</td><td colspan="2">The sensor has been designed to fit directly in a pipe of external diameter D > 60 mm or 2″ with a threaded fitting
Maximum pipe diameter: DN 300 for iron pipe and DN 250 for PVC/HDPE
Length of the KAPTA™ probe : 300mm
Diameter of KAPTA™ probe head 35 mm Thread 1″ 1/8 Gaz BSP Cylindrical</td></tr>
</table>

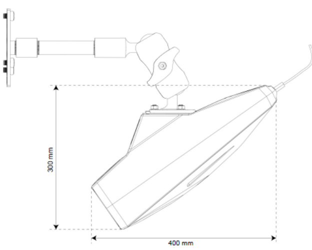
<table>
<tr><td>2</td><td rowspan="2"></td></tr>
<tr><td>Instllisonde
(BAR Instruments)</td></tr>
<tr><td colspan="2">Main features</td></tr>
<tr><td colspan="2">Membrane free and insensitive to pressure and flow
Fast response time, typically <20 seconds, 95% of step change</td></tr>
</table>

Flow forward and downstream 0 to 2 m/sec ± 10% sensors, flow direction information dependent on installation 0 to 2 m/sec ± 10%	Pressure 4-20mA or 0-100mVinput, external transducer 0 to 10 Bar	Temperature -5 to +50°C ± 0.2°C
Communication Interfaces Supported	• Ethernet • GPS (asset tracking) - optional • GPRS • Voltage Out 0 – 2.5V • Modbus RTU RS232	
Power supply	Battery pack or 9-24V DC power supply	
Enclosure protection	IP 68	

3 Aqua TROLL 400 Instrument (In-Situ Inc.)		
Main features		
Modbus RS485 and SDI-12 interfaces		
Pressure Accuracy: Typical ±0.1% FS @ 15° C; ±0.3% FS max. from 0 to 50° C Range: 76 m (250 ft); absolute (non-vented) Resolution: ±0.01% FS or better	**Temperature** Accuracy: ±0.1° C Range: -5 to 50° C Resolution: 0.01° C or better Response Time: <30 sec	**Conductivity** Accuracy: Typical ±0.5% + 1 μS/cm; ±1% max Range: 5 to 100,000 μS/cm Resolution: 0.1 μS/cm
Operating temperature	-5 to 50° C	
Environmental rating	IP68 with all sensors and cable attached. IP67 with sensors removed and cable detached.	
Reading rate	1 reading every 5 seconds (no internal logging)	
Power	Required: 8–36 VDC (no internal battery). Measurement current: 16 mA @ 24 VDC. Sleep current: 40 μA @ 24 VDC	

Pressure sensor	
AST20PT (American Sensor Technologies, Inc. (AST))	
Main features	
non-linearity and non-repeatability performance Superb Temperature Performance Real Time Thermal Compensation Real Time Linearity Correction Turndown Capability	
Operating Ambient Temperature	-40 to 85°C
Operating Media Temperature	-55 to 125°C
Protection rating	IP 66
Accuracy(includes non-linearity, hysteresis & non-repeatability)	< ±0.1% BFSL (<±0.2% BFSL over 15,000 PSI)
Proof Pressure	2X Rated Pressure, standard
Burst Pressure	5X or 50,000 PSI, whichever is less

Comparison between Ultrasonic Flow Meter and Mag meter			
	Ultrasonic Flow Meter	Mag meter	Comments
Installation	No penetration Very quick installation	Drilling / cutting required	Considering the installation cost, clamp-on type of ultrasonic flow meter is preferable.
Calibration	Built-in	None	
Communication technology	New-standard	Traditional	Considering further development of a water sensor network, ultrasonic flow meter is preferable.
Cost	High Return On Investment	Cost-effective but extra installation cost	Ultrasonic flow sensor is easy to install.
Maintenance	Easy	Laborious	Mag meter is apt to rust.

Part 4. Flow meter sensor for open channel		
Introduction		
The RAVEN-EYE® is a new generation radar velocity sensor. In combination with an appropriate level sensor, it provides an improved approach to open channel flow monitoring compared to older radar flow meters. The new sensor combines advanced digital Doppler radar velocity sensing technology with most modern and powerful DSP processor technology allowing a patent pending self-learning average velocity calculation.		
1		 RAVEN-EYE®
RAVEN EYE		

Main features	
Velocity measurement Method	Radar
Range	±0,15 to ±9 m/s (bi-directional)
Accuracy	± 0,5%, + zero stability
Zero stability	± 0,02 m/s
Resolution	0,001 m/s
Communication technology	RS-485 communications port with Modbus ASCII slave communication protocol
Level Measurement 1	
Method	Ultrasonic pulsed echo
Range	0,25 to 2,00 m (with ULS-02) 0,25 to 6,00 m (with ULS-06)
Accuracy	± 1% of reading, + zero stability
Zero Stability	± 2 mm
Resolution	1 mm
Level Measurement 2	
Method	Radar
Range	0,01 to 15 m
Accuracy	± 2 mm of reading
Resolution	1 mm
Flow measurement	
Method	Conversion from surface velocity measurement to average velocity based on patent pending self-learning model using velocity distribution measurements.

		Conversion of water level and pipe size to fluid area. Multiplication of fluid area by average velocity to obtain the flow rate.
Conversion Accuracy		±5.0% of reading Assumes pipe is 0 to 90% full
Outputs		4-20 mA
Internal Temperature Measurement	Method	Digital sensor
	Range	-40º to 80º C
Internal Humidity Measurement	Method	Digital sensor
	Range	0 to 100 %
Internal Pressure Measurement	Method	Digital sensor
	Range	0 to1500 HPa
Material & Dimensions	Enclosure	Polyurethane (PU)
	Weight	3,85 Kg (without the cable, level sensor and mounting accessories)
	Protection rate	IP68
	Dimensions	422 mm L, 140 mm W, 183 mm H
Environmental Conditions	Operating Temperature Range	-20° to 50° C
	Storage Temperature	-30º to 60º C
Sensor cable	Material	Polyurethane jacketed
	Length	Standard: 10 m - Optional: 20 m, 30 m or length as needed up to 300 m
Cost		€8000 - €12000

Appendix B: Survey Feedback

This appendix contains the feedback from internal pilot stakeholders on their wants and needs for the Waternomics platform.

