# D.1.2. Inventory Technology, Standards and Policies

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|---|---|
| Project Acronym: | **WATERNOMICS** |
| Project Title: | **ICT for Water Resource Management** |
| Project Number: | **619660** |
| Instrument: | **Collaborative project** |
| Thematic Priority: | **FP7-ICT-2013.11** |

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**D1.2**

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|---|---|---|
| **Work Package:** | *WP1* | |
| **Due Date:** | | 31/01/2015 |
| **Submission Date:** | | 31/01/2015 |
| **Start Date of Project:** | | 01/02/2014 |
| **Duration of Project:** | | 36 Months |
| **Organisation Responsible of Deliverable:** | | IHE |
| **Version:** | | 1.2 |
| **Status:** | | Final |
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| **Nature:** | ☒ R – Report ☐ P – Prototype<br>☐ D – Demonstrator ☐ O – Other | |
| **Dissemination level:** | ☒ PU - Public<br>☐ CO - Confidential, only for members of the consortium (including the Commission)<br>☐ RE - Restricted to a group specified by the consortium (including the Commission Services) | |
| Project co-funded by the European Commission within the Seventh Framework Programme (2007-2013) | | |

| Revision history | | | |
|---|---|---|---|
| **Version** | **Date** | **Modified by** | **Comments** |
| 0.1 | 15/07/14 | Glauco Donida | Initial technology scouting |
| 1.0 | 05/09/14 | Mireia Tutusaus | Initial Version of Document |
| 1.1 | 24/11/2014 | Mireia Tutusaus | Simplified version to reflect purpose of report: high level reference for other project deliverables |
| 1.2 | 03/12/2014 | YingYing Lu | Input on technologies: advantages and disadvantages |
| 1.2 | 03/12/2014 | Leonardo Alfonso | Comments on technology section |
| 1.2 | 03/12/214 | Daniel Coakley | Added data platform section |
| 1.2 | 07/12/2014 | Mireia Tutusaus | Developed policy section, Introduction and added text on inventory sections from previous versions of the document. Added some comments from EC (03/12/2014) |
| 1.3 | 09/12/2014 | Christos Kouroupetrolgou | Partly input on 'software' section |
| 1.3 | 09/12/2014 | Mireia Tutusaus | Added comments from call with partners 07/12/2014 (see meeting notes) |
| 1.3 | 23/12/2014 | Schalk Jan van Andel | Editing document |
| 1.4 | 04/01/2015 | Mireia Tutusaus Domenico Perfido Thomas Messervey | Add final draft technology inventory from R2M |
| 1.4 | 04/01/2015 | Mireia Tutusaus | Add final draft technology inventory from ULTRA4 |
| 1.5 | 11/01/2015 | Eoghan Clifford | General proof read and comments |
| 2.0 | 24/01/2015 | Mireia Tutusaus | Incorporate revised version with contributions from Domenico Perfido, Christos Kouroupetrolgou, Mireia Tutusaus |
| 2.1 | 24/01/2015 | Daniel Coakley | Revised section 2.2 (Data platform) based on comments from reviewers. |
| Final 1.1. | 19/02/2015 | Mireia Tutusaus | Revised and final version including all feedback and comments from all reviewers |
| Final 1.2 | 25/02/2015 | Umair ul Hassan | Revised Section 2.2 and general formatting |
| Final 1.3 | 01/03/2015 | Daniel Coakley | Revised Section 2.2.3 based on feedback from Edward Curry |

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# Executive summary

This report provides a review of the state-of-the-art technologies relevant for the project, and an assessment of policies and standards that govern the implementation and use of these technologies by utilities and water users. This work is part of Work Package (WP) 1 - Exploration, Scoping, Engaging Stakeholders and Architecture - , which aims at setting the lines and focus of Waternomics to ensure the innovations that derive from it are of relevance to the industry. As such, in the context of Waternomics, and indeed with a view to a wider audience this task and deliverable (Task 1.3; Deliverable 1.2) documents water ICT technologies, policies decision makers should be aware of, and standards that must be complied with.

This deliverable builds upon the knowledge generated in D1.1 - Usage case scenarios and Initial Exploitation Scenarios. It contributes to the decisions that will be made based on the information generated in D1.3 - System Architecture and KPIs. D1.1 establishes all possible case scenarios and uses of the tools to be developed within this project. In this deliverable the project partners have discussed and agreed upon which uses and stakeholders should be considered, and have agreed, with reference to numerous external stakeholders the project key outcomes (usage cases and exploitation scenarios). D1.3 defines how the technology under Waternomics will be developed as well as its key functionalities. D1.3. is informed by the requirements of the project as developed in D1.1 as well as by the key gaps in technology or requirements of existing (or indeed proposed) standards and policies listed in this report (D1.2). These deliverables (D 1.1, D 1.2 and D1.3) form the basis of much of the work to be carried out in Waternomics.

The technology inventory in D1.2 compiles a set of technologies that complete the building phases of the Waternomics platform. A thorough technology inventory has been developed for: i) hardware - which compiles different types of sensing technology, ii) an inventory of data platforms and iii) several technologies available to build the platform that will be available to the final user such as back and front-end application frameworks or mobile app development technologies. Even though policies and standards are very often linked, in this deliverable policies and standards both have been developed in several chapters. The reason for separating the two in this report is because of the nature of the inventory. In the policies chapter we elaborate on the influence of policies in the development of ICT technology to conclude that there are no relevant policies that directly target the development of ICT technology in water management. However, the report elaborates on how policies and standards can positively influence the adoption of 'smart' water technology and refers to different policies, standards and pointers of information (organizations and IT-driven initiatives).

As the project progresses sections of this document will need to be revisited and complemented to serve specific local realities. The work developed in the chapter of policies and standards is further developed in subsequent Work Packages (WP) in Waternomics. In WP2 (Methodology) the consortium investigates in more detail matters of governance for selected cases (ie. Australia or the Netherlands) to inform how decisions around ICT technology take place and which factors are of influence. The technology inventory will be further refined in subsequent activities of the project (WP3 and WP5). Most importantly the consortium will continue to monitor the development the other influential industries such as energy (leaving significant differences aside), or general initiatives of making cities 'smarter', as they can significantly contribute to the marketability of the Waternomics platform.

# Contents

# 1 Introduction

To help reduce shortages in clean drinking water, 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 and will evaluate its results in three real-life experiments in Italy, Greece and Ireland.

The goal of Waternomics is to explore how ICT can help households, businesses and municipalities with reducing their consumption and losses of drinking water. A key component of the Waternomics information platform aims at collecting water consumption and contextual information from different sources to be used for effective data analytics to drive decision making: e.g., planning, adjustments and predictions and to raise user awareness of water consumption.

## 1.1 Work Package 1 Objectives

Work Package 1 (WP1) beings a project long focus on business designing and development which is used to ensure industry relevance of the project outcomes, while at the same time provides the best fit requirements, constraints and specifications for project technical development activities. As such, WP1 objectives are:

- Identify and analyse the state of the art of water information services
- Plan, organize and conduct round table sessions and interviews with potential stakeholders
- Identify and analyse the business models and collaboration opportunities for the project
- Develop use case scenarios and business strategies for interactive water information services
- Define the overall architecture for the Waternomics Platform

The work of this WP will rely on the expertise and field experience of the consortium partners as well as input elicited through key stakeholder water workshops and empirical data collected from the project pilot cases.

## 1.2 Purpose and Target Group of the Deliverable

This report provides a review of the state-of-the-art technologies relevant for the project, and an assessment of policies and standards that govern the implementation and use of these technologies by utilities and water users. This work is part of Work Package (WP) 1 - Exploration, Scoping, Engaging Stakeholders and Architecture - , which aims at setting the lines and focus of Waternomics to ensure the innovations that derive from it are of relevance to the industry. As such, in the context of Waternomics, and indeed with a view to a wider audience this task and deliverable (Task 1.3; Deliverable 1.2) documents water ICT technologies, policies decision makers should be aware of, and standards that must be complied with.

This deliverable has focused on the identification of standards and policies within a European Union context as the pilot cases of Waternomics are developed, without exception, within that context. Nevertheless, when required, the inventory exercise has been extended to other regions or we have enlisted standards that are of global (worldwide) reach. The listing of standards and policies from other regions has been motivated by the need felt by to observe good practice or lessons learned in other regions where ICT technology has been promoted and/or adopted for a ‘smarter’ water management. Such cases can serve as a benchmark to the project. The work developed for the inventory of standards and policy has been extended into

other work packages (WP), namely WP2 under the task 'Governance and Knowledge Transfer'. The regional scope used for the standards and policies has not been used for the inventory of technologies.

## 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 4 and are described as follows:

**Link 1**: D1.1 precedes this deliverable and it establishes all possible case scenarios and usability's of the tools to be developed within this project. In this deliverable the project partners have discussed and agreed upon which uses and stakeholders should be considered, and have agreed, with reference to numerous external stakeholders the project key outcomes (usage cases and exploitation scenarios).

**Link 2**: D1.3 defines how the technology under Waternomics will be developed (system architecture and KPIs), as well as its key functionalities. D1.3. is informed by the key gaps in technology or requirements of existing (or indeed proposed) standards and policies listed in this report (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 this deliverable as it constitutes a detailed analysis of technologies, policies and standards that will contribute to the design of each pilot solution.

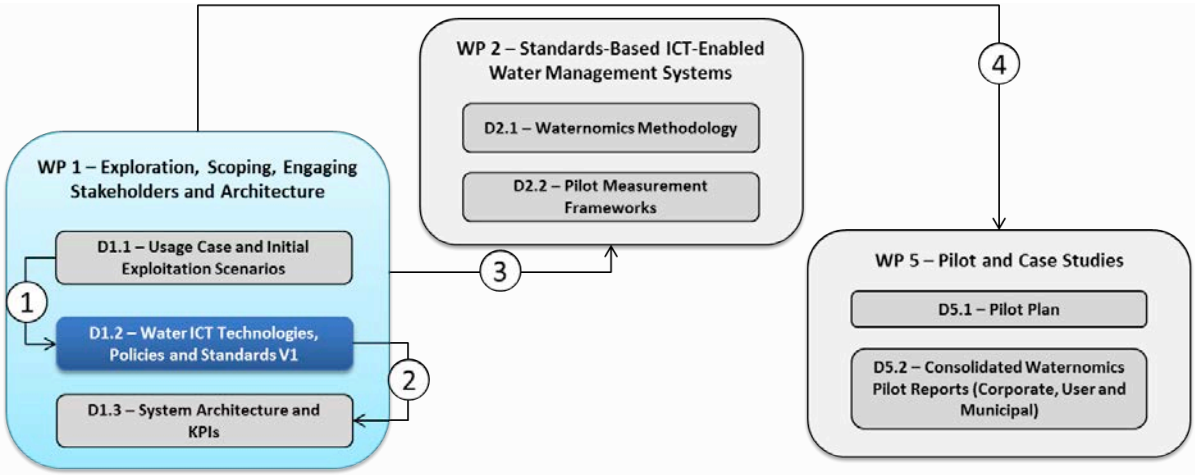



*Figure 1: Relationships between D1.2 and other activities in Waternomics*

## 1.4 Document Outline

This document is structured as follows: Chapter 2 includes an inventory of hardware technology, data, and software technology in the water sector that is relevant to Waternomics. The first section of Chapter 2 presents listings of sensors for flow measurement and leak detection, as well as existing technologies for data transmission. In the second section of Chapter 2 discusses the data platform for managing and processing heterogeneous real-time data. The third and last section of this chapter lists major groupings of software technology, including back and front-end web applications and mobile application development options. These three sections build up the technology inventory. Chapter 2 also elaborates on the advantages and disadvantages of each technology group.

In chapter 3 we elaborate on the importance of government-led policies and initiatives in the development and adoption of ICT technology and elaborate on how these policies have had or can have an effect. In chapter 4 we discuss standards and regulations that are required for the development of specific technology or guidelines that can be used to prototype and benchmark the final technology/platform. These include technical standards, EU regulations on water quality, management and certification standards, and privacy and data ownership policies.

# 2 Technology inventory

Measurement methods in a water network area the centre of the water supply cycle. Metering influences resource management, process control, planning of new works, distribution management, leak detection, financial control and environmental issues either directly or indirectly.

This chapter is organized in three sections:

- Water metering technologies
- Data platform
- Software technologies

## 2.1 Hardware

Under this section we describe technology groupings that are relevant for consideration in Waternomics. These groupings include mainly sensing and data transmission/power technologies applicable to the project. This section includes an overview of actuating and combined/smart technologies.

Technology clusters provide the basic characteristics of the each technology group along with advantages and disadvantages. Whenever relevant the document elaborates on specific factors that the project should consider in the use of specific technology in Waternomics. The consortium and future foreground end users can use this document as a resource to inform decisions on technologies available in the water sector.

The water metering section structure will follow the following scheme (Figure 2):

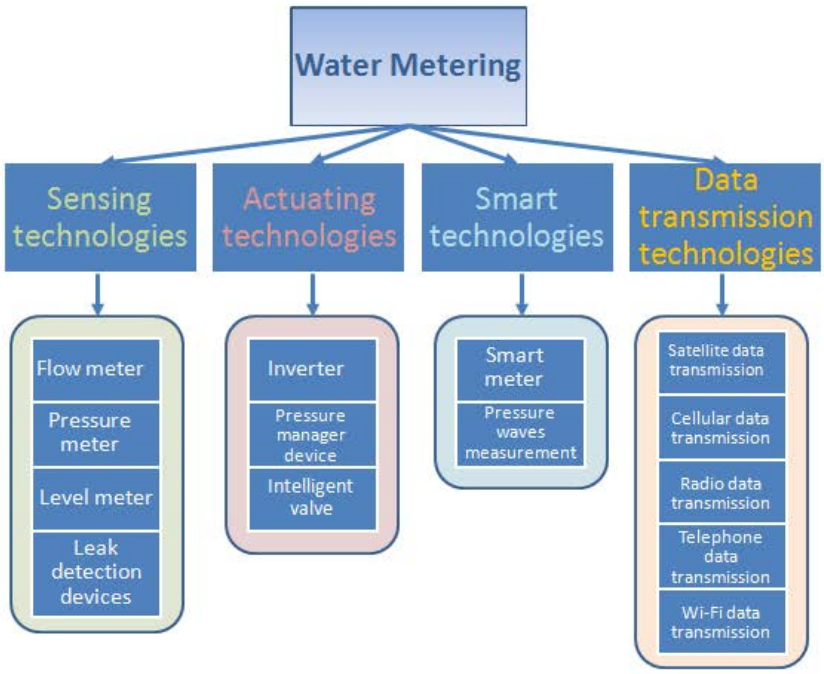



*Figure 2: Organizational scheme of the "Water metering" section* [1]

[1] The technologies that are directly applied to WATERNOMICS are developed in detail in this document. The technologies that the consortium has deemed necessary (ie. for their water saving potential) to document but not being currently applied to any of the WATERNOMICS pilots have been documented in the annex (ie. level meter or under sensing technologies or actuating technologies).

## 2.1.1 Sensing technologies

Under this section we describe key measurement techniques focused on flow, pressure measurement and leakage detection devices. These three elements are the information triggers that the Waternomics platform will collect and visualize to the user.

### 2.1.1.1 Flow measurement: existing methods

Most liquid flow measurement instruments determine the flow rate based on measurements of the liquid's velocity or the change in kinetic energy.

Many flow meters exist for closed-piping systems. In general, the equipment can be classified as;(i) differential pressure, (ii) positive displacement, (iii) velocity, and (iv) mass meters. The various technologies employed are summarised in Table 1.

*Table 1: Types of flow meters for closed-piping system*

| Differential Pressure | Positive displacement | Velocity | Mass |
|---|---|---|---|
| Orifice Plate | Piston Flow Meters | Electromagnetic | Thermal |
| Venturi Tube | Gear Flow Meters | Ultrasonic | Coriolis |
| Flow Nozzle | Helical Flow Meters | Turbine | |
| Segmental Wedge | Oval – Gear Meters | Paddle Wheel | |
| V-Cone | Rotary Vane Meters | Vortex | |
| Pitot Tube | Nutating Disk Meters | Target | |
| Averaging Pitot Tube | | Var. Area/Rotameter | |
| Elbow | | | |
| Dall Tube | | | |

All the technologies for flow meter listed in the Table 1 are suitable for water network with the only problem that they produce an important load loss in the water system. For this reason technologies like these listed below, even though they are valid in the water sector are not particularly suitable in some water systems like that of the airport of Linate where excessive load loss have to be avoided. In the following section we will explain in detail the velocity based method and later on the respective devices. For an extended explanation of other measurement techniques and respective devices please refer to Annex 1.

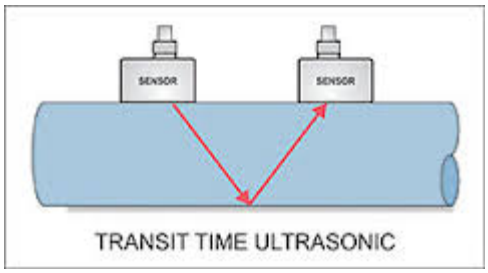
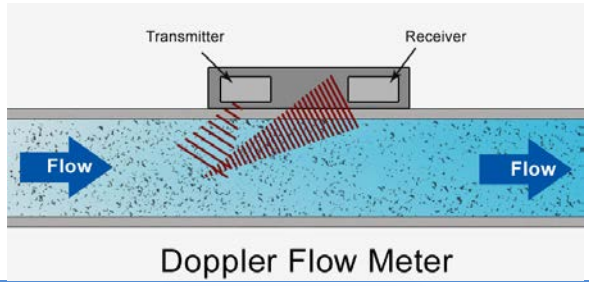
***Velocity based method***

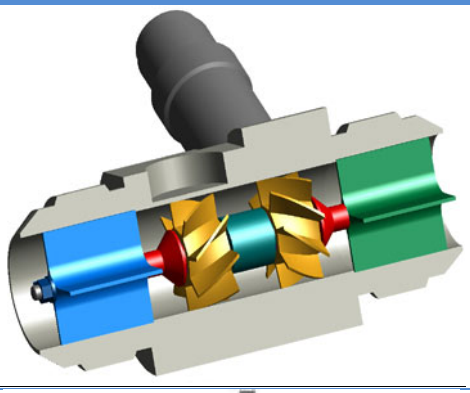
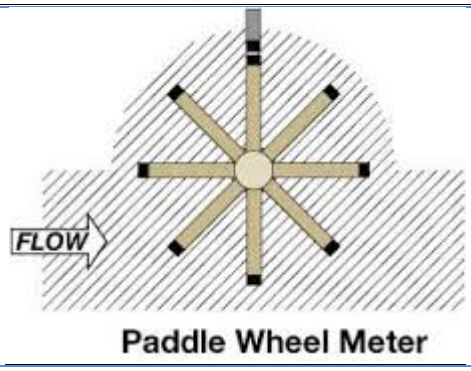
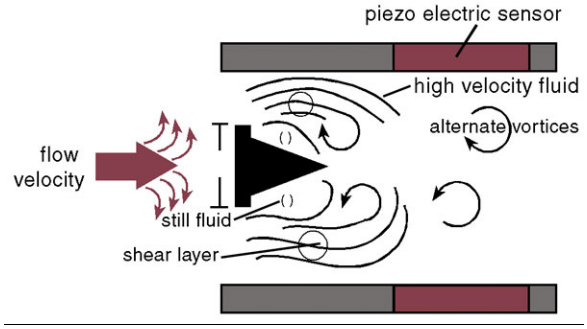
Often used in the water sector are Electromagnetic, Ultrasonic and Turbine flow meters. These have good accuracy, low maintenance, can perform repeatable measurements, and are reliable in demanding conditions. These sensors could be used in the WATERNOMICS pilots as well.

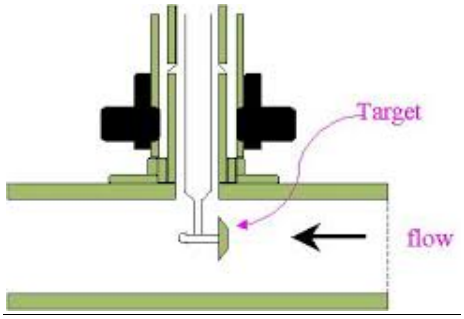
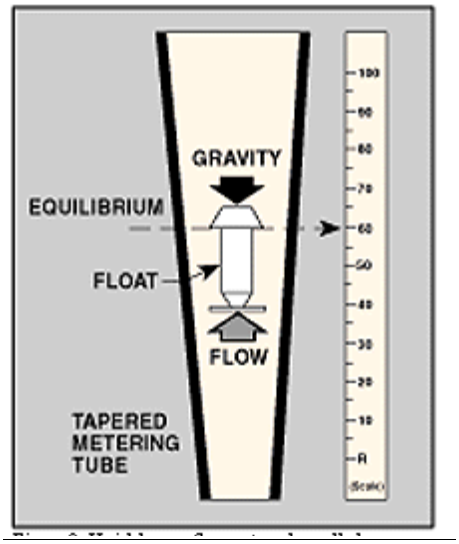
*Table 2 Metering to measure the flow in a closed piping system based on velocity method (adopted from www.greyline.com and www.flowmeters.com[2])*

| Figure | Description |
|---|---|

[2] http://www.greyline.com/twotechnologies.htm - accessed 20 October 2014
http://www.flowmeters.com/turbine-technology - accessed 20 October 2014

| | Figure | Description |
|---|---|---|
| **Ultrasonic flow meters** |  <br>  <br>  | Main types of ultrasonic flow meters: Doppler and transit time. Both utilize ultrasound to make measurements and can be non-invasive and they can measure flow using different methods.<br>Time of Flight Ultrasonic Flow meter: measurement of time travel of sound between the transmitter and the receiver. Two transmitters/receivers (transceivers) are located on each side of the pipe. The transmitters send ultrasonic from one side to the other. The average fluid velocity is calculated from the differences in proportional frequency<br>Doppler Effect Flow mete: measurement of particles in the fluid based on ultrasonic sound waves. The velocity is measured based on the ultrasonic source, the fluid carrier and the receiver. This method is not suitable for clear liquid as it is highly dependent of the properties of the fluid it can only be used for applications that do not require high accuracy. |
| **Electromagnetic Flow Meter** |  | Magnetic flow meters, often called "mag or electromag meters", use a magnetic field applied to the metering tube. The physical principle at work is Faraday's law of electromagnetic induction. The magnetic flow meter requires a conducting fluid and a non-conducting pipe liner. Magnetic flow Meters have no moving parts and are ideally used for measurement of dirty or corrosive liquids (electrically conductive). |
| **Turbine Flow Meter** | | Turbine flow meters calculate flows based on the rotations of the rotor placed inside a pipe. When fluid passess through the rotor it spins. This motion is picked up and generates electrical pulses. These pulses counted are directly |

| | Figure | Description |
|---|---|---|
| |  | proportional to the fluid flow. In ideal applications the flow must be constant and stable across the cross section. |
| **Paddle Wheel Flow Meter** |  Paddle Wheel Meter | The paddle wheel flow meter is a cost effective device typically used for water or water like fluid and operates under a similar principle than a turbine meter. The rotor of the paddlewheel sensor is perpendicular to the flow and contacts only a limited cross section of the flow. |
| **Vortex Flow Meter** |  | "Vortex meters make use of a natural phenomenon that occurs when a liquid flows around a bluff object. Eddies or vortices are shed alternately downstream of the object. The frequency of the vortex shedding is directly proportional to the velocity of the liquid flowing past the bluff object. The three necessary components of a vortex flow meter are a bluff body mounted in the flow meter bore, a sensor to detect the presence of the vortex and generate an electrical impulse, and a signal amplification circuit. The main advantages of vortex meters are their low sensitivity to variations in process conditions and low wear relative to orifices or turbine meters. Used in both gas and liquid applications, Vortex flow meters are used abundantly in steam measurement application (description as presented in: http://www.maxmachinery.com/what-is-a-flow-meter/vortex-flow-meter - accessed January 2015) |

| | Figure | Description |
|---|---|---|
| **Target Flow Meter** |  | "Target meters sense and measure forces caused by liquid impacting on a target or disk suspended in the liquid stream. A direct indication of the liquid flow rate is achieved by measuring the force exerted on the target. In its simplest form, the meter consists only of a hinged, swinging plate that moves outward, along with the liquid stream. In such cases, the device serves as a flow indicator. More sophisticated versions use a precision, low-level force transducer sensing element. The force on the target caused by the liquid flow is sensed by a strain gage. Target meters are useful for measuring flows of dirty or corrosive liquids.' (description as presented in http://www.omega.nl/techref/flowcontrol.html - accessed January 2015) |
| **Variable Area Flow Meter or Rotameter** |  | 'The variable area flow meter consists of a vertically oriented glass (or plastic) tapered tube with a larger inside diameter at the top, and a metering float which is free to move within the tube. Fluid flow causes the float to rise in the tube as the upward pressure differential and buoyancy of the fluid overcome the effect of gravity. The float rises to a level where the area between the float and tube reach a state of dynamic equilibrium between the upward differential pressure and buoyancy factors, and downward gravity force. The height of the float is an indication of the flow rate. The tube can be calibrated and graduated in appropriate flow units.' (description as presented in http://www.maxmachinery.com/what-is-a-flow-meter/variable-area-flow-meter-or-rotameter - accessed January 2015) |

For example Ultrasonic flow meters, are suitable in water network in which is not allowed to interrupt the water flow and for this reason these sensors are very simple to install. This is the case of Linate Pilot. While electromagnetic flow meter and turbine flow meters require the flow interruption and for this reason their installation is more complex and require the help of a specialized worker. Ultrasonic flow meter and electromagnetic flow meter could be suitable to be installed in all the three pilot site of the WATERNOMICS project.