Public Buildings - Engineering Building, Galway, Ireland

Building Services Manager NUIG – Noel O'Connor (NOC) – 17-11-14

For NOC the main value is identifying leaks, their locations, the associated leakage rates and finally repairing leaks (across the entire NUIG campus and in each building). Budgeting and projections are important, so reducing the overhead cost of water to NUIG is important. Building services do report on power, gas and water per head of population and per m^2 on an annual basis. NOC also highlighted a number of common water related faults that could possibly be identified by automated fault detection diagnosis methods.

Some features that were seen as important included:

- **Early warning of leaks would be very beneficial**, as currently some leaks are only identified by spikes in invoices, 2 or 3 months after the leak began. AFDD rules comparing pressure drops over time, or
- Data to indicate the **benefits of fixing leaks** would be very useful, such as €; **Chemical treating costs saved, water saved, pumping cost saved**.
- For **budgeting/ forecasting KPIs for projection**, **a definable time period is important,** as the NUIG Financial Year is 1st Oct – 30th Sep (i.e. not a calendar year).
- NOC noted that a facility to **benchmark against other universities** would be useful.
- If Waternomics employs a League Table approach at any point, then due to varying building stock (i.e. old and new, large and small, different uses) it is worth considering the performance being based on **mutually exclusive improvements against the baseline of each building,** not against each other.
- **NOC highlighted a number of example faults** around stuck ball cocks, pressure drops in heating system due to leaks, and **methods of finding/diagnosing leaks**, such as, comparing invoices, comparing night time and daytime use, comparing summer water use to during semester 1 or 2.
- NOC often uses invoice comparison to indicate leaks; however there is a lag of up to 8-10 weeks. The leak could be ongoing for a long time before it is identified. It would be very useful to have a way to reduce this lag by **more frequent comparison of metering data used for invoice calculation**.
- Notification **false alarms would be acceptable** to begin with while the system is being bedded in.
- NOC discussed how a **cold weather warning** would be useful in advance of freezing temperatures.
- Waternomics could present some key updates data table/report in a unique URL that would be **displayed on the NUIG Building Services page**.

Chief Technical Officer, Engineering Building – Aodh Dalton (AD) – 13-11-14

AD is most concerned with the health and well-being of the Engineering Building occupants. The quality of the water (especially potable water for use in laboratories and for drinking), is a priority for AD. Secondly, AD believes it is vital that Waternomics allows easy accessible access to the academic community in the Engineering Building. Cost is currently not a priority for AD, as water supply to the engineering building does not affect his budgets.

One of the biggest reasons why water quality is important is due to **high retention rates of the water in the mains water supply** pipe work around the building. This water has been known to become high in traces of copper. This is due to copper leaching. This has caused problems in the Biochemistry labs as copper is a contaminant and in the quality of drinking water.

There is a solution to this problem which involves flushing the system by running the end-uses for approximately 15mins in each laboratory in sequence. There are a number of issues with this.

1. AD has to estimate / guess how often this should be done;
2. currently there is not the man power to carry out this practice on a regular basis, so it can only be done when absolutely necessary;

Hence, it would be very useful for AD to know:

1. When the system needs to be flushed?; and
2. Secondly for how long for each end use?
3. How much water is wasted by doing this?

Some other features of the platform which were suggested included:

- In the context of Waternomics, monitoring the chemical or biological composition of water may be beyond the scope, however, it may be worth possibly investigating and possibly measuring the retention rates in the mains water supply and notifying AD when it is high, it could be a way to solve/inform him on the problem.
- AD believes that **access levels or download numbers to the measured data** from water supply and consumption in the Engineering Building should be monitored. AD believes that this data should be accessible for manipulation by software tools, such as Matlab. The data should be well mapped and clearly identified to the relevant sensors or meters.
- Although cost is not currently a concern of AD's, he would like to be engaged by an **interface which displays the water supply use and cost on a daily basis**. In fact, AD believes there should be **customisable reporting periods** (standard year, academic year, financial year, semester, week, weekend, summer).
- AD recommends that there be **admin access to the dashboard displays** to allow for easy update of the information displayed / revise it perhaps annually. A final year student could work on this for example.
- AD suggested that a good target for a display would be to **inform students of the cheapest time of day to take a shower** in the Engineering Building (this would be based on the Combined Heat and Power (CHP) heating profile). The CHP is active in the morning time in the building.

Table 6 - Engineering Building – Top KPIs

	KPI name	Who is it for	What will it be used for	Units to be reported (if relevant)	Frequency	Reported by
1	Retention Rate	AD	*To flag/indicate high copper levels*	m^3/m	Day/month	AD during interview by NUIG
2	Data Access Nos.	AD	*To indicate access levels to water data by research*	Downloads of data from Waternomics Platform	month/ year / semester	AD during interview by NUIG
3	Water Use	AD	*To increase awareness / inform decisions*	$m^3/$	(min/hour/day/night time / day time / month / semester /year) – user definable	AD during interview by NUIG
4	Water Cost	AD	*To increase awareness / inform decisions*	€ /	(min/hour/day/night time / day time / month / semester /year) – user definable	AD during interview by NUIG

5	CWS total building use	reports to President, EDO	*energy metrics, budgeting*	m3	day/week/month/year, mains meter	NOC inputted to template
6	CWS total building use	Management	*Leak evaluation*	m3	hour/day/week/year, mains meter	NOC inputted to template
7	CWS total building use	Tradesmen	*Leak evaluation*	m3	day/week/month/year, downstream sub meters	NOC inputted to template
8	CWS total building use	contractors	*energy metrics, Leak evaluation*	m3	hour/day/week/year, downstream sub meters	NOC inputted to template
9	baseline analysis (night time) of mains and sub meters, are we using water when building is closed	academics	*energy metrics, Leak evaluation*	m3		NOC inputted to template
10	UAFW - unaccounted for water/leakage mains meter	researchers	*energy metrics, Leak evaluation*	€		NOC inputted to template
11	UAFW - unaccounted for water/leakage sub meters	students		M3		NOC inputted to template
12	access to meter	ISO50001 metrics			by meter, floor by floor consumption	NOC inputted to template
13	RWS total building				use per day/week/month/year	NOC inputted to template
14	RWS total building				use per hour/day/week/year	NOC inputted to template