The turbine flow meter has potential use for WATERNOMICS as well. From discussions held with water utilities this sensor is widely use. The project is currently testing it in laboratory conditions and it will be installed in all the three pilot areas to obtain the users (domestic, scholars and commercial users) water consumption.

*Table 3: Field of application, maintenance and costs for velocity based method flow meter*

| | Field of application | Maintenance | Purchase Cost range |
|---|---|---|---|
| **Electromagnetic flow meter** | measure flow rates in pipes, when the fluid is water or other conductive fluid | low | € 400 – 1000 depending on the size of the pipes |
| **Ultrasonic flow meter** | This method is widely used to measure flow rates in pipes, when the fluid is water, oil of other fluids. | low | € 100 – 5000 depending on the size of the pipes |
| **Turbine flow meter** | This method is widely used to measure flow rates in pipes, when the fluid is water or gas | low | € 100 – 5000 depending on the size of the pipes |
| **Paddle wheel flow meter** | The paddle wheel flow meter is used for pure water applications | low | € 100 – 5000 depending on the size of the pipes |
| **Vortex flow meter** | The vortex flow meter is used for liquids, gas applications | low | € 100 – 4000 depending on the size of the pipes |
| **Target flow meter** | The target flow meter is used for corrosive liquids, gas and water applications | low | € 200 – 3500 depending on the size of the pipes |
| **Variable area flow meter** | The variable area flow meter is used for air and water applications | low | € 200 – 1500 depending on the size of the pipes |

### 2.1.1.2 Flow measurement: most used methods in water (supply)

On the basis of the various measurement techniques described above, in the case of monitoring of water networks, the equipment used must meet the following requirements:

1) robustness, reliability and therefore reduced maintenance;
2) electrical output signal for remote control;
3) wide range of applicability on pipes of different diameters;
4) bi-directionality;
5) small concentrated pressure drops

The main flow meters that have these characteristics are of the type[3]:

- electromagnetic meter (Mag meter)
- ultrasonic meter

Both of these meters are electronic in nature and do not induce additional pressure drops. This is because they do not have moving parts and fluid interactions between parts of the sensor and the fluid do not occur.

Another flow meter most used to account users water consumption is the turbine flow meter. It is installed upstream of the users to be monitored and also if it produce a load loss in the local water network it is definitely one of the methods of measurement and accounting most appropriate in water sector.

For the reasons listed above these typologies of flow meters could be suitable for all WATERNOMICS pilot areas, for example ultrasonic flow meter could be installed in Linate pilot, NUIG pilot and Thermi pilot where is needed to measure he flow meter without any flow interruptions. The same we can say about installing electromagnetic flow meters or the turbine

[3] "Ricerca e controllo delle perdite nelle reti di condotte" – B. Brunone et all (Città Studi editore)

flow meters. These last two technologies are suitable whenever we want to measure the water flow for domestic users (Thermi pilot), public users (NUIG pilot) or shops, restaurants and employees in a commercial setting (Linate pilot).

In the following section detailed information are given for the most suitable technologies for WATERNOMICS and a comparative table between ultrasonic, electromagnetic and turbine flow meters methods for water networks is provided.

#### 2.1.1.2.1 *Ultrasonic flow meter*[4]

Ultrasonic flow meters are suitable and commonly utilized because of: clear flow path, low pressure drop, corrosion resistance, and efficient power use (relative to Magnetic flow meters). These meters offer a normal accuracy of about 1%.

Ultrasonic flow meters require high frequency sound to be transmitted across the pipe for reliable recordings. Ultrasonic flow meters are suitable for potable water networks.[5]

*Table 4:Characteristics of ultrasonic flow meter*

| Characteristics ofultrasonicflow meters[6] | |
|---|---|
| Thermo physical properties of the measurement fluid | Max Temperature: 25°C<br>Max Pressure: 20 MPa<br>Max cinematicviscosity: none |
| Fluid dynamic parameters | Minimum number of Reynolds: $10^4$<br>Load Loss: none |
| Metrological performance | Accuracy: ±[1,0 – 2,0]%<br>Repeatability: ± 0,25%<br>Measuring range: > 20:1 |
| System and installation prescriptions | Upstream pipe straight sections: N = 20 (the length is expressed in N = number of diameters)<br>Easy installation |
| Costs | Purchase costs: medium<br>Installation costs: low<br>Operating costs: low<br>Maintenance costs: low |
| **Advantages** | **Disadvantages** |
| Non intrusive measurement | The measurement fluid must be clear |
| Wide range of measurement | Not suitable for fluidwithhigh temperatures |
| Purchase cost independent of the size of the pipes | Configuration with external transducers require periodic calibration |
| Easy installation | Require straight sections upstream and downstream piping, respectively N=20 time diameter upstream and N=5 times diameter downstream |
| Bidirectional flow measurement | |

This typology of flow meter could be very interesting for installation in WATERNOMICS pilots water networks because they are characterized by an easy installation, medium purchase cost and low maintenance costs. In addition this kind of technology allow to make a flow measurement without interruption of water flow and so users' problems are avoided and in addition, generally these meters are clamp-on meters and they are suitable to be moved around the water network to monitor water consumption.

[4] Refer to Annex 2 for specific producer sensor data overview

5 Transactions in measurement and control. A technical reference. vol. 4. Omega Engineering . serieshttp://www.omega.com/literature/transactions/transactions_vol_iv.pdf - accessed 02 March 2015

[6] "Ricerca e controllo delle perdite nelle reti di condotte" – B. Brunone et all (Città Studi editore)

#### 2.1.1.2.2 Electromagnetic flow meter (Mag meter)

Magnetic flow maters can be in-line or insertion systems, have no moving parts and are suitable for water and wastewater applications. Mag meters operate on Faraday's law of electromagnetic induction (which means tha the voltage is induced/calculated when a conductor moves through a magnetic field). Electromagnetic flow meters can only be used for electrically conductive fluids, being water then a perfect use for these meters (as long as it is not purified (de-ionized).

Electromagnetic flow meters are suitable for measuring corrosive liquids and slurries with a low pressure drop. Flow measurement accuracies range between 0.2 and 1%. Meters that need to be installed cost between € 400 to €1000 depending on pipe-diamter[7].

*Table 5: Characteristics of Mag meter*

| Characteristics of Mag meters[8] | |
|---|---|
| Thermo physical properties of the measurement fluid | Max Temperature: 200°C<br>Max Pressure: 20 MPa<br>Max cinematicviscosity: none |
| Fluid dynamic parameters | Minimum number of Reynolds: none<br>Load Loss: none |
| Metrological performance | Accuracy: ±[0,2 – 1,0]%<br>Repeatability: ± [0,10 - 0,25]%<br>Measuring range: > 20:1 |
| System and installation prescriptions | Upstream/downstream pipe straight sections: N=5 time diameter upstream and N=2 times diameter downstream<br>Easy installation |
| Costs | Purchase costs (depending on size of the pipes): low<br>Installation costs: low<br>Operating costs: low<br>Maintenance costs: low |
| **Advantages** | **Disadvantages** |
| Fixed measuring device | The measurement fluid must be conductive (1µS/cm) |
| | Intrusive measurement |
| | High cost particularly for large diameter pipes (D>500 mm) |
| Suitable for wastewater, corrosive fluid | Configuration requires periodic calibration |
| No load loss | Not suitable for fluid with high temperatures |
| Measurement independent of the flow regime | Not suitable for gas or less conductive fluids |

Also this typology of flow meter could be very interesting for installation in WATERNOMICS pilots water networks because they are characterized a low purchase cost and a low maintenance costs. In addition this kind of technology also if it is an intrusive technology, the installation requires the temporary interruption of the water flow, allow to make a flow measurement with a great accuracy. For example, the electromagnetic flow meters can be installed to monitor the fixture water consumption for domestic users (Thermi pilot), scholar users (NUIG pilot) or for shops and restaurants (Linate pilot).

[7] Transactions in measurement and control. A technical reference. vol. 4. Omega Engineering . serieshttp://www.omega.com/literature/transactions/transactions_vol_iv.pdf - accessed 02 March 2015

[8] See: “Ricerca e controllo delle perdite nelle reti di condotte” – B. Brunone et all (Città Studi editore)

#### 2.1.1.2.3 Turbine flow meter

The modern axial turbine flowmeter is a reliable device capable, when properly installed and calibrated, of providing the highest accuracies possible among available. Today's product is an impovement of an axial vaned flowmeter (Woltman in 1790) usually applied for the measurement of water flows[9].

*Table 6: Characteristics of Turbine flowmeters*

| Characteristics of turbine flowmeters[10] | |
|---|---|
| Thermo physical properties of the measurement fluid | Max Temperature: 270°C – 650°C |
| Fluid dynamic parameters | Load Loss: 0.3 kPa (0.05 psi) for gases to in the region of 70 kPa (10 psi) for liquids |
| Metrological performance | Accuracy: ±0,15%<br>Repeatability: ± [0,10 - 0,25]%<br>Measuring range: 10:1 – 100:1 |
| System and installation prescriptions | Upstream/downstream pipe straight sections are necessary<br>Installation requires the help of a specialized worker |
| Costs | Purchase costs (depending on size of the pipes): medium<br>Installation costs: medium<br>Operating costs: low<br>Maintenance costs: low |
| **Advantages** | **Disadvantages** |
| High accuracy | The installation isn't simple and require upstream and downstera straight pipes |
| | Intrusive measurement |
| | High cost particularly for large diameter pipes (D>500 mm) |
| Suitable for wastewater, corrosive fluid | Configuration requires periodic calibration |
| No load loss | Not suitable for fluid with high temperatures |
| Measurement independent of the flow regime | Not suitable for gas or less conductive fluids |

This last technology is suitable whenever we want to measure the water flow for domestic users (Thermi pilot), public users (NUIG pilot) or shops, restaurants and employees in a commercial setting (Linate pilot).

The following table gives a comparison between the flow measurement methods listed above.

*Table 7: Comparison table between mag meter, turbine flow meter an dultrasonic flow meter*

| | Mag meter (Electromagnetic meter) | Turbine flow meter | Ultrasonic flow meter |
|---|---|---|---|
| **Key features** | - Measuring Principle: Faraday's law of induction<br>- Output: voltage is proportional to flow rate | - Measuring Principle: velocity of fluid<br>- Output: flow is proportional to flow velocity | - Measuring principle: Transit-time difference/Doppler |
| **Advantages** | - No moving parts<br>- Suitable for dta transfer | - High accuracy<br>- Handle with pure fluid<br>- Suitable for dta transfer | - Non-intrusive<br>- Easy installation<br>- No leakage potential<br>- Handle with pure liquid<br>- Suitable for dta |

[9] Sourced from http://sensors-research.com/articles/turbines.htm
[10] http://sensors-research.com/articles/turbines.htm

| | | | |
|---|---|---|---|
| | | | transfer |
| **Disadvantages/Cautions** | - Invasive to pipe<br>- Pipe needs to be grounded<br>- Fluid needs to be conductive<br>- Time-costing installation | - Invasive to pipe<br>- Pipe needs to be grounded<br>- Time-costing installation | - Suffering from pipe wall interference<br>- Signals may influenced by the purity or bubbles of the liquid |

From the comparison in Table 13 it becomes clear that the ultrasonic flow meter is appropriate in cases in which you do not want to have excessive pressure drop in the water network as it is a non-invasive method of measuring and also it is a useful method for measuring water flows as it is a conductive and clear fluid. The installation of Mag meter systems and turbine flowmeters requires the interruption of flow in the water network but based on what said above the two technologies might be appropriate for the purposes of WATERNOMICS project of developing an ICT water metering system to increase awareness of end users about their water consumption, this is possible also because the two technologies described above are suitable to be connected with a system data transfer and so he installation of these flow meters is particularly important to provide the water consumption data for WATERNOMICS platform.

#### 2.1.1.3 Flow measurement for open channel system: the case of sewage discharge

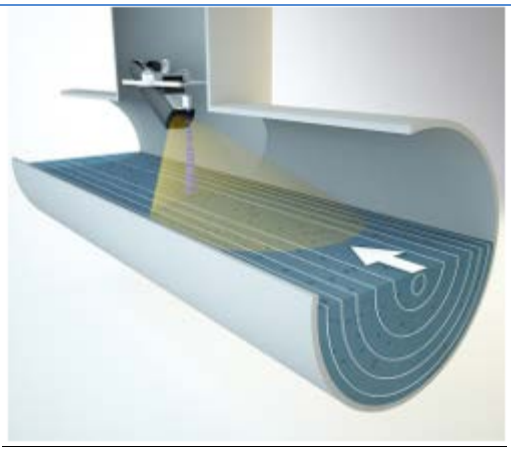
One of the “economic imperative” of WATERNOMICS project, with particular regard to LINATE Airport is: “Reduce wastewater tariffs” (see DOW page 55) this target is achievable through the full control on the water network meaning by this: an accurate knowledge of the water network, reduction of water leakages, a systematic monitoring of wastewater discharge points. Only doing this we can think to reduce wastewater tariffs. Moreover the measuring of wastewater discharge points for Linate pilot is relevant because it can help to assess water balance of the Linate airport In the case of sewage points where open channel flow is encountered it is unlikely any system that impedes flow can be used and thus is the needed of flow meter sensors for open channels.

In these cases it may not be advisable to use traditional measure methods like weirs or flumes. The optimal measurement device could be the following:

- submersible ultrasonic flow sensor (e.g. Mainstream);
- Installation of a non-contact flowmeter (e.g. Raven Eye).

The technologies listed above are provided in the following table:

*Table 8: Methodologies to measure flow rate in open channel*[11]

| | Figures | Description |
|---|---|---|
| **Mainstream** |   | The ultrasonic sensor, according to a pre-set geometry of the collector measures the fluid level, the speed and the wet area. Multiplying the speed by the wet cross sectional area gives the flow rate [m³ / h]. The sensor transmits ultrasonic signals in the fluid in order to create a wide area measurement and control. The particles and air bubbles suspended in the fluid in the control area reflect the ultrasonic signal that is detected by the sensor. The signals are processed to determine the following quantities: velocity of the fluid, level and the wet surface and subsequently flow in transit. |
| **Raven Eye** |  | The sensor, installed above the flow channel, creates a microwave beam above the surface of the fluid at the center of the channel. Level measurement is provided by installing a Radar/ultrasonic sensor, Speed measurement is provided by installing a Radar sensor. The sensor measures the surface velocity of the moving fluid by determining the displacement of the frequencies between the frequency of transmission and the frequency of the reflected signal from the surface. The measured velocity at the surface is then converted into average velocity of the hydraulic fluid. To obtain a flow measurement it is necessary to join the level parameter of the flow to that of the speed. It's possible to |

[11] Description as presented in http://www.dnk-water.com/en/product/flow-measurement/ultrasonic-flow-meters/open-channel-flow-meters/doppler-flow-meter - accessed October 2014 and Raven Eye technical data sheet

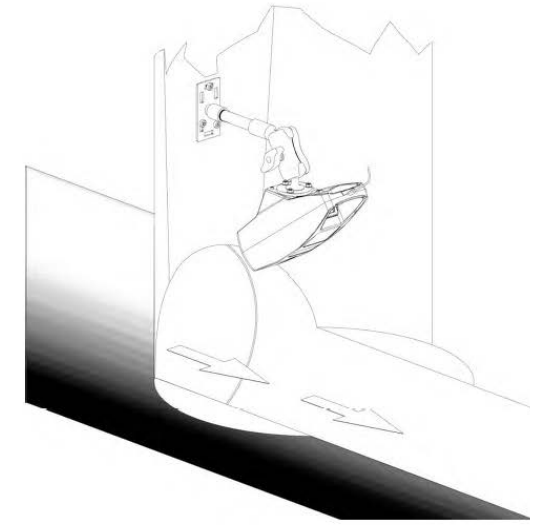


Figure 7: Wall installation

transmit GPRS data to a website.

The following table provide a comparison between the technologies listed above.

*Table 9: Comparison table between open channel flow rate measurement technologies*

| | Mainstream | Raven Eye |
|---|---|---|
| **Installation** | simple | simple |
| **Interrupt flow** | no | no |
| **Construction works** | no | no |
| **Accuracy of measurement** | high | high |
| **Maintenance** | minimum | no |
| **Cost** | € 10.000 | € 15.000 |
| **Suitability** |  |  |

In the context of WATERNOMICS and with particular regard to Linate pilot where there is the real opportunity for fitting and piloting of full range of WATERNOMICS technologies, it is clear the necessity to install flow meters for wastewater discharge points. The installation of metering devices, especially in a corporate pilots like SEA (the airport operator), has some principal words to define the overall target: “operation costs”. It is unthinkable to make a choice without taking into account the resulting operational costs and benefits expected, for this reason the choice of the appropriate flow measurement method is turned towards a non-contact sensor that may be more suitable, instead of a contact sensor, as they do not have submersible components and will likely need minimal maintenance.

### 2.1.1.4 Pressure measurement: existing methods

Pressure is defined as force per unit area that a fluid exerts on its surroundings. It is possible to measure this force by detecting the amount of deflection on a diaphragm positioned in line with the fluid. Given the known area of the diaphragm, pressure can then be calculated. Pressure sensors are packaged with a scale that provides a method to convert to engineering units. The SI unit for pressure is the Pascal (N/m2), but other common units of pressure include psi, atmospheres, bars, inches of mercury, millimetres of mercury, and torr.

There are three methods for measuring pressure;(i) absolute, (ii) gauge, and (iii) differential (Figure 3). Absolute pressure is referenced to the pressure in a vacuum, whereas gauge and

differential pressures are referenced to another pressure such as the ambient atmospheric pressure or pressure in an adjacent vessel. (http://www.ni.com/white-paper/13034/en/)

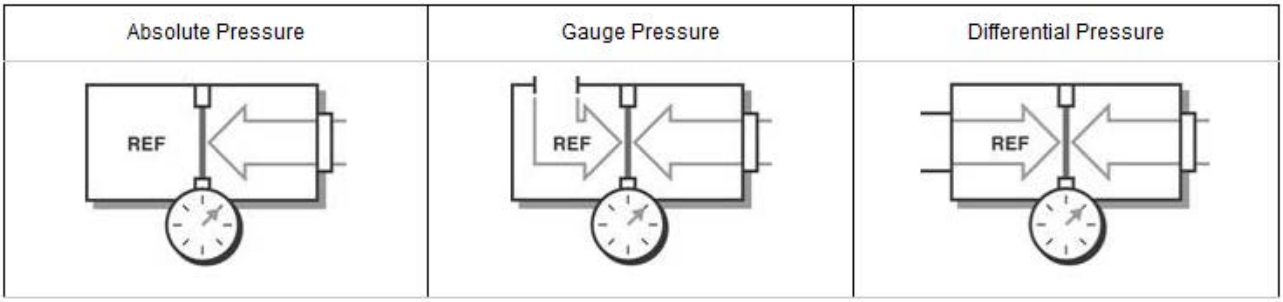



*Figure 3:* Pressure Sensor Diagrams for Different Measurement Methods. For reference pressure in each case *http://www.ni.com/white-paper/13034/en/.*

### Absolute Pressure

Absolute preasure measurement can be well used for atmospheric pressure, e.g. in altimeters or vacuum pressures[12].

### Gauge Pressure

Gauge and differential pressure measurement measure relative to a chosen reference pressure, e.g. atmospheric pressure. In this way the effect of the dynamic reference pressure is excluded. Example applications are tire pressure and blood pressure measurements.

### Differential Pressure

Differential pressure measurement is similar to gauge pressure; however, the reference is another pressure point in the system rather than ambient pressure. Common pressure sensor types include[13]:

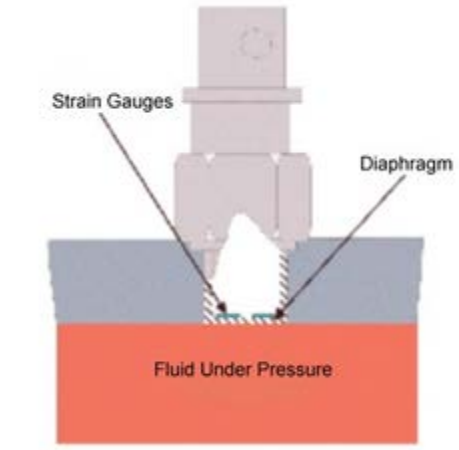
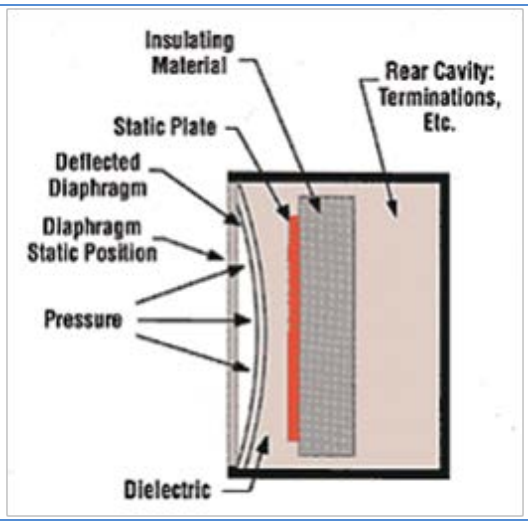
- Wheatstone bridge-based sensors,
- Capacitive sensors,
- Piezoelectric sensors.

Generally pressure sensors have an elastic element installed inside. The deformation of this elastic element under the action of the water pressure provides the pressure measurement signal. So the pressure is measured by converting the physical phenomenon to an intermediate form, such as displacement, which can be measured by a transducer. (www.ni.com/white-paper/13034/en/)

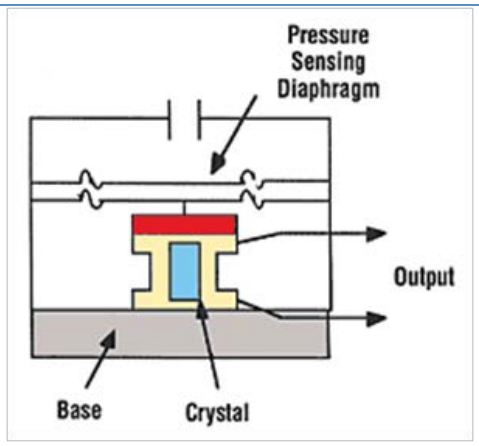
[12] http://www.ni.com/white-paper/13034/en/ - accessed 02 March 2015

[13] http://www.ni.com/white-paper/13034/en/ - accessed 02 March 2015

*Table 10: Common pressure sensors*[14]

| | Figures | Description |
|---|---|---|
| **Wheatstone bridge based sensors** |  | Bridge-or strain-based transducers are a common way of measuring displacement. Sensors using this type of design meet a variety of requirements such as accuracy, size, cost, and ruggedness. Bridge sensors are used for high- and low-pressure applications, and can measure absolute, gauge, or differential pressure. Bridge-based sensors use a strain gage to detect the deformity of a diaphragm subjected to the applied pressure. These strain gauge pressure transducers come in several different varieties: the bonded strain gauge, the sputtered strain gauge, and the semiconductor strain gauge. (description as presented in http://archives.sensorsmag.com/articles/0499/0499_36/ and http://www.ni.com/white-paper/13034/en - accessed December 2014) |
| **Capacitive Pressure Sensors** |  | A variable capacitance pressure transducer measures the change in capacitance between a metal diaphragm and a fixed metal plate. The capacitance between two metals plates changes if the distance between these two plates changes due to applied pressure. (description as presented in http://www.ni.com/white-paper/13034/en - accessed December 2014) |

[14] http://www.ni.com/white-paper/13034/en/. – accessed December 2014

| | | |
|---|---|---|
| **Piezoelectric Pressure Sensors** |  | Piezoelectric sensors rely on quartz crystals rather than a resistive bridge transducer. Electrodes transfer charge from the crystals to an amplifier built into the sensor. These crystals generate an electrical charge when they are strained. Piezoelectric pressure sensors do not require an external excitation source and are very rugged. The sensors, however, do require charge amplification circuitry and are very susceptible to shock and vibration. (description as presented in http://www.ni.com/white-paper/13034/en - accessed December 2014) |

In the context of Waternomics project and with particular regard to Linate pilot, in which we have the opportunity for piloting of the full range of Waternomics technologies and also we have the opportunity to examine a complete water network starting from abstraction wells to the discharge points, It is necessary to have installed in the water network pressure meters to develop a rational network pressure control to achieve the objectives of leakage reductions and pumps energy savings. To do this the choice of the pressure meter is turned towards a wheatstone bridge based sensor (piezoresistive sensor). This technology provides installation simplicity, low cost and excellent precision in the measurement.

The following table summarises the advantages and disadvantages of the pressure sensors described above.

*Table 11: Characteristics of Wheatstone bridge based sensors*

| Wheatstone bridge based sensors[15] | | |
|---|---|---|
| **Type** | **ADVANTAGES** | **DISADVANTAGES** |
| Bonded strain gauge | Good precision<br>Good thermal compensation<br>Good long-term stability | Limitedoperating temperaturedue to the useofglue |
| Sputtered strain gauge | High precision<br>Good thermal compensation<br>High long-term stability | Limitedresistanceto overvoltage |
| Semiconductor strain gauge | High precision<br>Excellent output signal<br>Small size | Limitedoperating temperaturedue to thermal drift |

*Table 12:Characteristics of capacitive pressure sensors*

| Capacitive Pressure Sensors[16] | |
|---|---|
| **ADVANTAGES** | **DISADVANTAGES** |
| Excellent precision | Alternating current supply |
| High resolution | |

[15]http://www.ni.com/white-paper/13034/en/ - accessed January 2015
[16]http://www.ni.com/white-paper/13034/en/ - accessed January 2015

| | |
|---|---|
| Low hysteresis | Sensitivity to temperature |
| Good frequency response | |

*Table 13:Characteristics of piezoelectric pressure sensors*

| Piezoelectric Pressure Sensors[17] | |
|---|---|
| **ADVANTAGES** | **DISADVANTAGES** |
| Low cost | Not measure static pressure |
| High sensitivity | |
| No external power | Output affected by changes in temperature |
| Good high – frequency response | |

The choice of pressure sensor used in the water sector will depend on the specific application. Generally it is preferable to use electric type pressure sensors because they allow for data logging and remote access to measure data, and thus particularly suitable for use in water network monitoring systems. For Waternomics targets to develop a system data transfer with all measured data needs to be captured and transferred for users to be able to make water consumption related decisions.

In many installations it is imperative that there is no disruption to water supply and insertion type sensors are often chosen in these circumstances, it is the real case of Linate pilot. Such installations are known as “taking charge” installations. They also enable the device to be extracted from the pipe without any disruption where a specialised insertion seal is installed.

There are other devices that can be associated with water savings. For example, sensors that measure the level of water in a tank can be related to fault detection or used for problem diagnostic. Detecting fault the earliest possible stage can lead to savings in maintenance and repairs. Because these devices will not be used directly in Waternomics they are not in detail explained in this text. However, we provide additional information on level measurements in Annex 3 as these devices may be considered at a later stage (WP 4).

### 2.1.1.5 Leak detection devices

New bursts and leaks occur as a combination of a general condition of the infrastructure and pressure management. Leak location practices and techniques have advanced rapidly in the last few years, with the result that leakage awareness and detection times have been reduced and repairs are carried out more quickly to minimise water loss and hindrance to customers.[18]

**Advanced leak detection techniques**

Many advancements have been made in leakage detection instruments and techniques. The new method for water leak detection to be developed in Waternomics is based on collecting and analyzing sound signals in the household plumbing system. Household water fixtures and appliances produce sound signals when in use. Recording, pre-processing and creating libraries of sound signals generated from household water fixtures will help to distinguish between normal operational conditions and abnormal conditions that would indicate a leak.

#### *2.1.1.5.1 Microphones:*

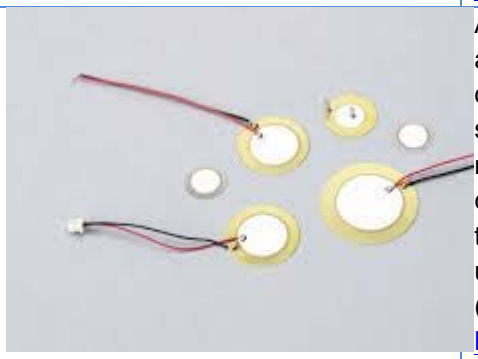
There are a number of criteria which needs to be taken in to account in selection of the appropriate type of microphones for collecting sound signals for leak detection. The main

[17] See: http://academic.udayton.edu/markpatterson/ECT459/Piezoelectric%20and%20PiezoSensors.pdf – accessed Jenuary 2015 and “Industrial instrumentations and control” Mc-Graw Hill

[18] Leak detection practices: a practical approach. IWA Water Loss Task Force. http://www.iwapublishing.com/pdf/ACF1B18.pdf / accessed January 2015

criteria being that the microphone needs to be low coat, easy to install and capable of sensing low intensity of signals normally generated in household plumping systems.

*Table 14: Common microphones for sound detection*

| | Figures | Description |
|---|---|---|
| **Electret microphone** |  | The electret condenser mic uses a special type of capacitor which has a permanent voltage built in during manufacture. This is somewhat like a permanent magnet, in that it doesn't require any external power for operation. However good electret condenser mics usually include a pre-amplifier which does still require power. Application: Electret materials have been known since the 1920s and were proposed as condenser microphone elements several times, but they were considered impractical until the foil electret type was invented at Bell Laboratories in 1962 by Gerhard Sesslerand James West, using a thin metallized Teflon foil. Advantage of these mics is that they do not need an external Voltage however they are not designed detect contact vibrations. (description as presented in http://en.wikipedia.org/wiki/Electret_microphone - accessed January 2015) |
| **Piezo sensors** |  | A contact microphone, otherwise known as a pickup or a piezo, is a form of microphone designed to sense audio vibrations through solid objects. Unlike normal air microphones, contact mics are almost completely insensitive to air vibrations but transduce only structure-borne sound. Often used as acoustic leakage probes. (description as presented in http://en.wikipedia.org/wiki/Electret_microphone - accessed January 2015) |
| **Clip-On Contact Microphone** |  | The CM-200 is a contact microphone that is normally used with musical instruments (brass instrument, a violin a guitar, etc). The microphone uses a piezo element to directly capture the vibrations and send them to tuner. An advantage of these mics is that they can fit to different sizes of pipes. |

Audio sensors or Microphones will be used to collect sound signals generated from household

water piping system. Sound sensors are relatively cheap and easy to install than flow and pressure sensors and provide opportunity to develop low-cost non-intrusive technique of detecting leakage. Using sound sensors, it is possible to generate time series data which can be analysed to generate useful information to detect leakage.

The type of microphones considered for collecting sound signals for leakage detection and their advantage and disadvantage are presented below.

#### 2.1.1.6 Actuating Devices

In water sector great importance is given to a group of water network control technologies that is named Actuating Devices (AD). These AD can be coupled with systems thath allow detection of things such as signals/alarms (e.g. lack of communication with the centre, a power failure, intrusion, tampering with the device), commands (e.g. congruence and validation command, preparation and availability in local-remote-automatic mode), control of 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: start and stop pumps. When coupled with an automation system, it is possible to control in a continuous manner the operating status and efficiency of the system and its components and reporting timely and recording any anomalies in the process and equipment. They also support the management of off-line information (collection, processing and data storage), using and sending the information to processing centres for spatial planning and they allow a control at distance control. These devices are not going to be installed in all pilots (with the exception of Linate) so we will not elaborate further on these. However, we include an overview of these devices in Annex 4.

### 2.1.2 Smart water sensor technologies

Any device that collects and transmits real-time data can be classified as a smart device. In a smart grid system parameters (such as flow and pressure) would be collected, stored, and transmitted to a computer by the meter itself. The advantages of smart water meters include[19]:

- ease of use in meter shafts and moist environments where data transmission prevents manual data readings.
- they may be more accurate due to the use of ultrasonic or other technologies
- several kinds of wireless remote reading: automatic and integrated in a radio network
- electronic display with that can display information about irregularities


[19] Moving Towards Sustainable and Resilient Smart Water Grids: networked sensing and control devices in the urban water system. Michele Mutchek. MSc Thesis. December 2012. Arizona State University.

| Smart water meters[20](ZENNER - technical details) | Smart water meters[21] |
|---|---|

*Figure 4: Examples of smart water meter*

The smart technology listed above could be very interesting for installation in pilots where the users' fixtures water consumption is needed. So it can be interesting to measure the water consumption of domestic, scholars and shops/restaurants users.

'An additional emerging smart technology that is an alternative to installing additional flow meters is to use a device that measures pressure waves. Each water fixture has a pressure that propagates through the piping system, and a sensitive pressure-gauge can distinguish between these signatures. One such measurement system is the HydroSense[22] technology which only needs only one sensor to determine the disaggregated use of all fixtures (e.g., faucets, toilets, and dishwashers) in a single family home. If a fixture starts to leak, the end-use sensing device will pick up this flow as "noise" in the system. For larger end-users, multiple smart meters and end-use sensing devices would be more appropriate. The key point is that a combined flow meter and pressure sensor system requires fewer devices, thus substantially reducing costs'[23].

The following figure taken from the Hydrosense webpage shows the working principles of the pressure wave measurement approach. Also this last technology could be interesting for WATERNOMICS purposes relate to water consumption at users level, water network control and fault detection and diagnosis.

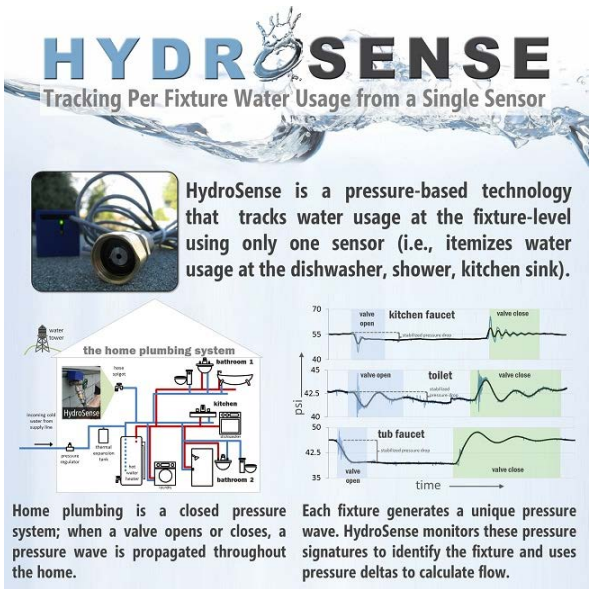



*Figure 5: HydroSense[24] technology*

[20] http://www.multical21.it/it/il-contatore-dacqua-intelligente.aspx - accessed October 2014
[21] http://www.multical21.it/it/il-contatore-dacqua-intelligente.aspx - accessed October 2014
[22] HydroSense: Infrastructure-Mediated Single-Point Sensing of Whole-Home Water Activity" J. Froelich, E. Larson etall. - http://dub.washington.edu/djangosite/media/papers/tmpXLm_Hi.pdf - accessed October 2014. Even though these technology was developed as a research project the use of it has been extended. the UW (University of Washington) TechTransfer office negotiated a licensing deal, and the HydroSense technology was acquired as part of a larger energy portfolio by Belkin International. So the technology went from being a research idea to being bought by a major international company that has the resources to commercialize HydroSense on a massive scale. (http://depts.washington.edu/foster/2009-grand-prize-winner-hydrosense-is-acquired-by-belkin-international/)
[23] Moving Towards Sustainable and Resilient Smart Water Grids: networked sensing and control devices in the urban water system. Michele Mutchek. MSc Thesis. December 2012. Arizona State University
[24] "HydroSense: Infrastructure-Mediated Single-Point Sensing of Whole-Home Water Activity" J. Froelich, E. Larson et all.- http://dub.washington.edu/djangosite/media/papers/tmpXLm_Hi.pdf - accessed October 2014

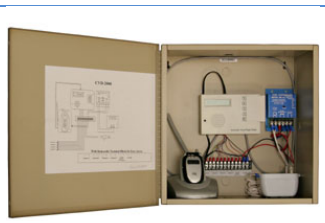
### 2.1.3 Data Transmission and Power[25]

After data collection, and/or local storage temporarily, data needs to be transmitted to a centralized location for further analysis, alerting, and archiving. Direct line transmission has the benefit of having no practical limitations to bandwidth, but in many cases it may not be possible to hardwire the sensor network. Using broadband from water customers to transmit data to the utility is also often not preferred because it would make the utility dependent on the customers.

Technical and legal limitations to the above mentioned methods make wireless data transmission an attractive approach. A variety of wireless technologies and protocols can be used depending on the requirements of the particular system, utility and end users. This includes mobile broadband, wireless broadband (Wi-Fi), personal area networks (device-to-device transmission), and satellite communication.

Things that need to be taken into consideration when developing these systems are: regularity in spacing of smart meters (to boost reach), availability of a wireless protocol specifically designed to capture the meter signals, availability and connectivity to power sources for the devices. Data transmission technologies are presented below.

*Table 15: System data transmission systems (description as presented in http://www.globalw.com/support/remote.html - accessed January 2015)*

| | Figure | Description |
|---|---|---|
| **Satellite data transmission** |  | The satellite data transmission method was designed for remote water monitoring systems in areas where power is not available, there are no telephone lines, cellular coverage is non-existent, and far enough away from the data collection point that a radio system is impractical. These environments are generally located in areas that also make it difficult to set up a datalogger for remote water monitoring system and return several months later to collect the data. In these environments the satellite data transmission system can gather remote system data and transmit it to a database where it can be viewed from any computer that has connection to the Internet. |
| **Cellular data transmission** |  | Remote water monitoring systems that use cellular data transmission require sites that are well covered by cellular transmission towers. These remote water monitoring system sites will generally be closer to developed areas as a result of this requirement. Cellular data transmission methods will allow for more rapid data transmission from your remote water monitoring site, however an appropriate cellular plan with a local service provider is required. It is also essential that the cellular system be set up to transmit according to the transmission guidelines of the country theremote water monitoring system is located in. |

[25] http://www.globalw.com/support/remote.html - accessed December 2014 and Moving Towards Sustainable and Resilient Smart Water Grids: networked sensing and control devices in the urban water system. Michele Mutchek. MSc Thesis. December 2012. Arizona State University

| | Figure | Description |
|---|---|---|
| |  | |
| **Radio transmission data** |  | Radio systems are used for relatively short-range transmission of remote water monitoring system data. The advantage of radion systems is that one receiver can collect data from a large number of remote water monitoring systems. This allows centrally located base stations or mobile platforms that can move within range of the remote water monitoring stations togather data without actually visiting the site. An additional advantage is that there are no additional fees with a radio system. |
| **Telephone modem data transmission** |  | Telephone modem data transmission systems are used with remote water monitoring systems that are near telephone lines. Typically this type of system is used where the remote water monitoring systems are near unmanned buildings such as small dams or gauging stations. This type of system has the lowest investment of all the remote water monitoring system data transmission methods if the telephone lines already exist at the monitoring site. |
| **Wi-Fi transmission data** |   | Wi-Fi (short for "wireless fidelity") is a term used to explain certain types of wireless local area networks (WLANs) that use specifications in the 802.11 family. IEEE 802.11 (Wi-Fi) is the most widely used wireless communication technology. The Wi-Fi data transmission system is capable of sending data packets through user datagram protocol (UDP) to a laptop computer with Wi-Fi capability. It is possible to build a data transmission module using inexpensive and simple components. This provides a simple and inexpensive design of data transmission for use in areas like real-time measuring and monitoring when combined with a sensing system. |

*Table 16:Comparison table between different data transmission technologies*

| | Suitable for difficult area | Suitable for residential & developed areas | Additional fee needed | Cellular transmission tower are needed | Telephone line needed | Costs |
|---|---|---|---|---|---|---|
| Satellite data transmission | X | x | | | | *high* |
| Cellular data transmission | X | x | x | x | | *medium* |
| Radio data transmission | X | x | | | | *medium* |

| | | | | | | |
|---|---|---|---|---|---|---|
| Telephone modem data transmission | | x | x | | x | low |
| Wi-Fi transmission data | | x | x | | | *medium* |

The three pilots in Waternomics are generally indoor environments. The Linate pilot (Italy) takes place inside the terminal building and other associated buildings, the pilot in Thermi (Greece) takes place inside houses of domestic users and small businesses and in Galway the pilot (Ireland) comprises a university building and a school. Although distances in the pilots will be relatively short and in some cases WiFi is available, access to power, signal strength and data transmission requirements will require case-by-case solution design.

## 2.2 Data Platform

As part of the Waternomics project, a 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 further discussed in following subsection.

Dataspaces propose a data co-existence approach to overcome problems in current data integration systems in a pay-as-you-go manner [1]. The idea is to bootstrap with simple integration, followed by incremental improvement of entity consolidation and related data quality aspects. In this respect, the Linked Data can be provides practical approach to realize a dataspace for Waternomics, supported by Semantic Web technologies. The proposed approach follows the same philosophy of incremental improvement, where automated data integration processes are developed according to the application requirements. Furthermore, the lookup and mappings of data sources in facilitated through open standards.

### 2.2.1 Linking Data Sources

Linked Data [2] targets the exposure of the data sources and making it available through the Web standards and protocols. This serves an important goal of integrating data silos all over the Web. The key is that most of that data is already structured, and thus converting it to standards of Web and the Semantic Web shall be a relatively easier step. Berners Lee [3] summarizes the principles of the Linked Data in four steps:

1. Use URIs as names for things
2. Use HTTP URIs so that people can look up those names.
3. When someone looks up a URI, provide useful information, using the standards (RDF,JSON, XML, SPARQL)
4. Include links to other URIs. so that they can discover more things.

Extending the abstract view of the Web architecture, URI can still be used to identify entities or resources. Representations of such resources though are not extended with the specific type of content. When a software agent (client) asks the Web server for a resource, it could ask for the representation of that resource in a standard format such as RDF or JSON. The process is also called content negotiation. Once a known representation is returned to the client, it can parse it according to the serialization used and then make use of the links as well as the references to ontologies and vocabularies in order to make sense of the relationships between entities and

make higher level reasoning.

Linked Data has been seen as a cornerstone in the Open Data initiative and thus Berners Lee defined a 5-stars scheme that can be used to publish Linked Data on the Web as shown in Table 17.

*Table 17: 5 stars sheme for Linked Data publishing*

| Rating | Requirement |
|---|---|
| ★ | Available on the web (whatever format) but with an open licence, to be Open Data |
| ★★ | Available as machine-readable structured data (e.g. excel instead of image scan of a table) |
| ★★★ | All of the above; and uses non-proprietary formats (e.g. CSV instead of excel) |
| ★★★★ | All the above; plus, uses open standards from W3C (RDF and SPARQL) to identify things, so that people can point at your stuff |
| ★★★★★ | All the above, plus: link data to other people's data to provide context |

Many projects have been launched in response to the need for availing as much Linked Data as possible and realizing the Semantic Web vision through the Linked Data principles. One notable project is the DBpedia [4] which is an online repository of structured content available in HTML and RDF formats, which can be also queried through SPARQL. DBpedia is extracted from Wikipedia and thus contains a large amount of broad and comprehensive structured information. If a resource is looked up in DBpedia, the content negotiation specifies if an HTML representation or an RDF representation is returned and then the content is sent back through HTTP response. Figure 6 shows the HTML of a URI http://dbpedia.org/resource/Water.

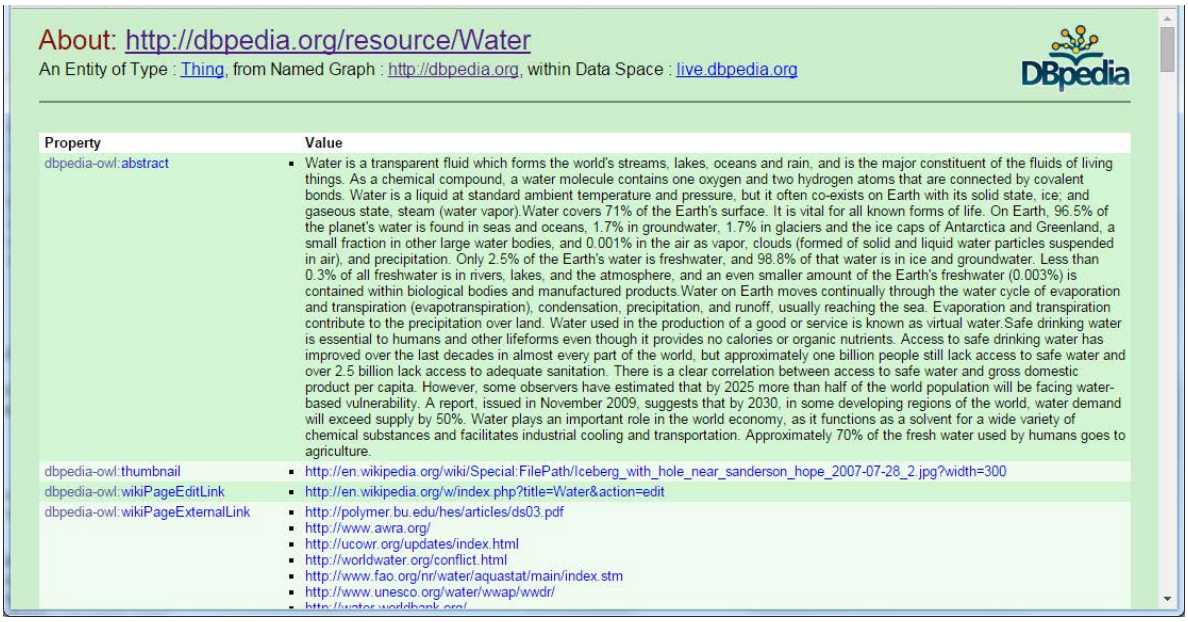



*Figure 6: Results of dereferencing http://dbpedia.org/resource/Water*

In order to integrate and link data from different sources, it has been proposed to use Linked data approach to overcome the heterogeneity of syntax and semantics for data sources. Table 18 below lists the requirements of the Linked data approach for Waternomics data platform.