Items for consideration on features list

- KPI projections for budgeting (NOC)
- A feature that present leakage rates costing estimate € (NOC)
- Cold Weather warning (NOC)
- A way of tracking and comparing invoices (NOC)
- Summary data table / report from Waternomics available to be embedded on pilot e.g. NUIG building services page. (NOC)
- Retention rate high notification (AD)
- Is Downloadable/interface able data available for research (AD)
- Admin access to displays in public areas to allow for update (AD)

Schools - Coláiste na Coiribe, Galway, Ireland

Principal - Stiofán Ó Cualáin (SOC) & Mícheál Ó Marcacháin(MOM)

What SOC & MOMare most interested in is:

1. to see how much the **rate drops during**
   a. **School holidays i.e. volume vs time graphs.**
   b. Also how it **varies during the day.**

      The usage rate should be 0 during holidays/ outside of school hours and if not, this will allow SOC to detect leaks.
2. SOC also expressed an interest in **usage rate per segment/end use** (i.e. urinals, taps, showers etc.).

Also from MOM's email:

"From the point of view of students for projects etc some of the following data might be useful:

- change in usage at various times of the year
- where is most of the water being used: toilets/showers/kitchen/hand basins/drinking fountains
- any stats on the quantity of usage per person compared to other schools"
- Access to data for student Apps development and projects

Table 7 - School – Top KPI's

	KPI name	Who is it for	What will it be used for	Units to be reported (if relevant)	Frequency	Reported by
1	Water usage	Reporting to department	To Benchmark against other schools	M^3 /	M2 / student	
2	Leakage Rate	SOC	Leak Evaluation			
3	"What were the numbers of faults that were detected by the automated fault detection and diagnosis system and which of these are currently open at the moment?"	SOC				
4	"I want to graph how we are doing on our targets for water use and associated cost and compare 2012,13&14?"	SOC				
5	change in usage at various times of the year, summer vs. term	STUDENTS				

6	where is most of the water being used: toilets/showers/kitchen/hand basins/drinking fountains	STUDENTS				
7	any stats on the quantity of usage per person compared to other schools	STUDENTS				
8	Usage rate of data and accessibility	STUDENTS				

Items for consideration on features list

- Benchmarking against other school usage

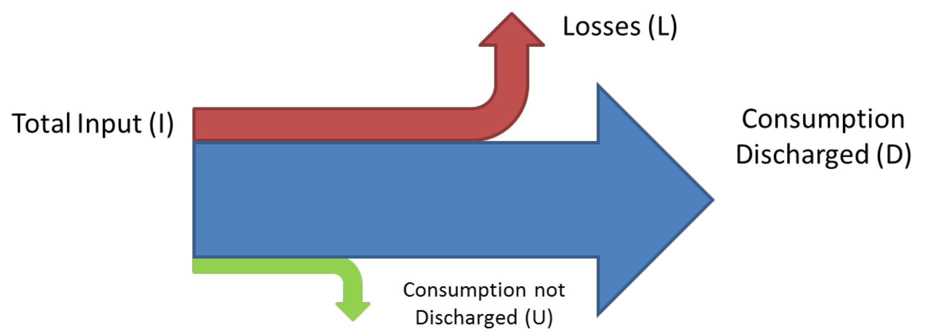
Domestic - Thermi, Greece

Table 8 - Domestic Users – Top KPI's

	KPI name	Who is it for	What will it be used for	Units to be reported (if relevant)	Frequency	Reported by
1	Overall consumption over user defined periods	Household leader/s	Check consumption on a frequent basis	m^3 or cost	Hourly?, Daily, weekly, monthly, annually, based on billing period	
2	Distribution over different parts of the house (kitchen, bathroom, etc)	Household leader/s	Frequent casual checks	m^3/ location	Hourly?, Daily, weekly, monthly, annually, based on billing period	
3	Distribution over various water uses	All family	Frequent casual checks	m^3/ use case	Daily, weekly, monthly, annually, based on billing period	
4	Comparison over water use alternatives (washing dishes by hand vs using dishwasher)	Household leader/s	Monitoring / Decision support	m^3or cost	Daily, weekly, monthly, annually, based on billing period	
5	Comparison of consumption between alternative devices	Household leader/s	Decision support	% of water (m^3or cost) saved or lost	monthly, annually, based on billing period	
6	Average consumption of similar households	All family	Decision support / Frequent casual checks	m^3or cost	Daily, weekly, monthly, annually, based on billing period	

7	Consumption in other metaphors	All family	Monitoring / Frequent casual checks	Variety of relevant units based on water use case and volume of water	Hourly, Daily, weekly, monthly, annually, based on billing period	
8	Consumption over specific members	All family	Monitoring, Gamification	m^3or other metaphors	Daily, weekly, monthly, annually, based on billing period	
9	Benchmark changes in behaviour (How much did I save by changing the program I use in the washing machine?)	All family	Monitoring	% of water saved or lost	weekly, monthly, annually, based on billing period	

Commercial – SEA / Linate Airport, Milano

<table>
<tr>
<td>Volumetric Performance</td>
<td>


<table>
<tr><th>Period</th><th>I (m³)</th><th>L (m³)</th><th>U (m³)</th><th>D (m³)</th><th>D/I</th><th>L/I</th></tr>
<tr><td>Day</td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Week</td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Month</td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Annual Projection</td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
</table>
</td>
</tr>
<tr>
<td>Costs</td>
<td>
<table>
<tr><th>Period</th><th>Discharge Costs</th><th>Energy Costs</th><th>Total Costs</th></tr>
<tr><td>Annual Baseline</td><td></td><td></td><td></td></tr>
<tr><td>Year to Date</td><td></td><td></td><td></td></tr>
<tr><td>Annual Projection</td><td></td><td></td><td></td></tr>
<tr><td>Daily</td><td></td><td></td><td></td></tr>
<tr><td>Monthly</td><td></td><td></td><td></td></tr>
</table>
</td>
</tr>
</table>