*Table 18 Requirements of a Linked data approach for Waternomics data platform*

| Requirement | Description |
|---|---|
| **Standardisation** | Standardize the semantics of water data generated by metering and sensing system. |
| **Consuming Open Data** | Collect and integrate openly available data for advance analytics. |
| **Publishing Linked Data** | Make the data about water related entities, schemas, and statistics available through web protocols using Linked data principles. |
| **Data Linking** | Map the entities and their attributes across different data sources to enable integration. |
| **Seamless Integration** | Enable easy integration of both static data and dynamic real-time data. |

Table 16 below lists the requirements of the Linked data approach for Waternomics data platform.

*Table 19 Comparison of Linked data platforms and tools*

| Requirement | Virtouso[5] | LinDA [6][26] | Apache Marmotta[27] | LOD2 Stack[28] | OpenCube Toolkit [29] | CKAN[30] |
|---|---|---|---|---|---|---|
| **Standardisation** | | | | + | | + |
| **Consuming Open Data** | + | + | + | + | + | + |
| **Publishing Linked Data** | + | + | + | + | + | + |
| **Data Linking** | + | + | + | + | + | + |
| **Seamless Integration** | | | | | | |

Waternomics entities management will make use of existing ontologies such as SSN[7] to create sensor descriptions among other entities [8] [9].

## 2.2.2 Processing Real-time Events

Recently there has been a realization among researchers and practitioners that a new class of information processing systems is needed [10] . The new class, or paradigm, has been motivated by a plethora of distributed applications that require on-the-flow and low latency processing of information items. Example applications include environmental monitoring from sensors, stock market analysis for emerging trend identification, RFID-based anomaly detection in inventories, and security systems. The application domains features include for example spatio-temporal correlation, event sequencing, out of order events, homogeneous aggregation,

[26] http://eis.iai.uni-bonn.de/Projects/Linda.html
[27] http://marmotta.apache.org/
[28] http://stack.lod2.eu/blog/
[29] http://opencube-toolkit.eu/
[30] http://ckan.org/

derived events, event enrichment, outlier handling, early filtering, mobility of event source, mobility of event subscriber, etc.

While these features can characterize the applications in question, they remain relatively at a higher level than the solution domain where the discourse on what characterizes the new paradigm can be facilitated. The concepts of timeliness and in-flow processing have been expressed in the literature using various terms such as low latency, high throughput, low delay, volume, and real-time processing. The new paradigm is called vent processing or alternatively stream processing. Events in the Waternomics context can be messages from water sensors or other systems within the water dataspace.

In order to process and analyze real-time event data from different sources, it has been proposed to realize Lambda architecture supported by complex event processing. Table 20 below lists the requirements of the real-time data processing architecture for Waternomics data platform.

*Table 20 Requirements of real-time data processing architecture*

| Requirement | Description |
|---|---|
| **Real-time data / events** | Process low latency data generated by sensors or other sources at large-scale. |
| **Real-time Analytics** | Make available aggregate statistical data based on real-time data and historical data along various dimensions and facts. |
| **Heterogeneity of Sensor Data** | Handle variety of sensor data formats and schemas to foster long term interoperability. |
| **Enrichment of Sensor Data** | Add contextual information to raw sensors data and events to enable integration, aggregation, and analytics. |

Table 21 compares some of the existing technologies in terms the requirements of the real-time data processing architecture.

*Table 21 Comparison of real-time data processing technologies*

| Requirement | Apache Spark[11] | Apache Storm[31] | DRUID[12] | Collider[13] |
|---|---|---|---|---|
| **Real-time data / events** | + | + | + | |
| **Real-time Analytics** | + | | + | |
| **Heterogeneity of Sensor Data** | | | | + |
| **Enrichment of Sensor Data** | | | | + |

## 2.2.3 Cloud Infrastructure

In order to reduce cost and improve efficiency, it has been proposed to use a cloud data storage platform to provide this service. This means that there is a reduced requirement for on-site data

[31] https://storm.apache.org/

collection and storage facilities, thus reducing capital costs for hardware, as well as ongoing maintenance costs.

In essence, there are three models for outsourcing data and applications in the cloud, known as cloud service models:

- Software as a Service (SaaS)
- Platform as a Service (PaaS)
- Infrastructure as a Service (IaaS)

Each of these models provide varying levels of service to the customer, allowing transfer of management of particular aspects of the service to the vendor (see Figure 7). With IaaS for example, the customer is responsible for managing what is put on top of the metal whereas with Software as a Service, the vendor manages everything. Platform as a Service falls in the middle, with levels up to the runtime managed by the vendor and the application the responsibility of the customer[14].

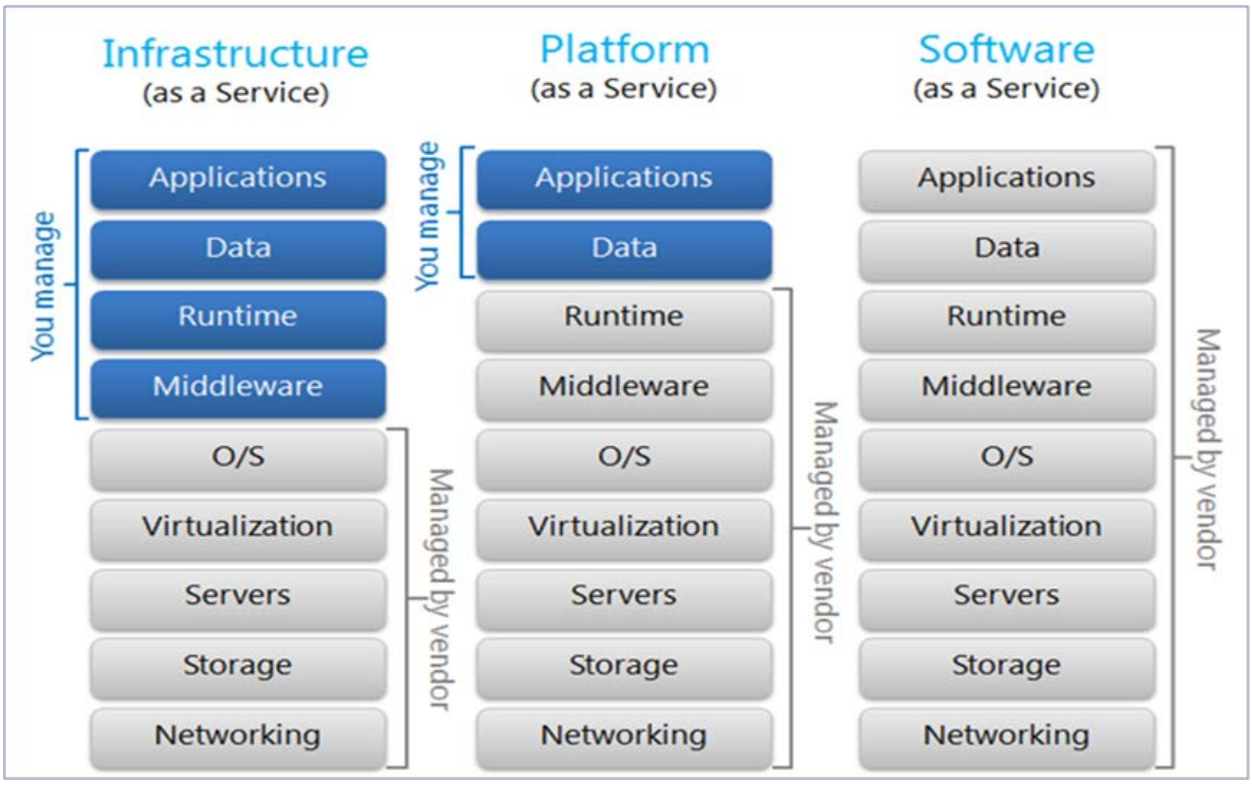



*Figure 7: Cloud service models* [14]

The proposed off-site model is known as **Infrastructure as a Service (IaaS)**. This is a "*cloud model which allows outsourcing of computing equipment and resources (e.g. servers, storage, and networking) as well as services (e.g. load balancing, analytics, and content delivery). The IaaS provider owns and maintains the equipment while the customer rents out the specific services it needs, usually on a "pay as you go" basis. In general, the question is less about whether or not to use IaaS services, but rather which providers to use*" IaaS Providers List: 2014 Comparison And Guide [32]. The various provider/vendor options are discussed later in this section.

A recent 2014 Gartner report analysed the current state of the market in terms of IaaS service providers[15]. Based on their analysis, a number of vendors emerged as clear leaders:

[32] Sullivan, D., 2014. IaaS Providers List: 2014 Comparison And Guide. Available at: http://www.tomsitpro.com/articles/iaas-providers,1-1560.html [Accessed December 3, 2014].

- Amazon Web Services (AWS)
- Microsoft Azure
- Google Compute Engine (GCE)

These are followed by a cluster of competitors (see Figure 8). It is outside of the scope of this report to analyse all of these services in detail. However, the following section compares the top three vendors in view of the Gartner report and the requirements of the WATERNOMICS platform.


*Figure 8 Comparison of IaaS vendors (Leong et al. 2014)*

Table 22 compares the features of the top 3 Infrastructure as a Service (IaaS) vendors, as per Figure 8 above. This table has been compiled from the latest information available online regarding the services provided by these vendors – primarily from two leading authorities on this topic - Leong et al. (2014) [15] and Sullivan (2014)[33].

[33] Sullivan, D., 2014. IaaS Providers List: 2014 Comparison And Guide. Available at: http://www.tomsitpro.com/articles/iaas-providers,1-1560.html [Accessed December 3, 2014].

*Table 22: General Comparison of leading IaaS vendors (Leong et al. 2014; Sullivan 2014)*

| Provider | Amazon AWS | Windows Azure | Google Compute Engine |
|---|---|---|---|
| Description | Amazon Web Servies (AWS), a subsidiary of Amazon.com, is a cloud-focused service provider. It is focussed on provision of highly automated, cost-effective IT capabilities, delivered in a flexible, on-demand manner. They offer a full range of compute and storage capabilities, including on-demand instances and specialized services such as Amazon Elastic Map Reduce (EMR) and Cluster GPU instances, as well as Elastic Block Storage (EBS) and high performance SSDs on the storage side. Additionally, the IaaS offers infrastructure services such as workflows, message passing, archival storage, in-memory caching services, search services, both relational and NoSQL databases and more. | Microsoft is a large and diversified technology vendor that is increasingly focused on delivering its software capabilities via cloud services. Its Azure business was previously strictly PaaS, but Microsoft launched Azure Infrastructure Services (which include Azure Virtual Machines and Azure Virtual Network) into general availability in April 2013, thus entering the cloud IaaS market.<br>Despite the name, Windows Azure is not a Windows-only IaaS. The compute and storage services offered are typical of what is found in other IaaS providers, and administrators used to Microsoft platforms will find working with Windows Azure much easier. The IaaS offers ready access to virtual networks, service buses, message queues, and non-relational storage platforms as well. | Google is an Internet-centric provider of technology and services. Google Cloud Platform combines an IaaS offering (Google Compute Engine [GCE]), an application PaaS offering (Google App Engine) and a range of complementary services. Google has been operating App Engine since 2008, but did not enter the IaaS market until the general-availability launch of GCE in December 2013. Google Compute Engine is well suited for big data, data warehousing, high performance computing and other analytics-focused applications. It is well integrated with other Google services, such as Google Cloud Storage, Google BigQuery and Google Cloud SQL. Although Google Compute Engine is still relatively new in the IaaS market, the fact that it runs on Google's global infrastructure, including the company's private global fibre network and high efficiency data centres sets it apart. |
| Key Features | Rich set of services and integrated monitoring tools; competitive pricing model. AWS can also be used as a PaaS. | Easy-to-use administration tool, especially for Windows admins. Windows Azure can also be used as a PaaS. | With the Google infrastructure backing it up, this IaaS is designed to scale. |
| Locations | AWS has groups of data centres, which it calls "regions," on the East and West Coasts of the U.S., and in Ireland, Japan, Singapore, Australia, Brazil, and (in preview) China. It also has one region dedicated to the U.S. federal government. It has global sales. Support is provided in English, Japanese and Portuguese. Technical account managers can also provide support in German, Spanish, Hindi, Korean and Mandarin. | Azure Infrastructure Services are available in multiple data centres in the U.S., as well as in Ireland, the Netherlands, Hong Kong, Japan, Singapore, China and (in preview) Brazil. Microsoft has global sales, and Azure support is provided during local business hours in English, French, German, Italian, Spanish, Japanese, Korean, Mandarin and Portuguese; 24/7 support is provided in English and Japanese only. | Google groups its GCE data centres into "regions," each of which contains at least two availability zones. There is a central U.S. region, a European region (located in Belgium), and an Asia region (located in Taiwan). It has global sales. Support is available in English and Japanese. The portal is available in English, Spanish, Portuguese, Japanese and Mandarin. |

| | | | |
|---|---|---|---|
| Compute | Elastic Compute Cloud (EC2) offers multitenant, fixed-size and non resizable, Xen-virtualized VMs without auto restart. Single-tenant VMs are available via Dedicated Instances. There are special options for HPC, including graphics processing units (GPUs). AWS does not have any formal private cloud offerings, though it is willing to negotiate such deals (such as its deal for the U.S. intelligence community cloud). | Azure VMs are fixed-size, paid-by-the-VM, and Hyper-V-virtualized; they are metered by the minute. | GCE offers multitenant, fixed-size and non resizable, KVM-virtualized VMs, metered by the minute. Provisioning is exceptionally fast (typically under 1 minute). |
| Storage | VM storage is ephemeral. Persistence requires VM-independent block storage (Elastic Block Store). There is an option for SSDs, as well as storage performance guarantees (Provisioned IOPS). Object-based storage (Simple Storage Service [S3]) is integrated with a CDN (CloudFront), there is an option for long-term archive storage (Glacier), and AWS offers its own cloud storage gateway appliance. | Block storage ("virtual hard disk") is persistent and VM-independent. Object-based cloud storage is integrated with a CDN. | VM storage is persistent, and there is also VM-independent block storage. All block storage is encrypted. |
| Network | AWS offers a full range of networking options. Complex networking and IPsec VPN is done via Amazon Virtual Private Cloud (VPC). Third-party connectivity is via partner exchanges (AWS Direct Connect). | There is no support for complex network topologies. Third-party connectivity is via partner exchange (Azure ExpressRoute). | Third-party private connectivity is not supported. Customers cannot bring their own private IP addresses (although this need may possibly be addressed by GCE's Advanced Routing features). There is no back-end load balancing. |
| Security | RBAC is per-element, with customer-defined roles and exceptional control over permissions. AWS has obtained many security and compliance-related certifications and audits. | Virtual network topology limitations prevent useful deployment of most security-related virtual appliances, such as a perimeter intrusion detection/prevention system (IDS/IPS). RBAC uses Azure Active Directory, but permissions are whole-account. | RBAC permissions apply to the whole account. |

| | | | |
|---|---|---|---|
| Other Notes | Enterprise-grade support is extra. The SLA is multi-fault-domain, but does not have any exclusion for maintenance; AWS also offers continuous availability on its portal and API. Notable capabilities include orchestration (CloudFormation and OpsWorks), autoscaling, database as a service (Relational Database Service [RDS]), Hadoop as a service (Elastic MapReduce), data warehousing as a service (Redshift), and desktop as a service (WorkSpaces). AWS does not offer colocation; a partner exchange must be used instead. | Enterprise-grade support costs extra. The SLA is multi-fault-domain, but does not have any exclusion for maintenance. Additional significant capabilities include orchestration (Azure Automation), scheduling, autoscaling and Hadoop as a service (HDInsight). Microsoft does not offer colocation; a partner exchange must be used instead. | Enterprise-grade support is extra. The SLA is multi-fault-domain, and excludes maintenance in Europe (where Transparent Maintenance is not available yet). Google cannot address the need for colocated equipment. Autoscaling capabilities (Replica Pools) are in preview (beta). |
| Recommended Uses | All use cases that run well in a virtualized environment, although highly secure applications, strictly compliant or enterprise applications (especially complex ones such as SAP business applications) require special attention to architecture. | General business applications and development environments for Microsoft-centric organizations; cloud-native applications; use as part of an overall Microsoft Azure solution. | Cloud-native applications and batch computing, as well as projects leveraging Google Cloud Platform as a whole. |
| Limitations | AWS is a complex mixture of services. As your workflows become more complex and you use more services it can be difficult to project expenses. However, Amazon offers a monthly calculator to help estimate your costs. | Minimal, easy-to-use portal interface may not be so appealing to command line gurus. | Lacks ease of administration features. Running Hadoop on Google Compute Engine, for example, requires more from users; because it's not integrated you have to download the Hadoop package, a patch for Hadoop and a set of JDK packages along with several other steps (outlined here) to deploy a Hadoop cluster. |
| Pricing | Instances range from $0.113/hour to $6.82/hour, with volume discounts available for reserved instances. Storage prices range from $0.095/GB/month to $0.125/GB/month. Additional charges for application services and data egress may apply. | $0.02 to $1.60 per hour. Storage prices range from $0.07/GB/month to $0.12/GB/month, depending on level of redundancy. | Instances range from $0.019/hour to $1.659/hour. Provisioned storage is $0.04/GB/month; snapshot storage is $0.125/GB/month. |
| Bonus | New users can get 750 hours, 30GB storage and 15GB bandwidth for free. | Free 30-day trial with a limit of up to $200 is available for new users. | Google charges by the minute after a minimum of 10 minutes in an hour. |

RankCloudz™ online cloud comparison service. This provides an insight into the performance of all major platform vendors, and can be customised to provide suitable recommendations depending on client requirements. In this case, the requirements of the proposed Waternomics platform were assessed on the basis on perceived needs under each of the headings outlined in *Table 23*.

*Table 23* below outlines the features and capabilities of IaaS platforms used to rank and prioritise the various vender offerings which meet the requirements of the WATERNOMICS platform. These feature categories have been developed by the RightCloudz RankCloudz™ [34] online cloud comparison service. This provides an insight into the performance of all major platform vendors, and can be customised to provide suitable recommendations depending on client requirements. In this case, the requirements of the proposed Waternomics platform were assessed on the basis on perceived needs under each of the headings outlined in *Table 23*.

*Table 23 Requirements for an Infrastructure as a Service (IaaS)*

| | Requirement | Description | | Requirement | Description |
|---|---|---|---|---|---|
| 1 | **Application Services** | Captures and measures various vendor service features and capabilities that support application development including pre-configured and versatility of APIs, toolkits, mobile app support, media services and other platform related services. | 7 | **Infrastructure** | Captures and measures the breadth and depth of vendor infrastructure, connectivity, and network capabilities including availability of edge locations, data centres availability globally, CDN spread. |
| 2 | **Compute** | Captures and measures various vendor service features and capabilities that provide flexible and extensible compute resources like memory, disk, vCPUs/cores, operating systems, on demand / reserved instances, range and granularity of compute configurations. | 8 | **Operating Cost** | Captures and measures various Cloud infrastructure cost related parameters including compute, storage, network, support, data transfer / connectivity, monitoring. |

[34] https://www.rightcloudz.com/RankCloudz.php

| | | | | | |
|---|---|---|---|---|---|
| 3 | **Data Protection** | Captures and measures various vendor service features and capabilities that protect user data by various mechanisms like fine-grained access control, encryption in transit and at rest, version controls, audits, logs, backup/restore. | 9 | **Performance** | Captures and measures various vendor service features and capabilities that are specific to performance. These include high speed connectivity, cache management, network scaling, load balancing, self-healing mechanisms, auto scaling and managing failover. |
| 4 | **Ease of Use** | Captures and measures various service features and capabilities provided by a vendor to make it easy for users to use various Cloud resources, creation of instances, monitoring, accessibility, documentation of methods and procedures. | 10 | **Security** | Captures and measures various vendor service features and capabilities that provide all levels of security in the Cloud infrastructure to data, users, connections, applications, data centres. |
| 5 | **Governance and Regulatory Compliance** | Captures and measures various mechanisms that vendor has in place to ensure compliance with regulatory requirements across the world. | 11 | **Storage** | Captures and measures various vendor service features and capabilities that provide flexible and extensible Storage resources like range of disk space, elasticity of disk space, built-in redundancy, variety of storage options, archival. |
| 6 | **High Availability & Disaster Recovery** | Captures and measures various vendor service features and capabilities that provide high availability to Cloud resources, fail over mechanisms, uptime, support mechanisms and provides ability to recover rapidly and reliably after a disaster/failure. | | | |

Based on these requirements, an initial prioritization of IaaS technologies, specific to WATERNOMICS planned requirements is defined in Table 24 below.

*Table 24: Priority ranking of requirements*

| # | Requirement | Priority |
|---|---|---|
| 1 | Application Services | 9 |
| 2 | Compute | 9 |
| 3 | Data Protection | 1 |
| 4 | Ease of Use | 6 |
| 5 | Governance and Regulatory Compliance | 5 |
| 6 | High Availability & Disaster Recovery | 6 |
| 7 | Infrastructure | 9 |
| 8 | Operating Cost | 8 |
| 9 | Performance | 9 |
| 10 | Security | 7 |
| 11 | Storage | 7 |

From this exercise the Windows Azure Platform scores the highest meeting high priority requirements such as application (1) and computing (2) services. The next section summarises the strengths and weaknesses of the above data platforms that may be relevant to WATERNOMICS (and indeed other water information platforms).

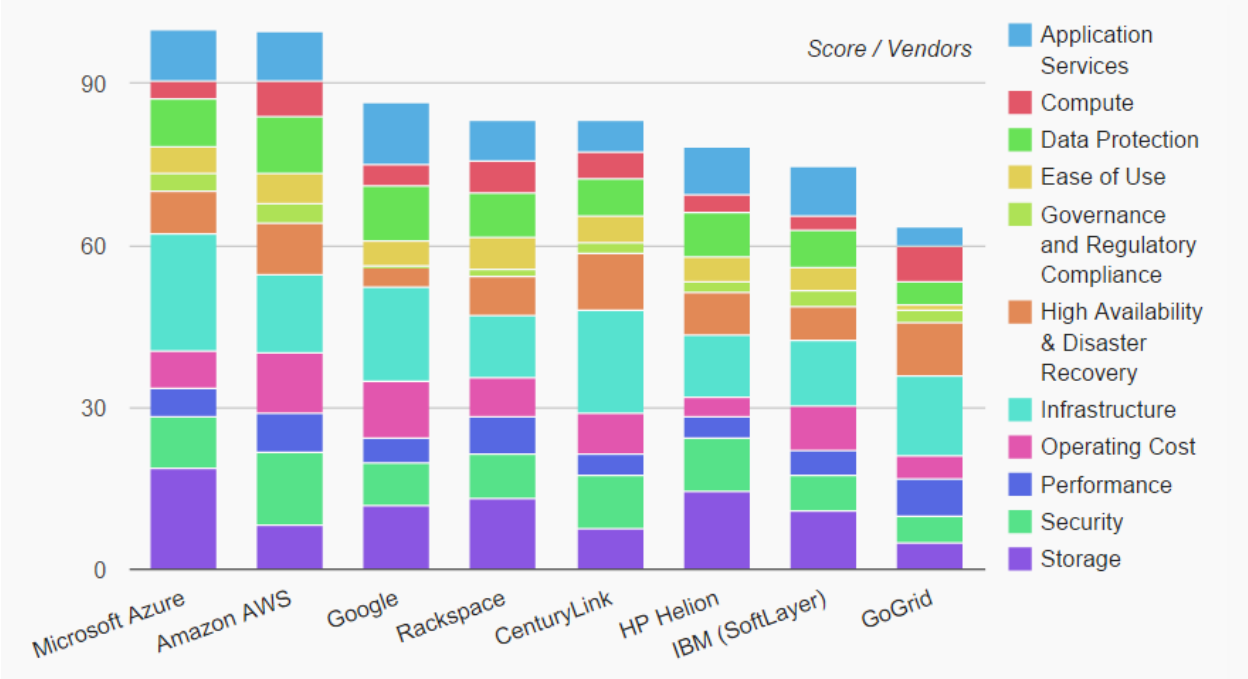



*Figure 9: Results ranking prioritization*

## 2.3 Software

This section presents software technologies related both to water information platforms and software components (listed below) that are going to be combined in the Waternomics platform.

- Water information platforms and applications
- Back-end web application development frameworks
- Front-end web application development frameworks

- Mobile app development platforms and technologies
- Charting technologies
- Notification and alerting technologies
- Web service technologies

### 2.3.1 Water information platforms and applications

Table 25 summarises existing water information platforms, applications and solutions that can inform the development of the Waternomics platform.

*Table 25 Overview water information platforms*

| Name | Target | Features | Key technologies | | Link to supplier |
|---|---|---|---|---|---|
| WaterSmart | Facilitate communication of water utilities with customers | • Personalized home water reports to help consumers manage water consumption more efficiently<br>• Customer portal for more detailed analysis of consumers' water use and water-saving recommendations<br>• Utility dashboard for staff to access visually insightful analytics, reporting and customer relationship tools | • Data analytics<br>• SaaS model<br>• Cloud computing<br>• Web technologies for UI<br>• Behavioural change methods | • Specifically targeting water utilities and domestic consumers enhancing their communication.<br>• Missing specialization for businesses and large enterprises internal water management (airport pilot)<br>• Difficult to be adopted for public spaces<br>• It does not allow access to data to third parties for additional applications | http://www.watersmart.com/ |
| TaKaDu | Facilitates water leakage detection in water networks and mainly target water utilities | • Water network management<br>• Leakage detection<br>• Fault detection<br>• Bursts detection<br>• Actionable alerts and reports about leaks, bursts and inefficiencies and network events<br>• Real-time alerts and dashboard | • Cloud computing<br>• Linked data<br>• Web technologies for UI<br>• Various types of alerts (email, SMS, etc.)<br>• SaaS model | • Targeted to water utilities and network management issues<br>• Missing domestic and large enterprise users<br>• Missing behavioural change tactics | http://www.takadu.com/ |
| Syrinix | A set of solutions targeting water utilities for efficient water network management | • Pipeline monitoring<br>• Tackling pressure transients<br>• Burst detection<br>• Alerts with SMS, emails etc.<br>• Real-time monitoring<br>• Configurable dashboards | • Smart sensors<br>• Web technologies for UI<br>• Various types of alerts (email, SMS, etc.)<br>• SaaS model | • Targeting network management for utilities and enterprises<br>• Missing behavioural change tactics<br>• Missing domestic users<br>• Not allowing access to third parties for external applications. | http://syrinix.com/ |

| Name | Target | Features | Key technologies | | Link to supplier |
|---|---|---|---|---|---|
| HydroPoint | A set of controllers , sensor and software for irrigation scheduling | • Web based application for real-time monitoring<br>• Site-specific weather data gathered and used for adjusting scheduling of irrigation<br>• Water use monitoring, analysis and diagnostics<br>• Simulation of water conservation plans<br>• Benchmarking water conservation plans implemented | • Sensors and remote controllers<br>• Web technologies for UI<br>• SaaS model | • Targeting agricultural uses of water with irrigation planning<br>• Missing support for any of the three types of users in WATERNOMICS<br>• Missing behavioural change tactics<br>• Not allowing access and expansion through third party applications | http://www.hydropoint.com/ |
| PureSense | Irrigation planning and monitoring | • Irrigation scheduling<br>• Pump control<br>• Flow meter monitoring<br>• Field monitoring<br>• Weather forecast to help irrigation planning<br>• Team management<br>• Task and operations management | • Sensors and remote controllers<br>• Cloud computing<br>• Web technologies for UI<br>• SaaS model | • Targeting agricultural uses of water with irrigation planning<br>• Missing support for any of the three types of users in WATERNOMICS<br>• Missing behavioural change tactics<br>• Not allowing access and expansion through third party applications | http://www.puresense.com/ |

### 2.3.2 Back-end web application development frameworks

As it is obvious from most of the enlisted products and applications in the domain the architecture is based on some common key technologies. Back-end web application frameworks are development frameworks for developing the core part of web applications dealing with data modelling and handling according to users actions. Most back-end applications utilize some cloud computing infrastructure (either a data storage mechanism and/or as an application hosting mechanism). Waternomics proposes similar approach with the cloud being used for storage purposes and communicating with applications using a set of web services. However, most of the applications developed based on the platform will be using web as the main platform for user interaction. Waternomics applications will follow a typical three tier architecture where the data space and data storage infrastructure is based on cloud technologies described in the previous section. The next layer of the architecture is the business layer of the applications; the data coming from the data layer are transformed into appropriate structures and models and subsequently presented and managed by the user. This layer also implements the main business logic of the applications.

The business layer for each application can be based on a variety of already existing development frameworks. Such frameworks provide a specific set of tools to organize data according to the business rules of applications and connect them (data) with appropriate interaction events that happen in the user interface. One of the most popular patterns for organizing the functionality of such a framework is the Model-View-Controller (MVC) pattern. The main component of the MVC pattern is the model which captures the behavior of the application in terms of its problem domain, independent of the user interface. The model manages the data, logic and rules of the application. A view can be any output representation of information, such as a chart or a diagram. The pattern allows for multiple views of the same information to be available, such as a bar chart for management and a tabular view for accountants. The third component of the MVC pattern, the controller, accepts input and converts it to commands for the model or view. So it initiates actions on the model which in turn output a specific view to the user.

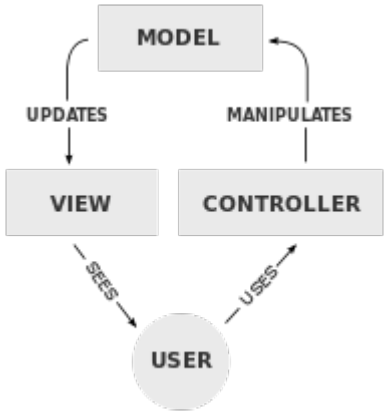



*Figure 10: Typical structure of components in the MVC pattern*

The following table outlines a selection of MVC web application frameworks that are quite popular together with UltraCore which is an web application framework developed by Ultra4 (one of the partners in the Waternomics consortium). A more detailed analysis and a more complete list of web application frameworks can be found in Wikipedia[35]. Some of the most

[35] http://en.wikipedia.org/wiki/Comparison_of_web_application_frameworks

important characteristics for choosing a technology in Waternomics is the degree of customization and changes allowed by each of these technologies for the specific purpose of the project. This means that factors such as licensing or programming language play a significant role. For example, the programming language used should be in line with the main applications developer partner's philosophy and know-how.

*Table 26 Table of popular back-end web application frameworks*

| Name | ASP.NET MVC | CakePHP | Zend Framework | Spring | UltraCore |
|---|---|---|---|---|---|
| Language | ASP.NET | PHP | PHP | Java | Java |
| Link | http://www.asp.net/mvc | http://cakefoundation.org/ | http://framework.zend.com/ | http://spring.io/ | http://www.ultra4.eu/ |
| Licence | | MIT Licence | New BSD License | Apache Licence 2 | Commercial Licence |
| ORM | Supports ORM with DataAnnotations used in definition of data models. Entity Framework also helps in creating model classes based on an existing database or create a database based on an existing data model developed on ASP.NET MVC | The CakePHP ORM borrows ideas and concepts from both ActiveRecord and Datamapper patterns. It aims to create a hybrid implementation that combines aspects of both patterns to create a fast, simple to use ORM. | ORM in Zend Framework is achieved by implementing the Table and Row data gateway patterns through the Zend_Db_Table and Zend_Db_Table_Row patterns.<br>It also uses Doctrine as an Object-Relational Mapper. | Spring allows to use a variety of Java libraries to achieve the object-relation mapping. Two of the most commonly used are Hibernate and iBatis | UltraCore has its own built in ORM library, which allows for easy automatic mapping of objects to tables, based on MDA (Model Driven Architecture) meta data tools that are defined for the Data |
| Templates | ASP.NET MVC can import templates using Master Pages and Razor Views in order to help developers build applications with already existing and pre-developed templates.<br><br>It also by default imports the Bootstrap front-end development framework as a default theming mechanism for new applications. | The view layer in CakePHP can be made up of a number of different parts. Each part has different uses:<br>• views<br>• elements<br>• layouts<br>• helpers<br>• cells<br>It also support the development of plugins to cooperate with front-end development frameworks such as Bootstrap and the template engine Twig | Templates are supported through the Zend_View class. Zend_View allows developers to use PHP as their template language, or create instances of other template systems and manipulate them within their view script.<br><br>This way Zend Framework ensures extensibility allowing the usage of other temple engines in combination with it. | Spring allows templating in two ways.<br><br>By using custom JSP tags which exist as Java classes or JSP snippets and provide a basic facility to encapsulate and reuse parts of JSP pages (headers, footers, etc.).<br><br>By using template engines like Commons Tiles, Velocity and Thymeleaf, etc. | UltraCore supports web templating, which allows for designers to independently create designs that are later at runtime injected with live UltraCOre components. |

| Name | ASP.NET MVC | CakePHP | Zend Framework | Spring | UltraCore |
|---|---|---|---|---|---|
| Scaffolding | Provides scaffolding for building views and controllers for CRUD functions of entities in the data model. Scaffolding also supports the creation of CRUD functionality for developing a REST API for the data model. | CakePHP provides scaffolding features to create prototypes of applications with code generated from the framework itself | A scaffolding mechanism is not provided by default within Zend Framework. However, there is an attempt by Alex Oroshchuk[36] to develop a controller scaffolding mechanism for Zend to facilitate easier development of basic CRUD functionality for a model. | Spring supports scaffolding through external tools and libraries such as MyEclipse IDE from Genuitec or Spring Roo, Grails etc. | UltraCore has built in designer tool that can generate complete functioning modules (CRUD) from database tables, or generate smaller application parts. Also the GUI can be designed with a drag and drop designer. |
| Validation | Validation can be achieved using DataAnnotations and metadata in the data model. Validation (wherever possible) is being implemented at client side with the use of data-variables on html5 elements. | Validation via Contexts (Table (DAO), Entity (VO) & Controller)<br>CSRF Protection Supports | Zand has a set of validators implemented for various types of data allowing the implementation of custom validators and their customization and translation of error messages | Spring allow for other libraries such as Commons validator and Bean Validation to support validation functionalities | A complete validation library is available, that works with MetaData definitions, so that the validation rules can be inspected both in the Frontend and the Backend, supporting a unified data model without breaks between layers |
| Other features | | Mobile Agent Detection | | | Integration with UltraTelecom, allowing for multichannel application access, e.g. via email, telephone, sms, etc. |

[36] https://code.google.com/p/zendscaffolding/

### 2.3.3 Front-end web application development frameworks

As previously presented most existing software presents information on a variety of devices using web interfaces. In some cases there are also additional mobile applications accompanying the solutions (discussed further in 2.3.4). Front-end web application development frameworks provide a set of user interface elements using CSS and JavaScript technologies. Developers using such frameworks can use them to easily develop the front-end of a web application using a specific consistent and in some cases widely used design language that it is easy for the users to understand and use. Moreover such frameworks are also usually taking care of compatibility issues with mobile devices employing responsive web technologies. This section presents three of the most popular frameworks and a more detailed analysis[37,38].

For the choice of a technology in the area of front-end development frameworks the richness in supported components and responsive design is a crucial one together with support of web browsers. Moreover, modularity and the learning curve for each of these frameworks play a significant role as well. The learning curve is largely affected by the use of semantic class names and the community activity.

[37] http://usablica.github.io/front-end-frameworks/compare.html?v=2.0

[38] http://en.wikipedia.org/wiki/CSS_frameworks

*Table 27 Comparison of characteristics of popular front end web development frameworks*

| Name | Bootstrap (v.3.3.1) | Foundation (v.5) | Semantic UI (v.1.2.0) |
|---|---|---|---|
| Link | http://getbootstrap.com/ | http://foundation.zurb.com/ | http://semantic-ui.com/ |
| Licence | MIT | MIT | MIT |
| Browser compatibility | IE8 and higher, Chrome (latest), Safari (latest), Firefox (latest), Opera (latest) | IE9 and higher, Chrome (latest), Safari (latest), Firefox (latest), Opera (latest) | IE9 and higher, Chrome (latest), Safari 6 and higher, Firefox (latest), Opera 12 and higher |
| Customization and theming | Compiled through SASS and LESS CSS engines<br>Allows for customization on download by customizing over a large set of variables | Compiled through SASS CSS engines<br>Allows for customization on download by customizing over a set of variables (limited)<br>Foundation for apps offers a few themes customized for specific types of apps | Compiled through LESS CSS engines<br>9 out of the box themes ready to be used |
| Responsive grid support | Mobile first design approach.<br>Includes responsive grid elements with fluid and fixed width of the grid and also includes helper classes that can be shown or hidden for specific devices. | Mobile first design approach.<br>Includes responsive grid elements but with fixed width only and includes helper classes that can be shown or hidden for specific devices. | Mobile first design approach.<br>Fluid and fixed width grid are supported with options for user defined rows and helper classes for showing and hiding content on specific devices. |
| Components | Apart from basic typography and helper utilities there are also 21 components and 12 jQuery plugins for interaction effects | About 35 components apart from typography and helper classes. | More than 50 UI components including typography elements and helper classes. |
| Modularity | Modularity supported by selecting which components to include in the download before downloading | Modularity supported by selecting which components to include in the download before downloading | Modularity supported by downloading separate files for each component |
| Semantic class names | No | Yes | Yes |

| Name | Bootstrap (v.3.3.1) | Foundation (v.5) | Semantic UI (v.1.2.0) |
|---|---|---|---|
| Unique features | • Unique elements include:<br>○ Badges<br>○ Media objects<br>○ Wells<br>○ Scrollpsy<br>○ Carousel<br>○ Affix | • Unique elements include:<br>○ Joyride*<br>○ Magellan site navigation bar<br>○ Pricing tables<br>○ Orientation detection visibility classes<br>○ Range sliders*<br>○ Equalizer to keep equal height columns in one row<br><br>*Potentially useful for WATERNOMICS apps | • User defined API to connect with states and behavior of components.<br>• Includes form validation behaviors<br>• Unique elements include:<br>○ Loaders*<br>○ Reveal images<br>○ Step*<br>○ Card<br>○ Feed*<br>○ Item (News or sales item)*<br>○ Statistic*<br>○ Rating<br>○ Shape<br>○ Transition<br><br>*Potentially useful for WATERNOMICS apps |
| Activity on GitHub | Excluding merges,<br>**51** authors have pushed<br>**105** commits to master and<br>**200** commits to all branches.<br>On master,<br>**135** files have changed and there have been<br>**6,357** additions and<br>**3,774** deletions.<br>  <br>**Almost 3 ½ years of life**[39] | Excluding merges,<br>**26** authors have pushed<br>**34** commits to master and<br>**50** commits to all branches.<br>On master,<br>**51** files have changed and there have been<br>**575** additions and<br>**236** deletions.<br>  <br>**Almost 3 years of life**[40] | Excluding merges,<br>**18** authors have pushed<br>**216** commits to master and<br>**237** commits to all branches.<br>On master,<br>**1,507** files have changed and there have been<br>**148,512** additions and<br>**278,971** deletions.<br>  <br>**Almost 1 ½ year of life**[41] |

[39] https://github.com/twbs/bootstrap/graphs/contributors
[40] https://github.com/zurb/foundation/graphs/contributors
[41] https://github.com/Semantic-Org/Semantic-UI/graphs/contributors

### 2.3.4 Mobile app development platforms and technologies

Waternomics will support various applications through a variety of devices. The variety of devices is also an important feature identified in many of the software solutions presented in 2.4.1. This section analyses briefly the benefits and problems faced in each case.

One of the most important factors for mobile apps development approach is the purpose and the target of the application. If the application requires using specific mobile devices characteristics (such as mobile phones sensors) then an approach closer to native and hybrid app development might be considered. If not then responsive web apps can be the best choice. Following that, the next more important aspect is the effort needed for the development and maintenance of the code base in combination with the range of devices supported by each platform.

*Table 28 Comparison of application development platforms*

| Category | Platform | Description | Technologies | Advantages | Disadvantages |
|---|---|---|---|---|---|
| Web applications | Web | Web applications for mobile devices are actually typical web applications which run on any mobile device through a web browser program provided by the mobile devices. Technologies of responsive web design are typically used to enable better presentation and layout of the application for a mobile device. The main benefit of a web application is that it is independent of mobile device platform or vendor. | HTML, CSS and Javascript | Potentially all devices supported independent of platform. The application can potentially run on any mobile device. | Difficult or no access to mobile specific features and sensors is hardware (gyroscope, accelerometer, notifications, etc.) |
| Native applications | Android | Native applications are developed for a specific mobile devices platform and depend highly on the characteristics and development environments provided and supported by each platform.<br>The Android platform covers the range of devices using the Android operating system. However, this range is not limited to mobile devices only, it currently also includes other devices such as TVs and set-top boxes.<br>Android is provided by Google and currently runs on devices from a large set of vendors. Applications for Android are provided mainly by google play and a variety of other market places. | Java | Easier access to mobile specific features and hardware (gyroscope, accelerometer, notifications, etc) | Different code base for each platform<br>Increased resources for maintenance<br>Fragmentation in devices, OS versions and capabilities |
| | iOS | This platform covers devices of Apple such as iPhones and iPads. Recently iOS has presented a new programming language for their applications called Swift while also continue to support development in Objective C.<br>Development for iOS also requires Apple computers to be used for the development and publishing of them. Applications are made available through the Apple Appstore | Objective C or Swift | | |
| | Windows | The platform covers mobile devices from a variety of vendors using the Microsoft's Windows Phone OS.<br>Main vendor of windows phone devices is Nokia which is currently bought by Microsoft. | | | |

| Category | Platform | Description | Technologies | Advantages | Disadvantages |
|---|---|---|---|---|---|
| | | Next version of Microsoft Windows OS is expected to be deployable in a variety of devices from desktop to mobiles. Development for windows platform is mainly done using Visual Studio in combination with C# of Visual Basic. | | | |
| Hybrid application development | Platform is a combination of native platforms with web | A variety of tools support the development of mobile applications using a common programming language for all device platforms. Developers can then develop applications using this language (usually JavaScript) and export the application in installation packages for a variety of supported mobile platforms.<br><br>A similar approach is also based on developing mobile applications that use heavily webview elements that display parts of a web page as parts of the user interface of the application | A combination of Native and Web technologies | Easier access to mobile specific features and hardware (gyroscope, accelerometer, notifications, etc)<br><br>Main core of the application remains the same for all platforms<br><br>Easier maintenance of code base. | Sill some parts fo the code base are different depending on the platform, but this is reduced comparing to native apps |

### 2.3.5 Charting technologies

An important part of application development is the presentation of information to end-users in easily accessible manner. Chart-type outputs of various types can be employed to achieve this and therefore charting libraries for web applications are a crucial part of application development. There is a wide variety of libraries for producing graphs of almost any imaginable type. However, the selection of a library should combine both the ability for rapid prototype development and enable scalability and extensibility to newer custom charts that might be developed. Table 25 shows a comparison of features for four main competitors in the charting graphs library (a more extensive analysis and comparison can be found at Wikipedia)[42].

For the choice in charting technologies the type of licence is a very important factor. The license determines the customisation and further development of new chart types. The extensibility of a charting technology (i.e. number and types of supported graphs) is also an important factor for making a choice. Having said that, the complexity of the API and its flexibility are also crucial factors for making a choice in this area.

[42] http://en.wikipedia.org/wiki/Comparison_of_JavaScript_charting_frameworks

*Table 29 Comparison of charting technologies (JavaScript)*

| Name | Google charts | D3.js | C3.js | Chart.js |
|---|---|---|---|---|
| Link | https://developers.google.com/chart/ | http://d3js.org/ | http://c3js.org/ | http://www.chartjs.org/ |
| Licence | Terms of Service provided | BSD | MIT | MIT |
| Available graph gallery | Area, Bars, Bubble, Calendar, Candlestick, Column, Diff, Gauge, Geo, Histograms, Lin, Maps, Org, Pie, Sankey, Scatter, Stepped Area, Table, timelines, Tree map, Trendlines, Word trees. | Box plots, Bubble, Bullet, Calendar, Chord, Dendogram, Bars, Stacked bars, Circle packing, Steamgraph, Treemap, Sunburstm Voronoi diagram, Symbol map, Zoomable pack, Collapsible force layout, Sankey, etc.<br>There is an extensive library of complex charts that is constantly populated by the developers' community.<br><br>https://github.com/mbostock/d3/wiki/Gallery | Line, Timeseries, Spline, Multiple line, Area, Line with regions, Step, Stacked area, Bar, Stacked bar, Scatter, Pie, Donut, Gauge, Combination, e.t.c.<br><br>The library supports a wide variety of graphs based on the D3.js library, thus it is also extensible using the D3.js library. | Line, Bar, Radara, Polar Area, Pie and Donut etc.<br><br>Provides support for extending and developing custom graphs |
| Interactivity | Supported through specific events provided for each chart type. | Extensive support for interactivity since developers can use any standards HTML based events to provide interactivity with charts | Provides some interactivity with some supported events (e.g. sub charts, zoom, etc.) but it is also extensible since it is based on D3.js library. | Provides support for building interactivity into graphs but not as easy and extensible as with D3.js based charts. |
| API Usability and complexity | Quite friendly and easy to develop graphs API which supports data binding with specific data related objects and JSON as input for graphs | Depending on the graph selected API can be quite easy or difficult to use. Many of the already provided graphs have friendly APIs but the library provides a good support for extending or developing new graphs with their own custom API's. Therefore flexibility comes at the expense of more work needed to develop new graph types and APIs | Provides a quite developer friendly API for updating graphs presentation and data. It is mainly based on JSON that describes the properties for the graph and the data and thus it can be considered as a good starting point for developing more graphs if needed. | Quite friendly API based also on JSON for formatting. However, it might be a limiting fir developing more complex features and interactivity on the graphs. |

### 2.3.6 Notification and alerting technologies

The Waternomics platform will provide users with notifications and alerts in case of emergency situations and in the form of personalised advice and prompts to action. Alerts and notifications can be implemented using a variety of technologies that in the following table (30) are presented alongside specific information regarding obtrusiveness and links to the proposed Waternomics platform functionality.