<table>
<tr><td>Savings</td><td>
<table>
<tr><th>Period</th><th>Discharge Savings</th><th>Energy Savings</th><th>CO2 Credit Savings</th><th>Total Savings</th></tr>
<tr><td>Year to Date</td><td></td><td></td><td></td><td></td></tr>
<tr><td>Annual Projection</td><td></td><td></td><td></td><td></td></tr>
<tr><td>Daily</td><td></td><td></td><td></td><td></td></tr>
<tr><td>Monthly</td><td></td><td></td><td></td><td></td></tr>
</table>
</td></tr>
<tr><td>Current Strategies</td><td>Pressure reduction Bldg 51 night hours midnight-6am
Staff Awareness October
Motion detectors Terminal Corpo D</td></tr>
<tr><td>Faults Annotated</td><td>Pump efficiency anomaly Pump Station #2
Weekly flow variation >2%</td></tr>
<tr><td>Actions</td><td>Check pump No.243622</td></tr>
</table>

Table 9 - Commercial Buildings – Top KPI's

	KPI name	Who is it for	What will it be used for	Units to be reported (if relevant)	Frequency	Reported by
1	Incoming / outgoing water rate	*Management*	*Internal reporting / negotiation of new contracts*	% of rate	monthly / quarterly	Linate through U4 user tests
2	Comparison of consumption with past periods (reduction or increase)	*Management*	*Internal reporting*	%	annually & quarterly	Linate through U4 user tests
3	Comparison of consumption with future targets	*Management*	*Internal reporting*	% of completion	annually & quarterly	Linate through U4 user tests
4	Comparison of consumption between different sections / sensors (difference)	*Management*	*Internal reporting*	m3 or % of difference	annually & quarterly	Linate through U4 user tests
5	Simulation of new pricing policies with seasonal variations	*Management*	*Internal reporting*	% increase/reduction of income	annually	Linate through U4 user tests
6	Simulation of	*Design /*		% of	annually /	Linate

	new infrastructure effects	*Management*		consumption decreased / € to be saved estimated	quarterly / monthly	through U4 user tests
7	Benchmarking new infrastructure effects	*Design / Management*		% of consumption decreased / € actually saved	annually / quarterly / monthly	Linate through U4 user tests
8	Comparison of consumption with past periods (reduction or increase)	*Technicians*	*Detection of anomalies*	m3 or % of difference	monthly?	Linate through U4 user tests
9	Detection of leakages / faults	*Technicians*	*Day to day maintenance*			Linate through U4 user tests
10	Estimation of leakage / faults costs	*Technicians*	*Day to day maintenance / decision support*	m3 and € lost in the leakage / time need for return of investment of the repair	daily / monthly / annually	Linate through U4 user tests
11	Benchmarking of repairs	*Technicians*	*Internal reporting / decision support*	m3 or € saved so far / % of the repair cost returned	monthly / annually	Linate through U4 user tests
12	Comparison of consumption with past periods (reduction or increase)	*Communications*	*Publicity efforts*	reduction in different metaphors that make more sense to common people and increase communication effect	annually / quarterly	Linate through U4 user tests

External Stakeholders - Corporate Users

Among the external stakeholders, we also surveyed multiple corporate users and identified potential KPIs that they are interested in. Table 10 reports on these KPIs and identify the associated unit of measurement

Table 10 - Main KPIs for Corporate users

Key Performance Indicators	Unit of measure
Incoming / outgoing water rate	% of rate
Comparison of consumption with past periods	% of reduction or increase
Comparison of consumption with future targets	% of completion
Comparison of consumption between different sections / sensors	m^3 or % of difference

Simulation of new pricing policies with seasonal variations	% increase/reduction of income
Simulation of new infrastructure effects	% of consumption decreased / € to be saved estimated
Benchmarking new infrastructure effects	% of consumption decreased / € actually saved
Detection of leakages / faults	Nr. of leakages/Km of network
Estimation of leakage / faults costs	m^3 and € lost in the leakage
Benchmarking of repairs	m^3 or € saved so far / % of the repair cost returned
Consistence of water losses against length of the network	m^3/Km of network
Consistence of water losses against the quantity of water users	m^3/users
Consistence of water losses through the number of maintenance operations	number of maintenance operations/year
Infrastructure leakage index	current rate of actual losses (m^3/d) /unavoidable annual real losses (m^3/d)
Water saving index	m^3 of water saved in one year and € saved in one year

Appendix C: Entity Relationship Model for Modelling Sensors and Readings

The object of this Appendix is to define an Entity Relationship model for describing different components of the system. This section introduces our methodology for defining this data model in Section 1. The data model itself is detailed in Section 2. Finally, in Section 3, we create a mapping of our data model with existing ones adopted previously in both NUIG and U4 sites.

1. Methodology

Even though the literature proposes multiple data modelling methodologies, Len Silverstone [17] affirms that they can be summarized into two categories:

- Top-down: creating a data model after several interviews with domain experts. The outcome of such methodology is a reference model that can be tailored to the local implementations.
- Bottom-Up: creating a data model by starting from existing data sources: forms, data models, screens or reports.

In our case we mix both methodologies in order to define our model. Indeed, we had access to existing data models from the project pilots. From these models we extracted common data items that are further refined with various discussions with domain experts.

In this following, we propose to model data items as an entities and relationships between them. An entity relationship modelling methodology has been introduced by Peter Chen[18] for describing data or information of a business domain in an abstract format that can be implemented in a database.

Please note that this model can be tailored to local implementations of each pilot.

2. Entity Relationship Model

We designed our data model as an Entity Relationship Model. We represent each concept of our model as a Table (in SQL jargon). Each table is detailed in the following.