For the notification and alerting technologies the choice is a matter of case-by-case analysis. The most important factor in choosing an option is the urgency of the notification in combination with the obtrusiveness of each technology. Nobody would like to get phone calls every time there is a new news article available or a friend shared a piece of information. However, a phone call or an SMS might make more sense as a notification mechanism in case of critical leakage detection.

*Table 30 Comparison of alerting and notification technologies*

| Name | Email | SMS | Push Notifications | Call centres | Alarm on sensor box |
|---|---|---|---|---|---|
| Description | Users are notified by receiving an email | Users are notified by receiving an sms | Users can be notified either by a mobile app that receives the notification and displays it or by web apps | User receives a call by a call centre | A LED light on the sensor flashes and notifies the user of a problem |
| Obtrusiveness | Low | High | Mild | High | Mild to high |
| Important points | • Urgent notifications might be lost if users do not check emails often<br>• Good for informational – not urgent notifications and advices<br>• Also good for newsletter functionality | • Urgent notification will not be lost often.<br>• To be used only for extra critical notifications and alerts | • Urgent notifications might be unnoticed on time of arrival<br>• Possibility for customization of how the alert/notification will respond to actions<br>• Allows for notifications that can prompt for an action | • Urgent notification will probably not get lost.<br>• To be used only for extra critical notifications and alerts<br>• Might require special infrastructure | • Immediate alert<br>• Users must have access and visual contact with sensor to take notice<br>• Sounds could also be combined to make alarms more obvious<br>• A mechanism for easy cancelling should be available |

### 2.3.7 Web service technologies

Between the dataspace and applications there will be a set of services responsible for providing the appropriate information requested from the applications and vice versa. A Web service is a method of communication between two electronic devices over a network. It is a software function provided at a network address over the Web with the service always on as in the concept of utility computing. The W3C (World Wide Web Consortium) defines a Web service generally as: "software system designed to support interoperable machine-to-machine interaction over a network."[43] The following table presents a comparison of three main types of web services used together with a brief description of their philosophy and main principles.[44]

The choice of web services technology is dependent on the back-end technology selected and the support is allows for each of the technologies. Moreover it is also a matter of what kind of technologies is mostly used and preferred by third parties since the critical role of web services is the connection of the other data layer with applications.

[43] http://www.w3.org/TR/2004/NOTE-ws-gloss-20040211/#webservice
[44] http://msdn.microsoft.com/en-us/magazine/dd942839.aspx

*Table 31 Comparison of web service types*[45]

| Name | RESTful APIs | SOAP | RPC |
|---|---|---|---|
| Description | REST (Representational State Transfer) is an architectural style that can is also applied for web services.<br><br>HTTP based RESTful APIs are defined with these aspects:<br><br>• base URI, such as http://example.com/resources/<br>• an Internet media type for the data. This is often JSON but can be any other valid Internet media type (e.g. XML, Atom, microformats, images, etc.)<br>• standard HTTP methods (e.g., GET, PUT, POST, or DELETE)<br>• hypertext links to reference state<br>• hypertext links to reference related resources. | SOAP web services are based on a "contract" between a service provider and the consumer which describes the rules of communication between them. These "contracts" are described using WSDL (Web Service Description Language) and through a directory called UDDI (Universal Description, Discovery and Integration) clients can identify which software system should be contacted for which type of data. So when one software system needs one particular report/data, it would go to the UDDI and find out which other system it can contact for receiving that data. Once the software system finds out which other system it should contact, it would then contact that system using a special protocol called SOAP (Simple Object Access Protocol). The service provider system would first of all validate the data request by referring to the WSDL file, and then process the request and send the data under the SOAP protocol. | XML-RPC works by sending a HTTP request to a server implementing the protocol. The client in that case is typically software wanting to call a single method of a remote system. Multiple input parameters can be passed to the remote method, one return value is returned. The parameter types allow nesting of parameters into maps and lists, thus larger structures can be transported. Therefore XML-RPC can be used to transport objects or structures both as input and as output parameters.<br>JSON-RPC is similar to XML-RPC but uses JSON instead of XML for exchange of data and communication with the service provider.<br><br>XML-RPC later evolved to SOAP. |
| Advantages | • More flexible and simple interface for API development and consumption<br>• Less bandwidth usage is possible<br>• Security can be left to network administration<br>• Less client side complexity | • Contract based<br>• Standards based<br>• Strongly typed<br>• Support from a wide variety of libraries for client side development | • Simple to implement<br>• Simple to consume (results come either in XML or JSON) |

[45] Description as presented in http://en.wikipedia.org/wiki/SOAP and http://en.wikipedia.org/wiki/Representational_state_transfer - accessed 02 March 2015

| Name | RESTful APIs | SOAP | RPC |
|---|---|---|---|
| Disadvantages | • Loosely typed<br>• Not good handling of attachments.<br>• Not many libraries supporting easy client side development | • Security is debatable<br>• More bandwidth possibly required<br>• More complex to implement and consume by third parties | • No contracts or standards based<br>• More bandwidth possibly required<br>• Older technique which evolved to SOAP |

### 2.3.8 Summary

This section provides an initial overview of existing water information platforms in the market. The consortium has identified their main features and benefits, as well as their shortcomings. The shortcomings are catalogued mainly in terms of how these platforms would be able to fulfill the requirements that the platform developed under Waternomics envisions to offer.

After that the section covers all obvious key technologies that build up the existing platforms. Based on these technologies (i.e. back-end or front-end web application frameworks or mobile app development platforms), the group identifies which features would be useful for each step of the process in Waternomics. Some of the most important characteristics for choosing technology in Waternomics is the degree of customization and changes allowed by each of these technologies for the specific purpose of the project. This means that factors such as licensing or programming language play a significant role. For example, the programming language used should be in line with the main applications developer partner's philosophy and know-how.

# 3 Policy inventory

In this section we describe the increase of governmental awareness of the role of ICT in the protection of resources and the environment. We elaborate on how these policies have been accompanied by efforts directly promoted from industry sectors through different programs. We briefly discuss the complexity of policy design and its application in regulations and standards at different levels. We present by means of an example (ie. water quality regulations) that the actual implementation and drive for specific standards will be very much dependent on the realities in the ground. In this section we raise as well our conclusions when it comes to policies directly designed for the adoption of ICT technology in the water sector. We conclude that even there has been an increase attention to fostering the development of ICT technology for the protection of resources (including water) there are no specific policies to which we can clearly attribute a push (or support) for the implementation of measures through the use of ICT technology in the water sector. In this discussion we engage on what are the consequences of these learnings for the project WATERNOMICS.

## 3.1 Governments' policies and programs

Increasingly governments are dedicating more time in their agendas around topics such as ICT development. What is more, governments are progressively seeing ICT technology as an enabling factor of their ongoing strategies to tackle environmental protection concerns. The OECD developed a study in 2009 where these developments are explained in detail.

Governments can encourage the adoption of Green46 practices by the implementation of rules that can be either of a voluntary enforcement (code of conduct) or legally binding national laws and regulations. Governmental programs can impact the promotion, adoption and use of ICT in different ways:

- Stimulate R&D and innovation: these would include all programs funded by governments dedicated to research new resource-efficient (ICT) technologies. This is a clear example of the efforts lead by EU funds to support research projects such as WATERNOMICS. Increasing the budget spent on R&D has been a priority in order to create economic stimulus. In times of recession, several governments (OECD and non-OECD), use part of their 'stimulus packages' to help and promote the investment in green technologies. For example Germany dedicated EUR 5.7 billion (2008 - ?) to green technologies such as smart buildings or smart electricity grids. Another program has been channelled through tax measures that encourage the adoption of green technologies by facilitating the investment or purchase of these products.[47]
- Increasing Green ICT diffusion and ICT applications: these practices include the sharing of best practices and developing either measuring tools, benchmarking programs, eco labels or standards. An example of best practices dissemination is the example of Denmark's Action Plan for Green ICT, which accumulates experiences of Danish enterprises using Green ICT and it is made available for other companies that wish to start incorporating Green ICT[48].

[46] Note: the original document does not describe the authors understanding of Green ICT but there are recurrent references to Green ICT being the control of the impact of green ICT as the impact reduction (ie. pollution, components disposal) rather than the enabling environmental protection processes that can be initiated through ICT technology.
[47] OECD. 2009. Towards Green ICT Strategies: Assessing Policies and Programmes on ICT and the Environment (p. 13)
[48] Ibid (p. 16)

Besides the direct assistance to research and development and the adoption of green practices of enterprises, policies can also be designed to target other types of users: individuals and households. Distribute environmental information through ICT applications are one of the most common uses of ICT technology. However, smart ICT solutions alone do not translate into behavioural changes of sustainable pattern consumptions. There are examples in which countries or regions have established these educational programs, always in relationship with the environmental context (and the importance of the resource - and its protection- to the region). For example, in California, due to extreme droughts in the summer of 2014 the Department of Water Resources, together with the California water department has developed a web-based educational support tool to raise awareness of water pattern behaviours. Even though that has been claimed to be important the OECD report (2009) mapping Green ICT strategies at government level identified only 50 national governments (out of the 92 participating in the study) explicitly engaged or had developed in this kind of policies.

The European Resource Efficiency Platform reporting49 to the European Comission (EC) on their policy recommendation reflects the influence that governments and the role and expectation it is put in the role of governments have in driving the change to resource conservation and environmental protection. Below an extract (adapted from original):

> *We urge the European Comission to take our recommendations forward making use of the opportunity of the Europe 2020 mid-term review to make resource efficiency (and circular economy) an essential block in the Europe 2020 agenda to deliver smart, sustainable and inclusive growth.*
>
> - *Promote new, resource efficiency business models: foster the transition to more resource-efficient and service-based business models. Remove possible legal, financial or institutional barriers that prevent resource conservation*
> - *Enabling consumers to make more sustainable choices: Support the extension of consumer choice to more sustainable products and services.*
> - *Speeding up the development and use of indicators: include indicators that cover the resource use in the production chain, providing insights and raise public awareness on the global effects of (EU) production and consumption.*

This extract of the Manifesto shows the extend of reach of influential groups and the weight and importance is given to governments in setting the path for adoption of green strategies.

## 3.2 Other influences

The initiatives undertaken by the European Resource Efficiency Platform as illustrated above reflect the need (and the ambition) to include and work together with different organizations. There are several organizations and initiatives at the EU level that have been, and continue to be, important in the development of policies and technology related initiatives, and in this case specific, in their relation to water. Table 32 highlights these organizations and initiatives:

*Table 32 European influential groups*

| Name | Description |
|---|---|
| **European Innovation Partnerships on Water** | The European Innovation Partnership on Water (EIP Water) was established in 2012. It aims to speed up development of water innovation, contribute to sustainable growth and employment, |

[49] European Resource Efficiency Platform (EREP). Manifesto & Policy Recommendations (March, 2014) : http://ec.europa.eu/environment/resource_efficiency/documents/erep_manifesto_and_policy_recommendations_31-03-2014.pdf (accessed 15 January 2015).

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

## 3.3 Policies and standards at different governance levels

Due to the regional variability and potential severity of climate change, resource availability or degree of maturity of the organization of pressures in the sector (refer to WP2 - task 2.1. Governance and Knowledge Transfer - for more information), most adaptation measures will be taken at national, regional or local level. However, these measures can be supported and strengthened by an integrated and coordinated approach at EU level[50]. Each location will have its own idiosyncrasies, its own specific user portfolio, and will have to manage specific locally available natural resources. All these elements will shape which technology is used, which prioritization it receives and how effective its implementation will be. 'Regulatory bodies are characterized by different types of leadership and varying durations of term, with consequences on the stability of the process'[51] meaning that the way regulations are cascaded down and to what organizations could have an effect on their eventual enforcement and on their impact/implementation. However, when these policies or strategies, get translated to the national level a case by case study is necessary to determine how they have been adopted, who has promoted them and under which entity do they fall.

[50]Even though at times the document refers to standards and policies outside of the EU, the analysis is mainly restricted to EU applications due to the current scope of the project WATERNOMICS (ie. pilot cases). ICT for Water Management. EU. 2009.

[51] Staub, S. (2009). Governance in Water Supply. Thematic paper for the Global Development Network project "varieties of Governance: Effective Public Service Delivery'. Arqade and IDEI.

These variations can be observed in Table 33 Standards can be developed at a regional level (ie. EU), national level (ie. the Netherlands) or even at sector level (ie. energy, water, heavy industry) and at organizational level (ie. corporate culture). The variety of levels and the levels of enforcement will also translate into more or less detailed required standards. For example, while OFWAT in the UK has developed a levy system by which every unmet goal and standard a fine has already been determined (ie. 20 GBP for unmet appointment), other organizations will leave their standards for an indication (i.e. benchmarking initiatives in the Netherlands in which utilities can compare their performance against one another, but a lower performance does not translate into penalties).

*Table 33 Comparison drinking water standards*

| | WHO | EU | Netherlands |
|---|---|---|---|
| | Guidelines for Drinking-Water Quality | Council Directive 98/83/EC | Besluit kwaliteitseisen en monitoring water 2009 (in Dutch) |
| Chloride (Cl) | 250 mg/l | 250mg/l | 200mg/l |
| Bromate | 10 (provisional guideline) | 10 | 1 |
| *Escherichia coli* (*E. coli*) | 0 in 100 ml | 0 in 250 ml | 0 |
| Turbidity | Not specified | Acceptable to consumers and no abnormal change | 4 NTU |
| PH | Not specified | ≥ 6.5 and ≤ 9.5 | ≥ 8 and ≤ 9.5 (*from individual utility report) |

In the UK for example, each departmental government is responsible for the application of policies, including Green ICT related policies. Nevertheless, the national council has as well established a nation-wide Green ICT Strategy. The implementation of this strategy is supported by the Ministry of Defence. Arguably, even though policies are coordinated at a highest possible level (ie. EU initiatives are even intergovernmental level), the actual implementation may vary per location and for each and every governance level, that will have to deal with other influencing factors for that specific level, most clear example is budgetary autonomy to carry out the plans.

Under the scope of resource conservation (e.g. water and energy consumption) many regulations have been implemented that can potentially shape how water is used, disposed or the tariff imposed by the supplier. For example, the Energy Efficiency Directive does not establish direct obligatory prescriptions for the water sector. However, some associations or government organizations have taken the initiative to promote efficiency targets in terms of energy. The German Association for Water, Wastewater and Waste (DWA) has not specifically determined targets for energy efficiency at individual urban wastewater treatment plants (UWWTPs), but instead has proposed that energy checks and analyses are conducted. Resource efficiency targets may also be incorporated into policies by individual water utilities. For example, local authorities in the French towns of Orleans and Hyeres have requested that their water operators fulfil certain energy efficiency improvements, often with bonus/penalties clauses where such improvements are not met.

## 3.4 ICT policies in the water sector and Waternomics

From our review we conclude that governments and business initiates concentrate mainly on reducing energy consumption and CO2 emissions, and not necessarily targeting reduction of water consumption as a stand-alone objective (ie. reduction in water consumption is paired with

its associated reduction in energy - production, treatment). For energy and pollution reduction governments see the value and promote the use of ICT technology. The high concentration of programmes and initiatives targeting energy consumption reduction most probably indicate the importance of them in economic and environmental terms. Other environmental impact categories as it could be interventions for biodiversity protection, land use or reduction of water consumption are rarely targeted by these policies despite their important impact[52].

From this initial analysis we conclude that there are no specific water related policies that directly enforce the use of Green (ICT) technology. However, research has been developed to assess the positive connection that regulations have on technological change and innovation. Several research outcomes show that, specifically, environmental regulation affects the development of new green technologies [16]. For example, a research on the EU Emission Trading Systems (and the Annual Emission Audit linked to it) shows the positive effects this system has had on innovation in low-carbon technologies among regulated companies [17].

Influential industries such as Energy (leaving the significant governance differences between industries aside), or general policy initiatives of making Cities 'smarter', also have a potential influence on ICT developments in efficient water use and distribution. For example, in the EU and US climate change related legislation has driven the development of smart technology in the energy sector. Some of these efforts are reflected in mandatory national roll-out of smart metering. In the UK the government has committed to have all connections smartly metered by 2020 or the US has committed US$ 4.5 billion to the development of smart grids through their taxation system (through tax stimulus) (Accenture, 201053). Advanced Metering Infrastructure, which allows for a two-way data flow between utility and consumer is increasingly becoming important as energy companies move to this more advance metering infrastructure. The developments in this technology geared by advancements in the energy sector are translating into increasingly cost competitive infrastructure appealing to other less advanced utilities, for example water utilities. Developments in the energy sector do not only play a role in spearheading technological developments, but there is increased acknowledgment on how combined practices between utilities (energy/water) in the development and adoption of smart technology can be of benefit to both sectors. For example, a smart grid and smart water metering solutions has already been deployed in the Netherlands but its full potential will be reassured if utilities (water and others - energy) can developed a new business model by which they can combine efforts in the installation, maintenance and monitoring of these grids (see Accenture, 2010 but reconfirmed in interviews with Waternet Amsterdam - October 2014). For that to happen, privacy, security and communication protocols need to be critically assessed (legally - what is allowed, as well as technological - what is available).The CEN-CENELEC-ETSI (Three EU organizations forming the European Standards Organizations) coordination group 'Smart and Sustainable Cities and Communities' is aimed at catalysing progress made in ICT technology from water to energy to transportation, or any other relevant element to the development of cities for a wide-scale deployment and to foster innovative approaches. These initiatives, which are mostly not driven/spearheaded by the water sector, can have an impact on how technology should be developed for the sector.

Therefore, even though there are no regulations that dictate how ICT should be developed or adopted for and the water sector, there are still policies that (see next section). The project should continue alert on the developments of ICT in a) the energy sector, and how those can be rolled out to the water sector. Water specific regulations (even though not related to ICT

[52] OECD. 2009. Towards Green ICT Strategies: Assessing Policies and Programmes on ICT and the Environment (p. 5)

[53] http://ec.europa.eu/information_society/activities/sustainable_growth/docs/water_cons/henk-jan-top_presentation.pdf

adoption) are included in the next section. In addition, the project should remain in close contact to the industry influential groups to follow up on last developments and changes.

# 4 Standards inventory

There are several reasons why standardization is important in the development of new technologies. In order to develop ICT that reaches full market potential it is important to work towards a tool that works in itself, but that is also fully operational with its supporting infrastructure. Standards play a significant role in bringing different elements of a system to working order. Standards are technical specifications that support the development of technology (or others). In this way, standards set the norm (or requirements) for any given technical system. Standards vary from technical standards, to criteria and methods and processes: “the effectiveness of the Information Society is determined by the ability of the component parts to 'talk' to each other, or to interoperate each other's messages. Without this prerequisite, the use of ICT products and services would be restricted. Networks and platforms require interoperability" (ICT Standards Board). On the other hand, there have been several projects initiated at EU level to standardize the development and implementation of technology in the regional market. Such projects (through CEN-CENELEC-ETSI) helped minimize the fragmentation of the technology market and facilitate the exploitation of technologies and unify development efforts.

This section reviews standards necessary to comply with, or use as guiding principle for the development of future technology within Waternomics. Compliance with such standards will ensure any technology developed within Waternomics is enabled to communicate and operate with surrounding systems and infrastructure. This section also lists policies (and regulations) that have been influential in the water sector (different, but linked to the previous section). It is not the aim of this inventory to make an exhaustive listing of standards, nor of policies, but rather to enumerate significant standards that can guide, but also inspire, the development of Waternomics technology. At the same time it lists regulations (or policies) that even though not directly related to water distribution networks, do still play a role in the development of the Waternomics technology. For example, EU directives related to water quality are listed because of the influence and push for change they have had in water management in EU. Similarly regulations related to data privacy and ownership are discussed as these will be vital elements of the Waternomics platform. This section mainly focuses on mapping EU-regional standards and policies; but also includes listings of other relevant standards that can be used by the project (i.e. US or global reach). The definite standard (minimum requirements) list to follow is identified at a later stage in the project (see Deliverable 1.3. - System architecture and KPIs)

## 4.1 Guidelines and standards for the provision of water

Guidelines and standards around the provision of water (in relation to end users, but also resource protection) concern minimum service level agreements on, for example, quality and continuity of services (e.g. hours per day a household receives tap water), and customer service. The way these services are met or how utilities (and by extension corporations) fulfil them is not necessarily specified in these guidelines. This is illustrated in Table 27 below, several regulations that describe the different elements water distribution utilities normally consider as important are presented. The UK and the Netherlands[54] are known for having a well-developed regulated system water sector, be it through independent authority’s or the central government. The case of Australia responds to the aim of Waternomics to reflect practices in regions where water availability has proven to be a challenge and the management of water resources has been characterized by the implementation of advanced (including technology) operational guidelines.

[54] These are not cases of WATERNOMICS but provide a leading example for the water sector in Europe. We provide these two examples because we expect the markets in the water sector of UK and the Netherlands to be most advanced and therefore, include topics such as ICT implementation practices.

*Table 34 comparison of guiding principles between water supply utilities*

| | OFWAT (UK The Water Services Regulation Authority)[55] | Government of the Netherlands[56] | Urban Water Services ( Victoria, Australia)[57][58] |
|---|---|---|---|
| | Guiding principles | Drinking Water Act 2009 | Water Industry Act 1994 |
| Water Quality | Not mentioned | The owner of a water company shall ensure that the drinking water that he makes available to consumers or other customers , does not contain organisms, parasites or goods, in number per unit volume or concentrations that adversely affect could affect public health | Not (explicitly) mentioned |
| Communication (to customers: what, when and how) | Each company should adhere to the following principles: accurate, transparent, clear, accessible, timely and customer led. In addition: Each company will: provide information to customers which empowers them to secure the lowest possible bills and best possible service, involve customers and representatives in preparing, changing and implementing its information provision approach, consider its adherence to our information provision requirements in its yearly risk and compliance statement and demonstrate this to Ofwat if required to do so | contributing to it in terms of public health responsibility deal with drinking water by owners , consumers and other users between the point of delivery and the point where the drinking water for consumption is made available , which is understood in any case : 1 °. providing information to consumers; 2 °. preparation of technical requirements for the connect to its network and connected facilities; | A water business must inform affected customers in writing of the time and duration of any planned interruption to a service at least two business days in advance. |
| Environmental protection | Water is a precious resource, and is likely to become more so in the coming years. [...]. Water companies have an important role to play in | contributing to the protection of sources of drinking water in its distribution area from pollution, which is understood in any case : | A water business must have policies, practices and procedures to deal with a burst, leak or blockage in its system, including to: [...] (4) the |

[55] http://www.ofwat.gov.uk/regulating (accessed 17th December 2014)
[56] http://wetten.overheid.nl/BWBR0026338/geldigheidsdatum_17-12-2014#HoofdstukI (accessed 17th December 2014)
[57] http://www.esc.vic.gov.au/getattachment/b2a40cfc-617a-4a24-80b4-4d521fa2c520/Code-Customer-Service-Code-for-Victorian-metropoli.pdf (accessed 17th December 2014)
[58] Another example can be Ireland: http://www.water.ie/docs/Irish-Water-Business-Codes-of-Practice.pdf

| | OFWAT (UK The Water Services Regulation Authority)[55] | Government of the Netherlands[56] | Urban Water Services ( Victoria, Australia)[5758] |
|---|---|---|---|
| | delivering water supplies. They have to plan how they will meet the demand for water in the most efficient way. That includes meeting targets to reduce leakage and increase water efficiency. | 1 °. conducting research into the quality of these sources ;<br>2 °. managing or co-managing areas around these sources aimed at preventing or reducing pollution from these sources | environment |
| Continuity (of supply) | All customers of water and sewerage companies are entitled to guaranteed minimum standards of service, as laid down by the Government. These rights are known as the guaranteed standards scheme (GSS). Where a company fails to meet any of these standards of service then it is required to make a specified payment to the affected customer. We monitor the scheme and recommend charges. | The owner of a water company must ensure that the supply of good drinking water to consumers and other customers guaranteed in the distribution range established for his water company is in such quantity and at such pressure as in the interest of public health is required | A water business must ensure that a customer's water supply and recycled water supply is at least equal to minimum flow rates specified in the water business's approved service standards |
| Metering (consumption) | Water metering is encouraged to utilities as to consumers: Paying for what you use means you are more likely to use water wisely. This means each water company should set the metered volumetric charge to recover the costs that it will spend over the longer term to meet demand. This will help the companies meet the environmental challenges that the water and sewerage sectors face | Not mentioned | A water business must use reasonable endeavors to ensure that all customers whose properties have a meter which measures volumetric use for billing purposes have an actual meter reading every billing cycle, or otherwise at least once every 12 months. |

The degree of detail and importance given to each and every one of the elements responds the needs of the specific context. However, there are several factors and categories that become recurrent with discussing the minimum of service level (ie. water quality, metering or continuity) of water utilities (or likewise operating organizations). Most of these elements can be aided by the installation of technology, such as water quality controls, environmental protection through monitoring of discharges and abstractions, metering consumption, maintaining service

continuity and many others. However, none of the analysed guidelines explicitly refers to a specific type of technology, and also not to ICT or 'smart' technology, to be implemented.