2.1 Sensors

Sensor Table contains the set of sensors being deployed in a particular site (e.g., NUIG Engineering Building, VTEC Building, etc.).

As depicted in Figure 8, a sensor is described via four attributes**: Sensor_ID, Sensor_Name, Site_Name** and **Description**.

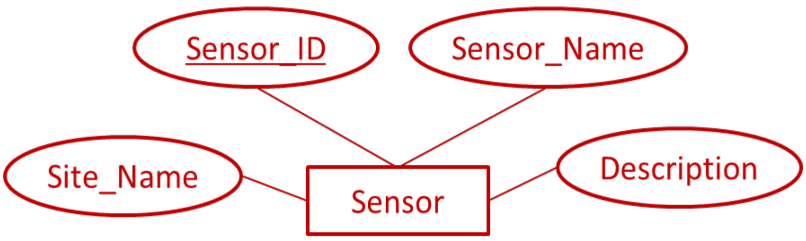


Figure 8 - Entity Relationship Model: Sensor

- **Sensor_ID**: is a unique identifier for sensors (i.e., Primary key). It can be either a string or an integer. As a design choice we propose to use a string of 80 characters (i.e., varchar (80)) for this attribute.
- **Sensor_Name**: is a label given to the sensor as a short description. As a design choice we propose to use a string of 20 characters (i.e., varchar (20)) for this attribute.
- **Site_Name**: is a label for the location where the sensor is installed. This location concerns only the site rather a particular location in a building. As a design choice we propose to use a string of 80 characters (i.e., varchar (80)) for this attribute.

- **Description**: is a textual description that can be used in the UI for a user-friendly description of the sensor. As a design choice we propose to use a string of 200 characters (i.e., varchar (200)) for this attribute.

Table 11 shows two examples of entries in **Sensor** Table.

Table 11 - Example of entries in Sensor Table

Sensor_ID	Sensor_Name	Site_Name	Description
1	Vtec Sensor	VTEC	This is VTEC building
2	NUIG Sensor	NUIG	This sensor is installed in the NUIG Engineering Building

2.2 Sensor Observation Types

Observation_Type table contains the set of observations that the system handles.

As depicted in Figure 9, an Observation_Type is described via three attributes: **Observation_Type_ID, Observed_Property** and a **Unit_Of_Measurement**.

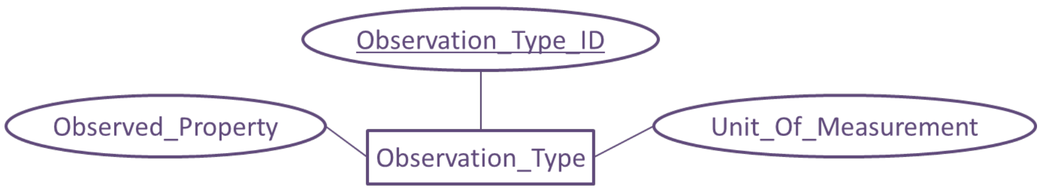


Figure 9 - Entity Relationship Model: Observation_Type

- **Observation_Type_ID**: is a unique identifier for observation types (i.e., primary key). It can be either a string or an integer. As a design choice we propose to use a string of 20 characters (i.e., varchar (20)) for this attribute.
- **Observed_Property**: indicates the property being observed. As a design choice we propose to use a string of 20 characters (i.e., varchar (20)) for this attribute.
- **Unit_Of_Measurement**: indicates the associated unit of measurement to the considered property. As a design choice we propose to use a string of 20 characters (i.e., varchar (20)) for this attribute.

Table 12 shows three examples of entries in **Observation_Type** Table.

Table 12 - Example of entries in Observation_Type Table

Observation_Type_ID	Observed_Property	Unit_Of_Measurement
fvel	Flow Velocity	m/s
flow	Flow	m3/h
waterc	Water Consumption	m3

2.3 Sensors and Observation Types

Sensor_Observation_Type table contains the link between a sensor and the properties that it observes with additional features. Because a sensor observes one or many Observation_type(s), we capture this in our model as a relation (i.e., observes).

As depicted in Figure 10, a **Sensor_Observation_Type** is captured as **Observes** relation described via the following attributes: **Range_Min, Range_Max, Accuracy** and **Observation_Interval.**

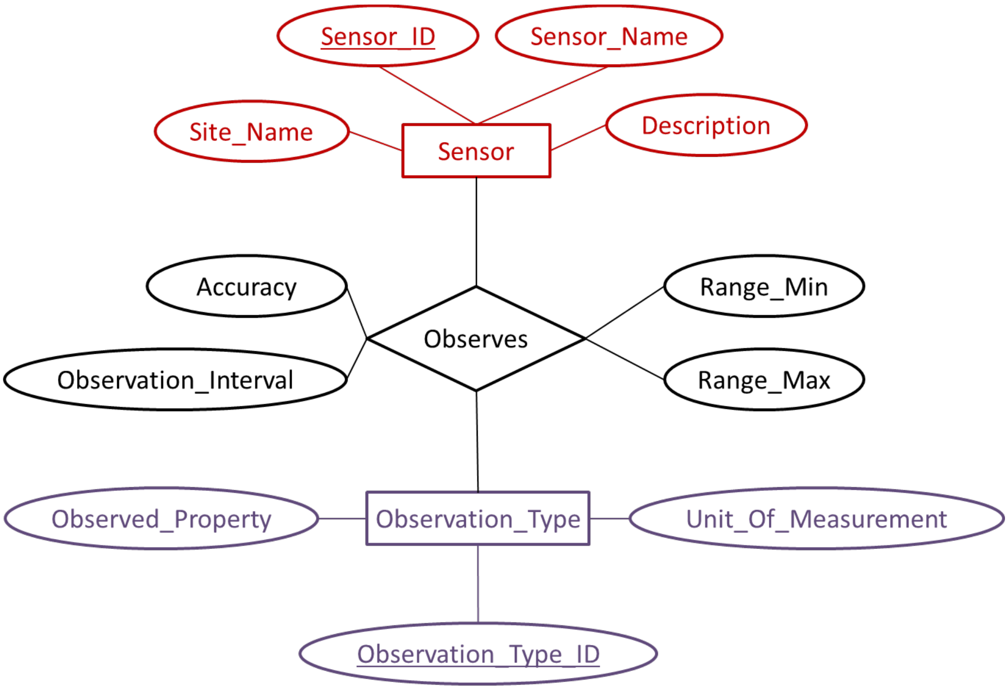


Figure 10 - Entity Relationship Model: Sensor_Observation_Type captured as Observes relation

- **Range_Min and Range_Max**: define, respectively, the lower and upper limits of the values that of the observed property by the considered sensor. As a design choice we propose to use a number (i.e., number (15,10)) for this attribute.
- **Accuracy**: indicates the accuracy of the sensor when observing the indicated property. As a design choice we propose to use a number (i.e., number(15,10)) for this attribute.
- **Observation_Interval**: reports on the measurement period every which the sensor sends data expressed in seconds. As a design choice we propose to use an integer (i.e., int(10))) for this attribute.

The identifier of this relation is composed of: **Sensor_ID** and **Observation_Type_ID**. These are two foreign keys for the Sensors and the Observation Types tables.

Table 13 shows two examples of entries in **Sensor_Observation_Type** Table.

Table 13 - Example of entries in Sensor_Observation_Type Table

Sensor_ID	Observation_Type_ID	Range_Min	Range_Max	Accuracy	Observation_Interval
1	fvel	0	200	10	20
1	flow	0	200	1	20

2.4 Sensor Observations

Observation table contains the actual observations / measurements generated by sensors.

As depicted in Figure 11, an **Observation** is described via the following attributes: **Observation_ID**, **DateTime** and **Value**.

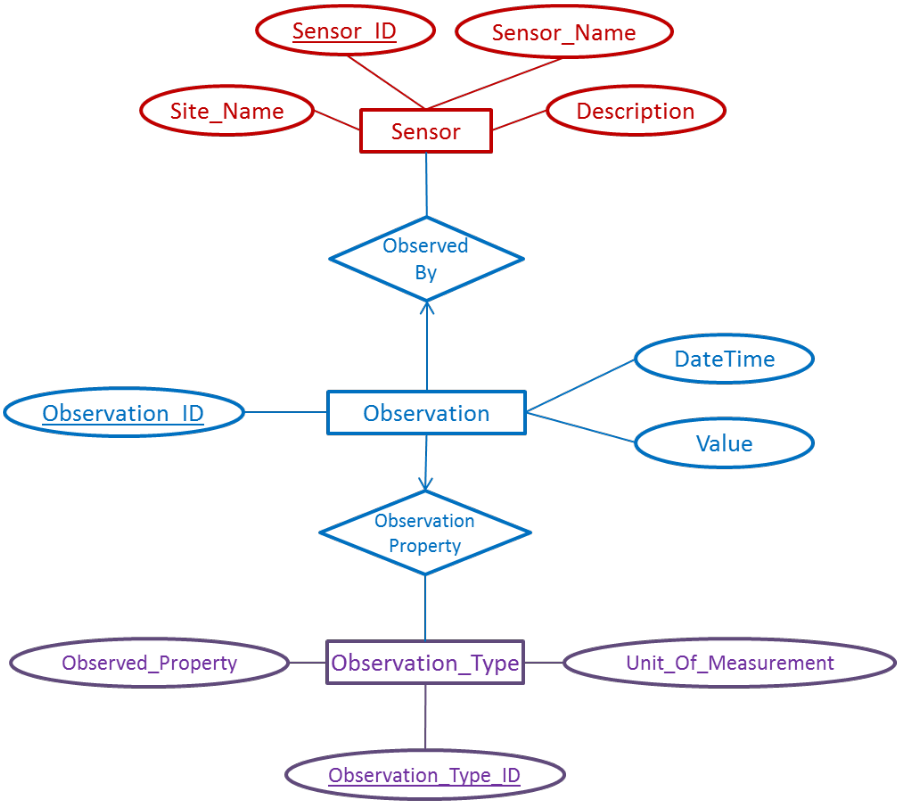


Figure 11 - Entity Relationship Model: Observation

- **Observation_ID**: is a unique identifier for the observation (i.e., primary key). It can be either a string or an integer. As a design choice we propose to use a string of 80 characters (i.e., varchar (80)) for this attribute.
- **DateTime**: defines the observation Time in milliseconds. As a design choice we propose to use a number (i.e., number(15)) for this attribute.
- **Value**: indicates the actual observation/measurement value. As a design choice we propose to use a number (i.e., number(15,10)) for this attribute.

As the **Observation** Entity is related to **Sensor** and **Observation_Type** via the relations **Observed by** and **Observation Property** (respectively), both primary keys from those entities (i.e., **Sensor _ID** and **Observation_Type_ID**) are also part of the description of the table Observation.

Table 14 shows two examples of entries in **Sensor_Observation_Type** Table.

Table 14- Example of entries in Sensor_Observation_Type Table

Observation_ID	Sensor_ID	Observation_Type_ID	DateTime	Value
0	1	fvel	1417786723000	1429.6
1	1	flow	1417786723000	1.32423

2.5 Aggregated Observation

Aggregated_Observation table contains the aggregations of observations / measurements generated by sensors. They can be hourly, daily, weekly aggregations depending on the requirements for the data consumers.

As depicted in Figure 12, an **Aggregated_Observation** is described via the following attributes: **Aggregation_ID, Agrgegation_Interval, Aggregation_Function, Aggregation_Label, DateTime** and **Value**.