## 4.2 Reference to key standards

Having acknowledged the divergence between standards, and accepting that standards will have to be monitored locally, in this section we provide an overview of standards that we believe are relevant to keep in mind for the development of the Waternomics platform.

### 4.2.1 Technical

In the following table we collect several standards developed at European level for the installation, monitoring and maintenance of meter reading or leakage control in particular, or asset management more in general.

*Table 35 Overview selected technical standards*

| Name | Reach | Brief description/ Comments | Links |
|---|---|---|---|
| **CEN/TC 294 - Communication systems for meters and remote reading of meters** | EU | Standards which are under approval (yet to be approved by EU). This European Standard specifies data exchange and communications for meters and remote reading of meters in a generic way. This European Standard establishes a protocol specification for the Application Layer for meters and establishes several protocols for meter communications which may be applied depending on the application being fulfilled. | http://standards.cen.eu/dyn/www/f?p=204:32:0::::FSP_ORG_ID,FSP_LANG_ID:6275,25&cs=1A1D2A71837AB4AB1532B872DBD554033 |
| **CEN/TC 92 - Water meters** | EU | This European Standard specifies definitions, requirements and testing of additional functionalities for water meters, without metrological impact, in combination with Additional Functionality Devices (AFD) | http://standards.cen.eu/dyn/www/f?p=CENWEB:110:::::FSP_ORG_ID,FSP_PROJECT:6075,37072&cs=1333BCE1437CC5F96DB134A589DCC40B9 |
| **EN 16646:2014 (WI=00319016) Maintenance - Maintenance within physical asset management** | EU | This European standard introduces physical asset management as a framework for maintenance activities. It also introduces the relationship between organizational strategic plan and maintenance management system and describes the interrelations between maintenance process and all the other physical asset management processes. It addresses the role and importance of maintenance within physical asset management system during the whole life cycle of an item. NOT specifically for water utilities. | http://standards.cen.eu/dyn/www/f?p=204:110:0::::FSP_PROJECT,FSP_ORG_ID:36065,6300&cs=103C6938952FC9E44DAAD244CA1B571A9 |
| **Asset Management: A Best Practices Guide** | | This guide will help you understand:<br>• What asset management means.<br>• The benefits of asset management.<br>• Best practices in asset management.<br>• How to implement an asset management program. | http://water.epa.gov/type/watersheds/wastewater/upload/guide_smallsystems_assetmanagement_bestpractices.pdf |
| **Different standards related to leakage** | US | Water-related leakage standards are mainly found for the main pipes in distribution systems as obligatory testing during installation. Some relevant standards include standards from America Water Works Association (AWWA), ISO 10802:1992, American Society for Testing and Materials (ASTM) and US EPA standards. For which the links are provided. This standards are not mainly for leakage detection in service pipe. | http://www.awwa.org/publications/standards.aspx<br>http://www.iso.org/iso/catalogue_detail.htm?csnumber=18864<br>http://www.astm.org/Standards/G18.htm<br>http://www.epa.gov/oust/pubs/protocol.htm |

### 4.2.2 Water quality

In this sub-section we add the EU driven directives directly related to water quality conservation and water quality. Although in Waternomics the focus is not directly on water quality issues, it is important to collect at this point as they significantly influence how water is managed and have driven the agenda of, among others, technology use in monitoring and water management.

*Table 36 Overview selected water quality standards*

| Name | Reach | Brief description/ Comments | Links |
|---|---|---|---|
| **DIRECTIVE 98/83/EC on the quality of water intended for human consumption** | EU | This Directive concerns the quality of water intended for human consumption.<br>2. The objective of this Directive is to protect human health from the adverse effects of any contamination of water intended for human consumption by ensuring that it is wholesome and clean. | http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:1998:330:0032:0054:EN:PDF |
| **Urban Waste Water Directive (9 1 /271 /EEC)** | EU | This Directive concerns the collection, treatment and discharge of urban waste water and the treatment and discharge of waste water from certain industrial sectors.<br>The objective of the Directive is to protect the environment from the adverse effects of the abovementioned waste water discharges. | http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:31991L0271 |
| **Water Framework Directive** | EU | This directive commits European Union member states to achieve good qualitative and quantitative status of all water bodies. | http://eur-lex.europa.eu/legal-content/EL/TXT/PDF/?uri=CELEX:32000L0060&from=EN |

### 4.2.3 Management and certification

This section presents standards developed by the International Organization of Standardizations (ISO). These standards present series of business processes that should to be adhered to in order to certify and assert quality in business processes. While these standards do not drive the adoption of specific technology, some of the process improvements they require for certification may be aided by the implementation of technology, as for example, monitoring of performance indicators (i.e. resource abstraction, water losses) or assessment tools.

*Table 37 Overview selected management standards*

| Name | Reach | Brief description/ Comments | Links |
|---|---|---|---|
| **ISO 24512 (2007) - Guidelines** | Global | It provides guidelines for the management of drinking water utilities and for the | http://www.iso.org/iso/home/store/catal |

| | | | |
|---|---|---|---|
| **for the management of drinking water utilities and for the assessment of drinking water services** | | assessment of drinking water services. It is applicable to publicly and privately owned and operated water utilities. It addresses drinking water systems in their entirety and is applicable to systems at any level of development (e.g. on-site systems, distribution networks, treatment facilities). The following are within the scope of ISO 24512:2007:the definition of a language common to different stakeholders, guidelines for the management of drinking water utilities; guidelines for objectives, service assessment criteria and related performance indicators, appropriate for the assessment of drinking water services | ogue_tc/catalogue_detail.htm?csnumber=37248 |
| **ISO/TC 224 (2008) - Quality criteria of the service and performance indicators** | Global | Standardization of a framework for the definition and measurement of service activities relating to drinking water supply systems and wastewater systems. | http://www.iso.org/iso/home/standards_development/list_of_iso_technical_committees/iso_technical_committee.htm?commid=299764 |
| **ISO 24510 (2007) - Guidelines for the assessment and for the improvement of the service to users** | Global | It specifies the elements of drinking water and wastewater services of relevance and interest to users. It also provides guidance on how to identify users' needs and expectations and how to assess whether they are being met.<br>The following are within the scope of ISO 24510:2007:the definition of key elements and characteristics of the service to users, guidelines for satisfying users' needs and expectations, service to users assessment criteria; examples of performance indicators. | http://www.iso.org/iso/home/store/catalogue_tc/catalogue_detail.htm?csnumber=37246 |
| **ISO 50002 (2014) - Requirements with guidance for use in energy audits** | Global | It specifies the process requirements for carrying out an energy audit in relation to energy performance. It is applicable to all types of establishments and organizations, and all forms of energy and energy use. | http://www.iso.org/iso/home/store/catalogue_tc/catalogue_detail.htm?csnumber=60088 |
| **ISO 12242 (2012) - Measurement of fluid flow in closed conduits** | Global | Requirements and recommendations for ultrasonic liquid flowmeters. It specifies performance, calibration and output characteristics of ultrasonic meters (USMs) for liquid flow measurement and deals with installation conditions. | http://www.iso.org/iso/home/store/catalogue_tc/catalogue_detail.htm?csnumber=51289 |

### 4.2.4 Privacy and data ownership

The WATERNOMICS' platform will collect, store and share information and data from sensors. Some of these sensors are located in private property, and some of them collect data from private users in public spaces. It is important for the project to consider what data can be shared, how it can safely be stored so that privacy and ownership data rights are not violated, following the directives described in the table below.

*Table 38 Overview selected privacy and data ownership standards*

| Name | Reach | Brief description/ Comments | Links |
|---|---|---|---|
| **Data Protection Acts 1988 and 2003** | National (IE) | Irish Water may keep the customer's data for a reasonable period after the customer ceases to be supplied with water services but will not keep it for any longer than is necessary and/or as required by law […]Irish Water may share the customer's data (excluding PPS – Personal Public Service-numbers which will be deleted as outlined above) with authorised agents or third parties who act on behalf of Irish Water in connection with the activities referred to above, pursuant to a contractual relationship | http://www.water.ie/data-protection-notice/ |
| **EU Directive 95/46/EC – Data Protection Directive** | EU | Personal data can only be gathered legally under strict conditions, for a legitimate purpose. Furthermore, persons or organisations which collect and manage your personal information must protect it from misuse and must respect certain rights of the data owners which are guaranteed by EU law | http://eur-lex.europa.eu/legal-content/en/ALL/?uri=CELEX:31995L0046 |
| **Directive 2002/58 – E-privacy Directive** | EU | Drafted specifically to address the requirements of new digital technologies and ease the advance of electronic communications services. The Directive complements the EU 95/46/EC and applies to all matters which are not specifically covered by this previous Directive. In particular, the subject of the Directive is the “right to privacy in the electronic communication sector” and free movement of data, communication equipment and services. | http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX:32002L0058:en:HTML |

# 5 Conclusions

The aim of this document has been to present an, even though not exhaustive, inventory technologies available to Waternomics, and an analysis of standards and policies that will be considered during the development of the Waternomics platform. In the technology chapter we have listed state-of-the-art examples from hardware technology, to cloud storage and data warehouses, to user interfaces and web development. This logic follows the development logic of the holistic platform being developed by the project. The inventory of technology has been explored in great detail. The purpose is, especially for the sensing technology part, to be able to provide potential clients with an overview of technologies available and explain how the platform of Waternomics makes use of them or builds on them.

The technology inventory in D1.2 compiles a set of technologies that complete the building phases of the Waternomics platform. The platform will be built upon flow, pressure and losses in water systems information. This information will be sent, captured and stored in data platforms to be subsequently presented to the final users by means of a web application or a mobile device. This document collects an inventory of all these technologies following this logic. The inventory starts with a list of sensing technologies that will collect the information necessary to build the platform. The project will measure flows, pressure and leakage detection. For each and every type of measurements the inventory provides a brief list of techniques and lists relevant devices most appropriate for the pilot cases of Waternomics. Relevant devices for flow measurements should be robust, reliable, have an electrical output signal for remote control, be able to be installed on pipes of different diameters, be able to operate bi-directionally. Electromagnetic, ultrasonic and mag meters fulfil these requirements. For pressure measurements the document highlights the Wheatstone bridge-based sensor, the capacitive sensor or the piezoelectric sensor. These sensors seem to all be sensitive to temperature changes but all offer good to excellent precision. The decision will be based on availability to electricity outlets or space available for installation. Audio sensors or microphones will be used to collect sound signals generated from household water piping system. Sound sensors are relatively cheap and easy to install than flow and pressure sensors and provide opportunity to develop low-cost non-intrusive technique of detecting leakage. For data transmission the inventory ranges from satellite data transmission devices to Wi-Fi devices. The pilot cases are generally indoor environments. Although distances in the pilots will be relatively short and in some cases Wi-Fi is available, access to power, signal strength and data transmission requirements will require case-by-case solution design.

The next step in the inventory is dedicated to the available data platforms and focuses on the analysis Infrastructure as a Service of available vendors (Amazon Web Services, Microsoft Azure and Google Compute Engine) as it allows self-managing more than other types of platforms. The decision of which of the platforms to use will be based on elements related to data protection, operating costs, infrastructure, performance. Once the data has been stored the report describes different water information platforms that can inform the development of the Waternomics platform in terms of gaps to cover or flexibility of services. After that the report elaborates on minimum requirements and recommendations of technologies (ie. languages) that build the platform: back and front-end web application frameworks or mobile app development technologies.

The policies and standards have been developed in two different chapters. Policies and standards are intimately linked; being standards often times the product of compliance with a specific policy. The reason for separating the two in this report is because of the nature of the inventory. In the policies chapter we have elaborated on the influence of policies in the development of ICT technology. With respect to the guidelines, standards and policies relevant for the development of ICT in water management, no specific regulation has been found that prescribes the development or adoption of a specific ICT technology in enabling a more efficient use and supply of drinking water. However, what we discuss is how several

policies and standards can positively influence the adoption of 'smart' water technology. It is to these policies, standards, and pointers of information (organizations and IT-driven initiatives) that the project needs to relate to in order to develop a product that is relevant for water providers and water users and ensure the marketability of the Waternomics platform. Most importantly the consortium will remain alert in development the other influential industries such as energy (significant differences aside), or general initiatives of making cities 'smarter', as will be analysed more in-depth in the subsequent WP2 of Waternomics. This document does not serve as a static picture for the project, but it does provide some initial indications. As the project progresses sections of this document will need to be revisited and complemented to serve specific local realities. The work developed in the chapter of policies and standards is further developed in subsequent Work Packages (WP) in Waternomics. In WP2 (Methodology) the consortium investigates in more detail matters of governance for selected cases (ie. Australia or the Netherlands) to inform how decisions around ICT technology take place and which factors are of influence. In this same package, standards are developed in more detail. More specifically, the consortium analyses how standards in the energy sector, as we have seen far more developed, can inform developments of the project.

# Annexes

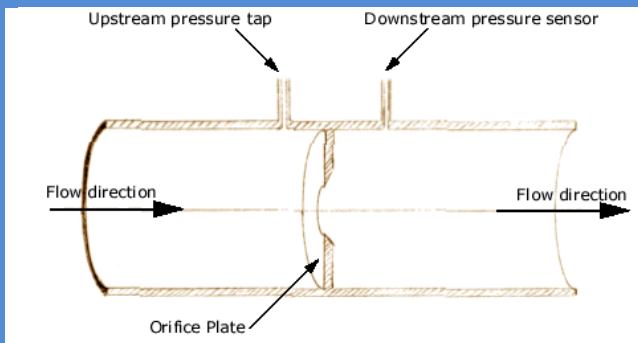
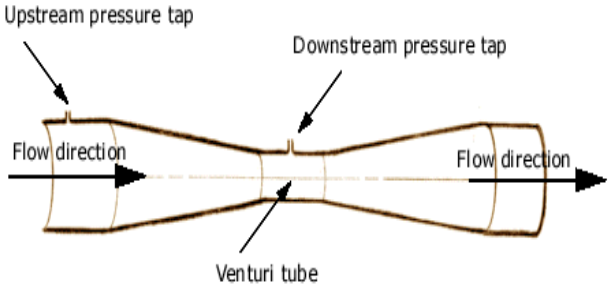
## Annex 1: Sensing technologies

This annex collects in detail all measuring methods are not directly relevant for WATERNOMICS but that the consortium deemed important to document to inform eventual later stages of the project.

### Differential Pressure based method

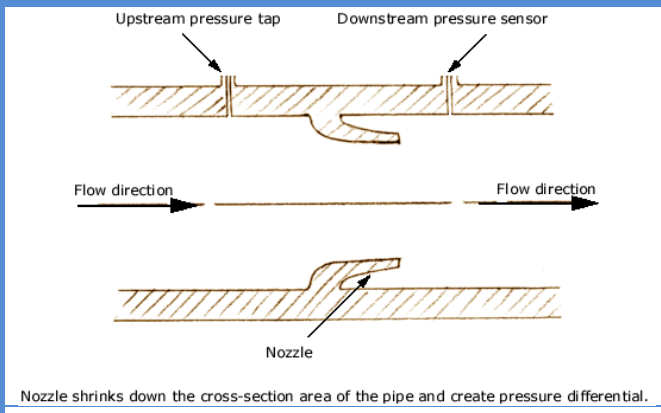
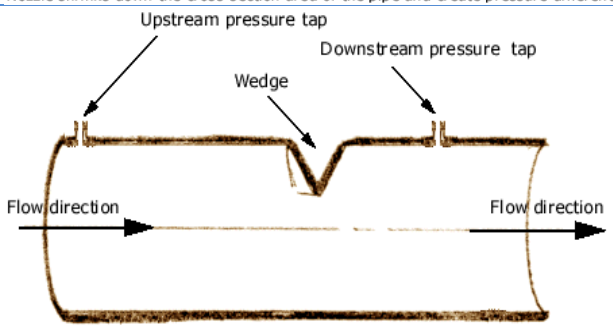
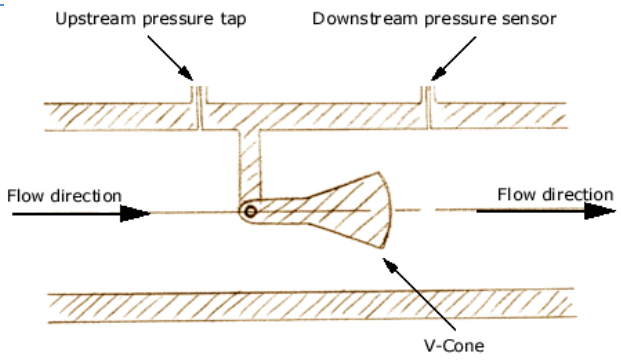
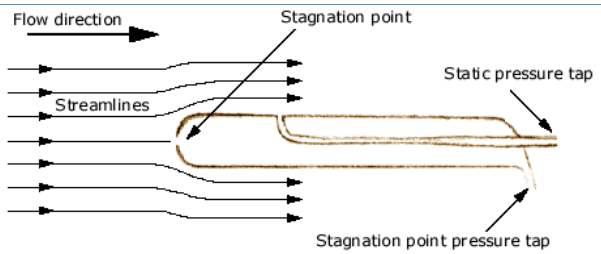
Differential pressure flow meters are a well established technology and commonly used today in all kinds of liquid flow measurements. The flow rate is obtained by measuring the pressure differential and extracting the square root. Differential pressure flow meters have two elements: a primary element causes a change in kinetic energy and the second element measure the differential pressure. It is important that the first element is properly installed in relation to pipe size, flow conditions and liquid's properties[59].

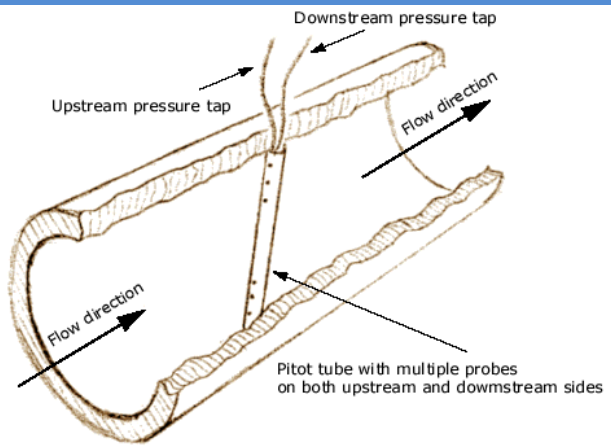
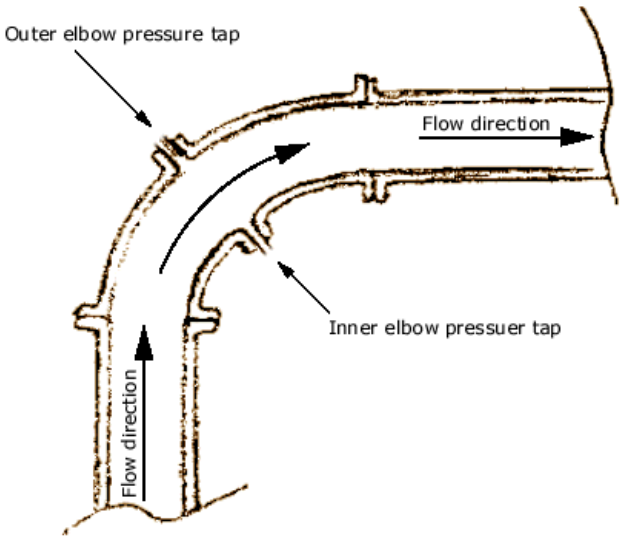
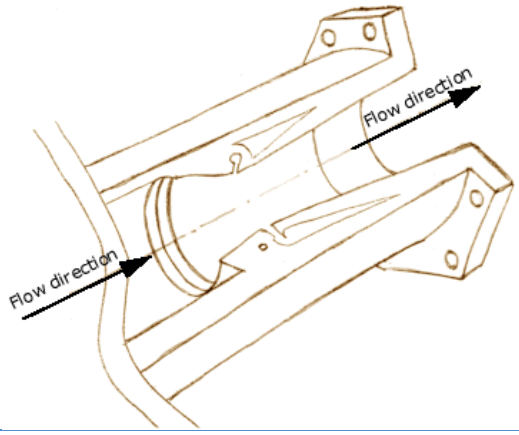
*Table 39: Different technologies to measure the flow in a closed piping system based on differential pressure method[60]*

| | Figure | Description |
|---|---|---|
| **Orifice Plate:** |  | A flat plate with an opening is inserted into the pipe and placed perpendicular to the flow stream. As the flowing fluid passes through the orifice plate, the restricted cross section area causes an increase in velocity and decrease in pressure. The pressure difference before and after the orifice plate is used to calculate the flow velocity. |
| **Venturi Tube:** |  | A section of tube forms a relatively long passage with smooth entry and exit. A Venturi tube is connected to the existing pipe, first narrowing down in diameter then opening up back to the original pipe diameter. The changes in cross section area cause changes in velocity and pressure of the flow |

[59] Guide to the Measurement of Pressure Vacuum. National Physical Laboratory. 1998/ http://www.npl.co.uk/upload/pdf/Guide_to_PV.pdf and http://saba.kntu.ac.ir/eecd/ecourses/instrumentation/projects/reports/Flowmeter/diff.htm - accessed 02 March 2015

[60] http://www.bingo-sensor.com/blog/2013/07/types-of-differential-pressure-flow-meters/ (accessed 20 October 2014).

| | Figure | Description |
|---|---|---|
| **Nozzle:** |  Nozzle shrinks down the cross-section area of the pipe and create pressure differential. | A nozzle with a smooth guided entry and a sharp exit is placed in the pipe to change the flow field and create a pressure drop that is used to calculate the flow velocity. |
| **Segmental Wedge:** |  | A wedge-shaped segment is inserted perpendicularly into one side of the pipe while the other side remains unrestricted. The change in cross section area of the flow path creates pressure drops used to calculate flow velocities. |
| **V-Cone:** |  | A cone shaped obstructing element that serves as the cross section modifier is placed at the centre of the pipe for calculating flow velocities by measuring the pressure differential |
| **Pitot Tube:** |  | A probe with an open tip (Pitot tube) is inserted into the flow field. The tip is the stationary (zero velocity) point of the flow. Its pressure, compared to the static pressure, is used to calculate the flow velocity. Pitot tubes can measure flow velocity at the point of measurement. |

| | Figure | Description |
|---|---|---|
| **Averaging Pitot Tube:** |  | Similar to Pitot tubes but with multiple openings, averaging Pitot tubes take the flow profile into consideration to provide better overall accuracy in pipe flows. |
| **Elbow:** |  | When a liquid flows through an elbow, the centrifugal forces cause a pressure difference between the outer and inner sides of the elbow. This difference in pressure is used to calculate the flow velocity. The pressure difference generated by an elbow flow meter is smaller than that by other pressure differential flow meters, but this system does not obstruct flow as much of other technologies. |
| **Dall Tube:** |  | A combination of Venturi tube and orifice plate, it features the same tapering intake portion of a Venturi tube but has a 'shoulder' similar to the orifice plate's exit part to create a sharp pressure drop. It is usually used in applications with larger flow rates. |

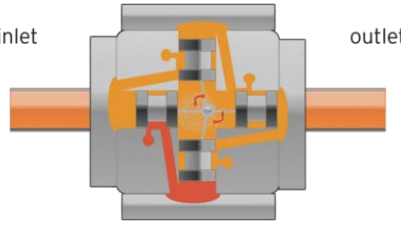
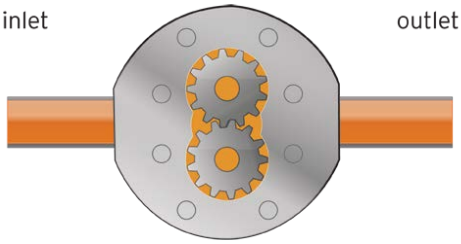
### Positive displacement based method

Positive Displacement (PD) flow meters are volumetric flow measurement instruments that measure flow by passing a precise volume of fluid with each revolution. This meter can measure intermittent flows, very low flow rates, and liquids of almost any viscosity[61].