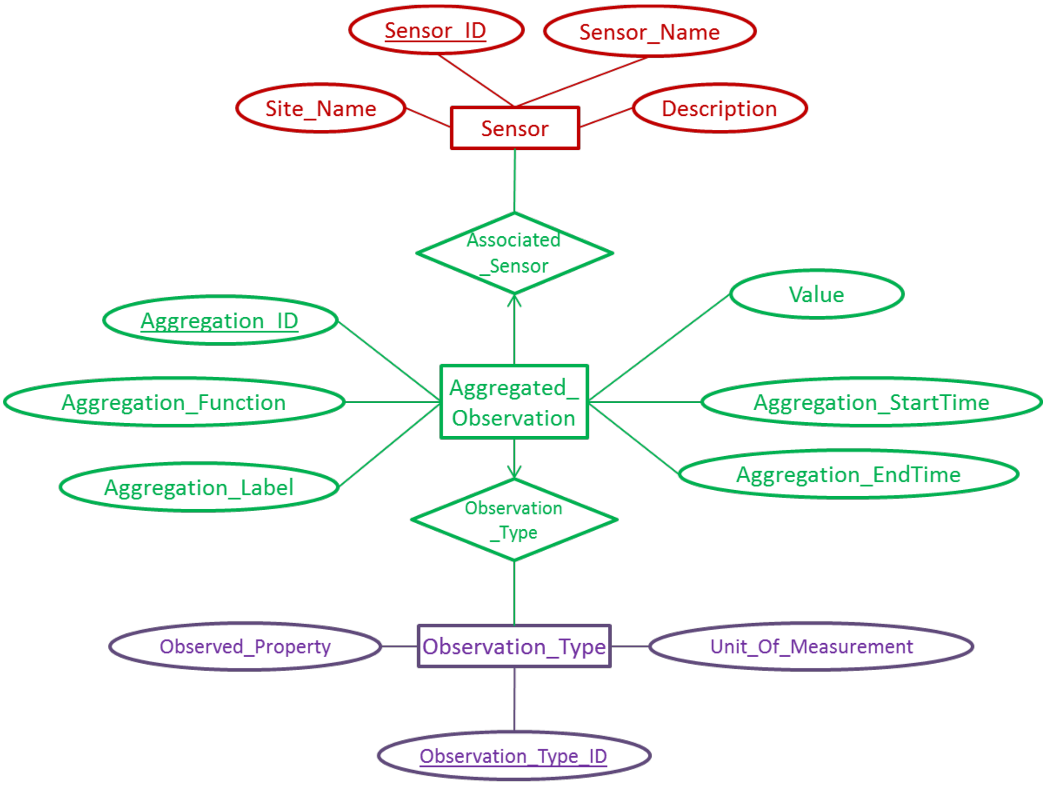


Figure 12 - Entity Relationship Model: Aggregated_Observation

- **Aggregation_ID**: is a unique identifier for the aggregated_observation (i.e., primary key). It can be either a string or an integer. As a design choice we propose to use a string of 80 characters (i.e., varchar (80)) for this attribute.
- **Aggregation_Function**: indicates the function used for generating the actual aggregation. This is simple text such as "sum" or "avg". As a design choice we propose to use a string of 20 characters (i.e., varchar (20)) for this attribute.
- **Aggregation_Label**: is a label given to the aggregated_observation as a short description (e.g., daily, hourly, etc.). As a design choice we propose to use a string of 20 characters (i.e., varchar (20)) for this attribute.
- **Agrgegation_StartTime** and **Aggregation_EndTime**: describe the interval of aggregation used for created the current aggregation. Both attributes are expressed in milliseconds. As a design choice we propose to use a number (i.e., number(15)) for this attribute.
- **Value**: indicates the actual aggregated_observation value. As a design choice we propose to use a number (i.e., number(15,10)) for this attribute.

As the **Agrgegated_Observation** Entity is related to **Sensor** and **Observation_Type** via the relations **Associated_Sensor** and **Observation_Type** (respectively), both primary keys from those entities (i.e., **Sensor _ID** and **Observation_Type_ID**) are also part of the description of the table Observation.

Table 15 shows an example of entries in **Aggregated_Observation** Table.

Table 15 - Example of entries in Aggregated_Observation Table

Aggregation_ID	Sensor_ID	Observation_Type_ID	Aggregatoin_Function	Aggregation_Label	Aggregation_StartTime	Agrgegation_EndTime	Value
123	1	waterc	sum	today	1417737600000	1417786723000	7.1783

2.6 Summary

The proposed data model highlights three main entities:

- **Sensor**: contains the sensors being considered in the system;
- **Observation_type**: contains the observed properties in the system;
- **Observation**: contains the actual observations values.
- **Aggregated_Observation**: contains aggregated values of observations.

These four entities are presented here as table stables.

Five relations are also considered:

- **Observes**: this relationship indicates that a sensor can observe multiple observation properties. This relationship is captured as **Sensor_Observation_Type** table.
- **Observed By**: this relationship links the observations to the sensor that generated them. This relationship is captured in as a foreign key in the table **Observation**.
- **Observation Property** this relationship links the observation to it associate type. This relationship is captured as a foreign key in the table **Observation**.
- **Associated_Sensor** this relationship links the aggregated observations to the sensor that generated the input observations. This relationship is captured as a foreign key in the table **Aggregated_Observation.**
- **Observation_Type**: this relationship links the aggregated observation to it associate type. This relationship is captured as a foreign key in the table **Aggregated_Observation**.

Figure 13 depicts the entire Entity Relationship Model that represents all these entities and relationships. In addition, Figure 14 shows the generated tables for our model as well as the links between the foreign keys.

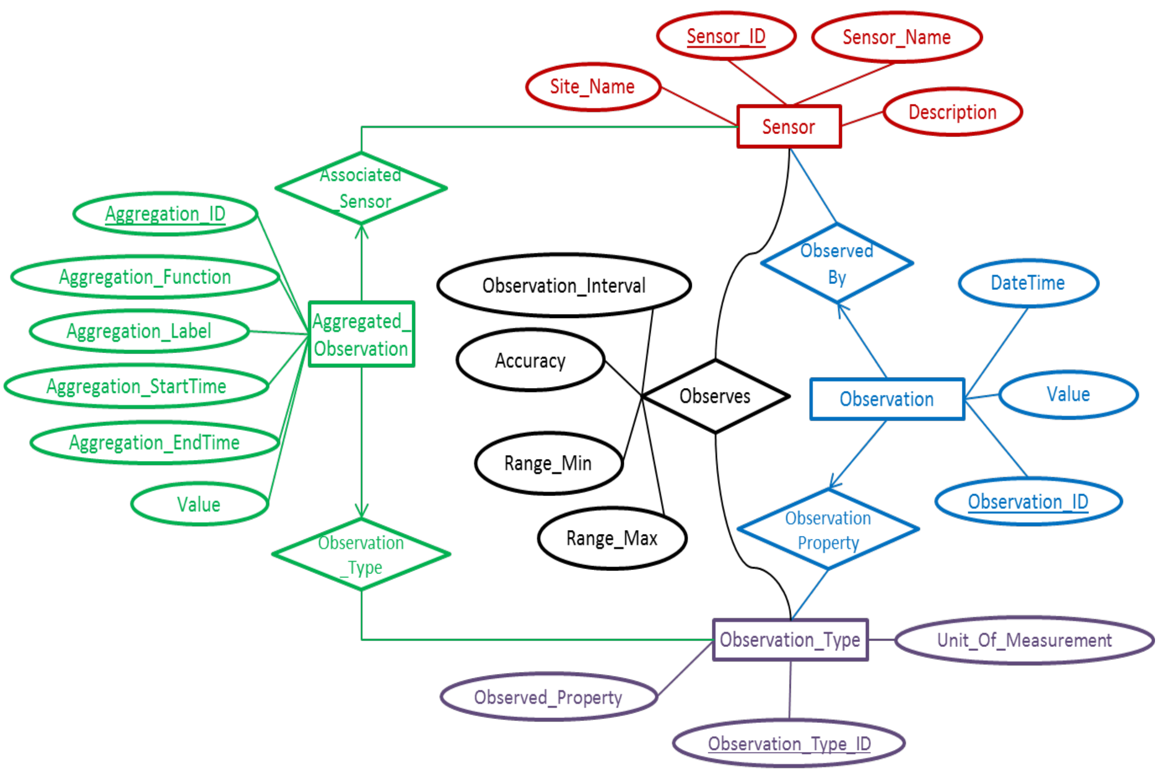


Figure 13 - Entire Entity Relationship Model

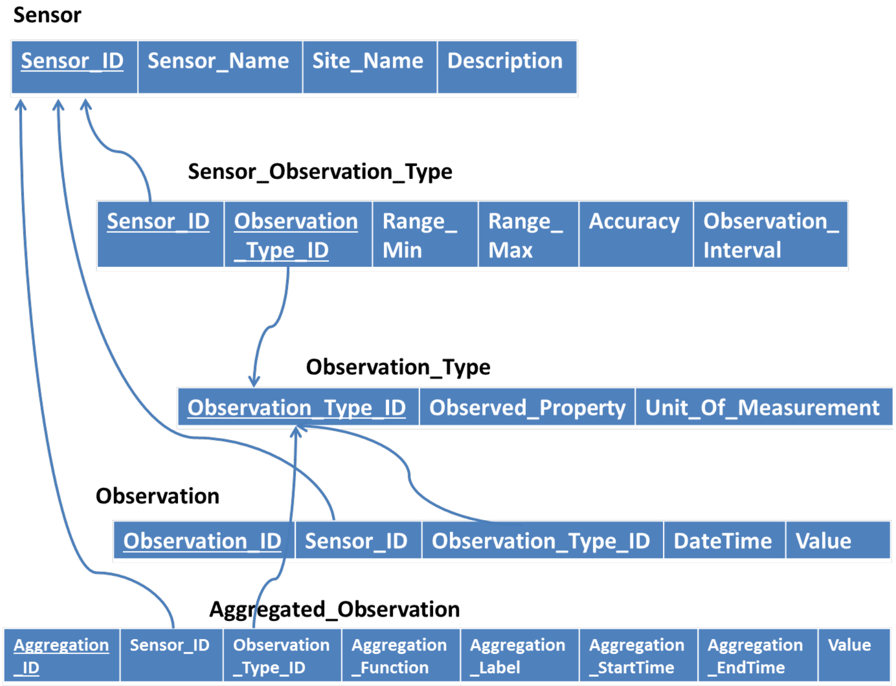


Figure 14 - Tables and Foreign keys relations

It is important to note that this model is independent from any existing implementation (i.e., existing databases in NUIG or VTEC). In the following section, we will map it to existing models.

3. Mapping the proposed model with NEB NUIG and VTEC models

Table 16 - Mapping the proposed model with NEB NUIG sensors models

Data Item	Matching Item from NEB NUIG data model	Comment
Sensor Table	Datalog Descriptors	
Sensor_ID	Datalog_ID	
Sensor_Name	Datalog_Name	
Site_Name	Site_Name	
Description		
Observation_Type		Not captured as a separate table
Observation_Type_ID		
Observation_Property	Datalog Descriptors → Type	
Unit_Of_Measurement	Datalog Descriptors → Units	
Sensor_Observation_Type		
Range_Min		
Range_Max		
Accuracy		
Observation_Interval	Datalog Descriptors→ Interval	
Observation		
Observation_ID		
Observation_Type_ID		

DateTime	Time	
Value		
Aggregated_Observation		Not yet covered
Aggregation_ID		
Aggregation_Function		
Aggregation_Label		
Aggregation_StartTime		
Aggregation_EndTime		
Value		

Table 17 - Mapping the proposed model with VTEC sensors model

Data Item	Matching Item from VTEC sensors data model	Comment
Sensor Table	Sensors	
Sensor_ID	sensors→sensor_id	
Sensor_Name		
Site_Name		
Description	sensors→sensor_description	
Observation_Type		
Observation_Type_ID	Type_of_measurement→name	
Observation_Property	Type_of_measurement→description	
Unit_Of_Measurement		
Sensor_Observation_Type		
Range_Min		
Range_Max		
Accuracy		
Observation_Interval		
Observation	Measurement	
Observation_ID	Measurement →measurement _id	
Observation_Type_ID		
DateTime	Measurement →datetime	
Value	Measurement →measurement	
Aggregated_Observation		
Aggregation_ID		
Aggregation_Function		
Aggregation_Label		
Aggregation_StartTime		
Aggregation_EndTime		
Value		

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