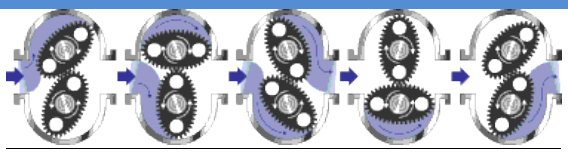
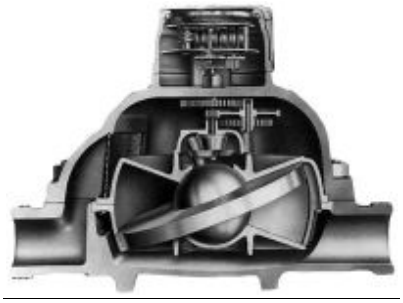
[61] http://www.maxmachinery.com/positive-displacement-flow-meters - accessed 02 March 2015

Their high precision has allowed PD flow meters to be almost universally accepted for billing and transfer standard applications, such as gasoline and fuel oil dispensing, natural gas or water measurement.

*Table 40: Different technologies to measure the flow in a closed piping system based on positive displacement method*[62]

| | Figure | Description |
|---|---|---|
| **Piston flow meters** |    | Piston flow meters comprise single or multiple-piston systems. The pistons displace fluid in the same way that a syringe operates. Each piston displacement captures the same amount of fluid |
| **Gear flow meters** |   | Gear flow meters use two round gears that are mounted in overlapping compartments.The measured fluid is trapped in the voids of the gear teeth and transported from the inlet port to the outlet port as the fluid flow causes the gears to rotate. |
| **Helical flow meters** |    | Helical [Gear] Flow Meters use two screw-shaped rotors to chop the fluid stream into fixed displacement volumes. The rotors' orientation is in-line with the fluid flow path. These meters rotate with a very low pressure drop, and can turn at high rpm's making them accurate over wide flow ranges and compatible with very high viscosity fluid applications. |
| **Oval-gear meters** | | Oval gear meters have two rotating, oval-shaped gears with |

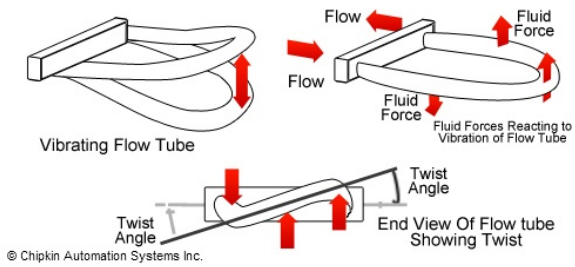
[62] http://www.maxmachinery.com/positive-displacement-flow-meters - accessed 20 October 2014

| | Figure | Description |
|---|---|---|
| |  | synchronized, close fitting teeth. A fixed quantity of liquid passes through the meter duringeach revolution. |
| **Rotary vane meters** |  | Rotary vane meters consist of equally divided, rotating impellers, in two or more compartments, inside the meter's housings. The impellers are in continuous contact with the casing. A fixed volume of liquid is swept to the meter's outlet from each compartment as the impeller rotates |
| **Nutating disk meters** |  | Nutating disk meters have a moveable disk mounted on a concentric sphere located in spherical side-walled chambers. The pressure of the liquid passing through the measuring chamber causes the disk to rock (wobble) in a circulating path without rotating on its axis. The disk/sphere is the only moving part in the measuring chamber |

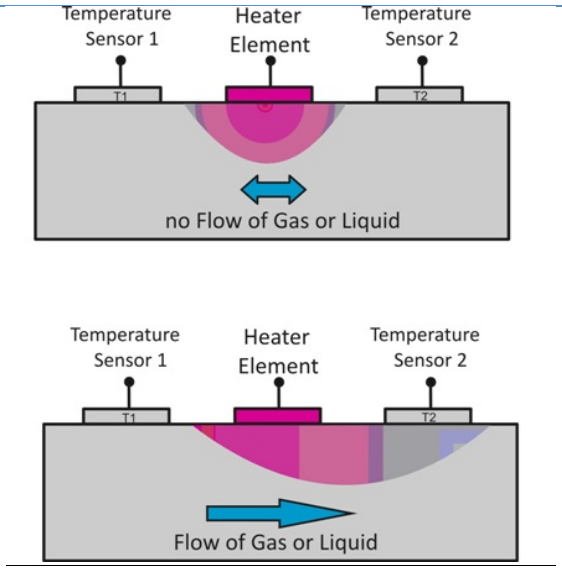
### Mass based method

In this kind of sensors the output signal is directly related to the mass passing through the meter. Thermal and Coriolis flow meters fall into this category. Generallysuch meters are not used for water however a brief description of the measurement method is presented as these meters have some potential in the water sector..

*Table 41 Different technologies to measure the flow in a closed piping system based on mass method*[63]

| | Figure | Description |
|---|---|---|
| **Coriolis Flow Meters** |  | Using the Coriolis effect (which causes a laterally vibrating tube to distort), a direct measurement of mass flow can be obtained in a coriolis flow meter. Furthermore a direct measure of the density of the fluid is obtained. Coriolis measurement can be very accurate irrespective of the type of gas or liquid that is measured; the same measurement tube can be used for hydrogen gas and bitumen without recalibration. Coriolis flow meters can be used for the measurement of natural gas flow. |

[63] http://www.maxmachinery.com/what-is-a-flow-meter - accessed December 2014

| | Figure | Description |
|---|---|---|
| | | (sourced from http://en.wikipedia.org/wiki/Flow_measurement - accessed January 2015) |
| **Thermal Flow Meters** |  | Thermal mass flow meters generally use combinations of heated elements and temperature sensors to measure the difference between static and flowing heat transfer to a fluid and using data on the fluid specific heat and density it can infer its flow rate. The fluid temperature is also measured and compensated for. If the density and specific heat characteristics of the fluid are constant, the meter can provide direct mass flow readouts, and does not need any additional pressure or temperature compensation over its specified range. (sourced from http://en.wikipedia.org/wiki/Flow_measurement and http://www.omega.nl/techref/flowcontrol.html - accessed January 2015) |

Thermal mass flow meters are used, generally, for gas flow applications. As the name implies, thermal mass flow meters use heat to measure flow. This method works best with gas mass flow measurement because it is difficult to get a strong signal using thermal mass flow meters in liquids, due to considerations relating to heat absorption.

On the other hand Coriolis mass flowmeters measure the force resulting from the acceleration caused by mass moving toward (or away from) a center of rotation, the "swinging" is generated by vibrating the tube(s) in which the fluid flows. Also this measurement method is particularly suitable for gas flow application while for water application is generally avoided because pipe vibration can cause problems during operation. However in the context of WATERNOMICS project pilot's installations we will prefer ultrasonic, electromagnetic and turbine flow meter for all the reasons mentioned in section 2.1.1.1.

The following tables show the main characteristics, the field of application and the purchase costs of the methods of flow measurement listed above.

*Table 42: Field of application, maintenance and costs for differential pressure based method flow meter*[64]

| | Field of application | Maintenance | Purchase Cost range |
|---|---|---|---|
| **Orifice plate** | measure flow rates in pipes, when the fluid is single-phase (rather than being a mixture of gases and liquids, or of liquids and solids) and well-mixed | low | €100 – 1700 depending on the size of the pipes |
| **Venture tube** | This method is widely used to measure flow rate in the transmission of gas through pipelines, and to measure small and large flows of water and wastewater | low | €100 – 4000 depending on the size of the pipes |
| **Flow Nozzle** | The flow nozzle is recommended for both clean and dirty liquids | low | € 100 – 2000 depending on the size of the pipes |
| **Segmental Wedge** | The segmental wedge is used for liquids, gas and steam applications | low | € 100 – 2500 depending on the size of the pipes |
| **V-Cone** | The V-Cone is suitable for today's most challenging oil / gas production, chemical, food & beverage, plastics, pharmaceuticals, district HVAC, textile, power and water & wastewater applications | low | € 100 – 1500 depending on the size of the pipes |
| **Pitot Tube** | The pitot tube is used for liquids, gas and steam applications | low | € 200 – 1000 depending on the size of the pipes |
| **Averaging Pitot tube** | The averaging pitot tube is used for liquids, gas and steam applications | low | € 200 – 1500 depending on the size of the pipes |
| **Elbow** | The averaging pitot tube is used for liquids applications | low | € 200 – 1000 depending on the size of the pipes |
| **Dall Tube** | It is more compact and is commonly used in large flow applications | low | € 300 – 3000 depending on the sizeof the pipes |

*Table 43:Field of application, maintenance and costs for positive displacement based method flow meter*

| | Field of application | Maintenance | Purchase Cost range |
|---|---|---|---|
| **Piston flow meters** | measure flow rates in pipes, when the fluid is water, oil or fuel | low | € 100 – 500 depending on the size of the pipes |
| **Gear flow meter** | This method is widely used to measure flow rates in pipes, when the fluid is water, oil or fuel | low | € 100 – 1000 depending on the size of the pipes |
| **Helical flow meter** | This method is widely used to measure flow rates in pipes, when the fluid is water, oil or fuel | low | € 100 – 2500 depending on the size of the pipes |
| **Oval gear flow meter** | The oval gear flow meter is used for liquids, gas and fuel applications | low | € 100 – 4000 depending on the size |

[64] Sourced from http://www.npl.co.uk/upload/pdf/Guide_to_PV.pdf and http://saba.kntu.ac.ir/eecd/ecourses/instrumentation/projects/reports/Flowmeter/diff.htm - accessed 02 March 2015

| | | | |
|---|---|---|---|
| | | | of the pipes |
| **Rotary vane flow meter** | The rotary vane flow meter is used for liquids, gas and fuel applications | low | € 100 – 4000 depending on the size of the pipes |
| **Nutating disk flow meter** | The pitot tube is used for water | low | € 100 – 4000 depending on the size of the pipes |

*Table 44: Field of application, maintenance and costs for mass based method flow meter*

| | Field of application | Maintenance | Purchase Cost range |
|---|---|---|---|
| **Thermal flow meter** | Thermal flow meters are most commonly applied to measure pure gases | low | € 500 – 5000 depending on the size of the pipes |
| **Coriolis flow meter** | This method is widely used to measure flow rates in pipes, when the fluid is natural gas | low | € 100 – 2000 depending on the size of the pipes |

## Annex 2: Overview devices

| Figures | Type | Application | Name | Features | Advantages | Disadvantages | Link to supplier |
|---|---|---|---|---|---|---|---|
| | Sensor | Flow measurement | Mag meter | - Principle: Farady's law of induction<br>- Output: voltage is proportional to flow rate | - No moving parts | - Invasive to pipe<br>- Pipe needs to be grounded<br>- Fluid needs to be conductive<br>- Time-costing installation | http://en.wikipedia.org/wiki/Magnetic_flow_meter |
|  | Sensor | Flow measurement | Magphant (Endress+ Hauser) | - Measuring principle: electromagnetic<br>- Insertion type<br>- Accuracy: ±2%<br>- Protection level: IP66 | - No moving parts | - Drilling holes in the pipe<br>- Time-cost installation<br>- Not cost-effective | Direct contact with the supplier |
|  | Sensor | Flow measurement | Proline Promag 50W, 53W (E+H) | - Measuring principle: electromagnetic<br>- Inline type<br>- Protection lelvel: IP 67/68 | - Good protection | - Pipe needs to be cut<br>- Time-cost installation<br>- Not cost-effectiv | Direct contact with the supplier |
| | Sensor | Flow measurement | Ultrasonic flow sensor | - Measuring principle: transit-time difference | - Non-intrusive<br>- Easy installation<br>- No leakage potential<br>- Handle with pure liquid | - Suffering from pipe wall interference<br>- Signals may influenced by the purity or bubbles of the liquid | http://en.wikipedia.org/wiki/Ultrasonic_flow_meter |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
|  | Sensor | Flow measurement | Proline Prosonic Flow 91W (Endress+ Hauser) | - Clamp-on type<br>- Measuring range: DN15mm to DN2000mm<br>- Accuracy: ±2% | - Non-intrusive<br>- Easy installation | - High cost | https://portal.endress.com/wa001/dla/5000300/2064/000/01/TI00105DEN_1311.pdf |
|  | Sensor | Flow measurement | OPTISONIC 6300 (Krohne) | - Clamp-on type<br>- Measuring range: DN15mm to DN4000mm<br>- Accuracy: ±1% ( DN≥50 mm); ±3% ( DN<50 mm) | - Non-intrusive<br>- Easy installation | - High cost | http://www.krohne-downloadcenter.com/dlc/TD_OPTISONIC6300_en_090818_4000255303_R05.pdf |
|  | Meter | Flow measurement | Woltman meters ( ZENNER ) | - Measuring principle: turbine<br>- Bulk water meter<br>- Vertical turbine shaft<br>- Measuring range: DN 50mm - DN 200mm | - Used for cold or hot water | - Pipe needs to be cut<br>- No electrical output itself | http://www.zenner.com/product_categories/category/products_bulk-water-meters/product/bulk-water-meter-woltman-s_perpendicular.html |
|  | Meter | Flow measurement | Smart meter (Elster) | - Electromagnetic water meter<br>- Bulk water meter<br>- Watertight<br>- High accuracy<br>- Measuring range: 50mm to 200mm | - With pulse unit for electrical output | - Pipe needs to be cut<br>- For cold water | http://www.elstermetering.com/en/product-detail/779/en/Q4000?fid=B0BE94CC8FFC46E0985D68A09733E46F#sbox0=; |
|  | Sensor | Data reading | Water meter sensor (Hamlin) | This one does not exist on the market. | | | http://www.hamlin.com/news-detail.cfm?article=15 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | Sensor | Leakage detection | Acoustic listening equipment | - Acoustic signal<br>- When a leak occurs, a resulting low frequency acoustic signal is detected | | | http://en.wikipedia.org/wiki/Leak_detection |
|  | Sensor | Leakage detection | Eureka3 | - 16-bit digital correlation processing<br>- Velocity correction function<br>- Compact, with in-case battery charging<br>- Automatic and manual filter options<br>- GPS connection for leak position | - High definition touch screen for easy operation<br>- Multiple applications on one processor | | http://primayer.com/wlc_leak_location_eureka2r.htm |
|  | Sensor | Leakage detection | Guterman n | - cordless leak noise correlator<br>- most compact and portable correlator | | | http://en.gutermann-water.com/products/leak-noise-correlators/ |

# Annex 3: Level measurements

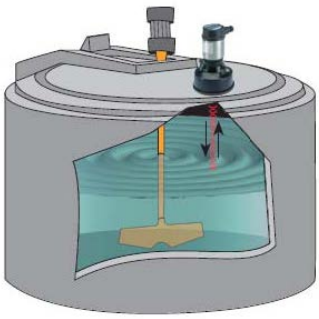
### Level measurement

Level measurement can be done in two ways; (i)contactless (without physical contact between the surface of the flow and the sensor) and (ii) contact (sensors immersed in the fluid). Level measurements are made contactless by the propagation and reflection of particular wave forms at high frequency, in particular:

- 30:70 kHz (ultrasonic measurement method)
- with frequency of 10 GHz (radar measurement method)

In the water sector ultrasonic contactless measurement methods are most commonly used.

*Table 45: Ultrasonic contactless measurement methods*[65]

| | |
|---|---|
|  | Ultrasonic devices employ a piezoelectric crystal stored inside a transducer. Sound energy is released towards the material and reflected back to the transducer, which converts the sound energy back to an electric signal. A proper signal processor then analyses this echo and calculates the distance between the target (material level) and the transducer, taking into consideration that the time lapse between the initiation of the sound signal and its return back is proportional to the distance between the target and the transducer. Ultrasonic technology is mainly used for continuous level measurements. Ultrasonic devices are easy to install, have no moving parts and are not in contact with the vessel material. Thus, material compatibility issues are avoided. One of the disadvantages of this technology is that foreign particles like dust or vapour can affect the reliability and accuracy of the ultrasonic device. |
|  | Radar devices transmit an electromagnetic wave towards the material. The overall transit time to and from the target (material level) is calculated and directly related to the distance in between taking into consideration that the difference between the transmitter and receiver frequency is directly proportional to the distance covered. Use of electromagnetic wave presents the advantage that the signal is not affected by environmental factors such as temperature, humidity, pressure, vapour, dust or others. |

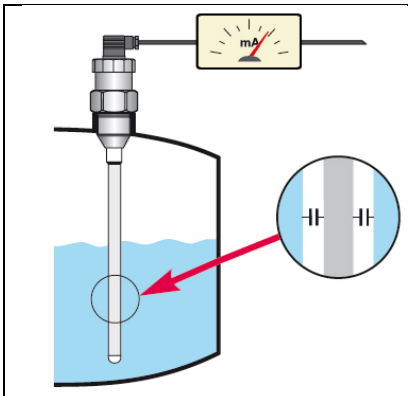
In the water sector the following sensors are most frequently used:

- capacitive transducers
- piezoresistive transducers

*Table 46: Level measurement with immersed sensors*[66]

| | |
|---|---|
| | Capacitive transducers typically comprise two parallel conductive plates that are separated by a proper insulator. A metal probe (measurement electrode) measures the |

[65] "Ricerca e controllo delle perdite nelle reti di condotte" B. Brunone – Città studi eizioni
[66] "Ricerca e controllo delle perdite nelle reti di condotte" B. Brunone – Città studi edizioni

| | |
|---|---|
|  | difference in the probe's capacitance when either fluid is present inside the vessel or pipe. A second reference electrode is also included in order to close the circuit and allow current flow. Capacitance measurement devices are generally easy to install and have no moving parts, thus minimising maintenance costs. On the other hand, any changes due to temperature or chemical composition of the material inside the vessel will alter the dielectric properties, thus resulting to errors and the need for recalibration. |
|  | Piezoresistive level transducers are based on the measurement of the hydrostatic pressure acting on the bottom of the tank to calculate the height of the liquid column. |

Piezoresistive level transducers are particularly suitable for situations where a pumping plant takes water directly from a well (see Linate pilot) and inputs directly to the water distribution network to be distributed to all the users for different uses (potable and industrial use) so could be necessary to monitor the groundwater level to avoid problems at the pumps.

# Annex 4: Actuating devices

### Specialized Pumps and Valve devices

Smart valves and pumps adjust their operations based on environmental conditions or signals from sensors. These adjustments are done automatically or remotely (from a central control point). The main benefit of smart controllers is increased efficiency. For example, variable frequency drive pumps sense water conditions and will increase or decrease pumping rate depending on specified parameters. Also systems can be included that sense blockages and take action such as breaking the blockage or remove the blockage (e.g. by reversing the flow). One manufacturer of a smart pump estimates up to 70% cost savings over the life cycle of the pump using such techniques. The ability of pumps self-regulation of the speed is obtained generally through the introduction of inverter devices.

Inverters are generally installed due to the potential to save energy, optimize resources and processes, integrate systems management (of control and supervision), extend the life of the plants, reduce maintenance costs, increase productivity and yield of a plant.

One example relevant to the Waternomics project is a pumping station pumping water directly from a well to a water supply network. If regulated by an inverter, one can control and maintain constant the pressure in a given "field flow" over the entire day, depending on the load demand (amount of water needed as shown in Figure 11). This type of scenario is present for the project pilot at Linate Airport where inverters at many of the pumping stations are used.

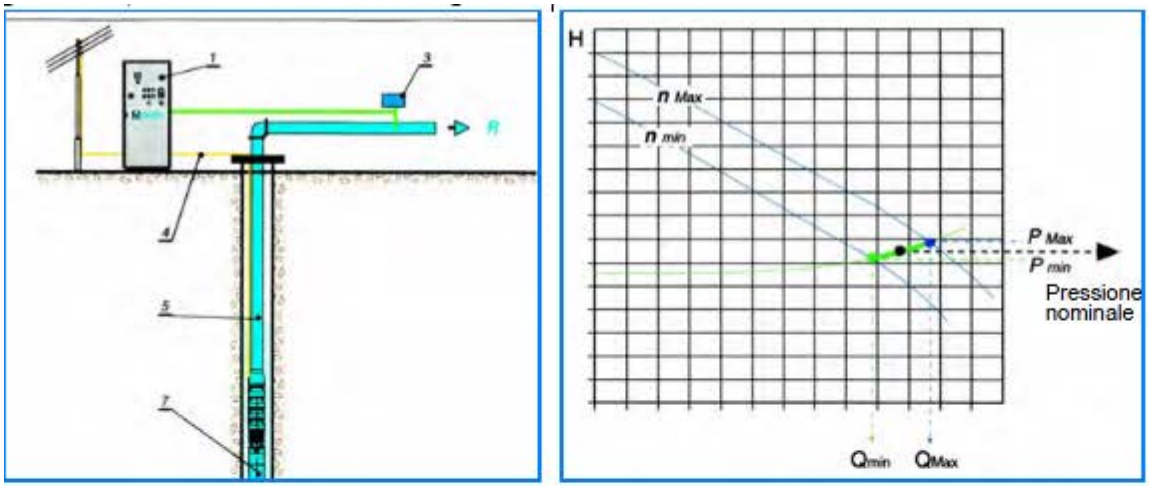



*Figure 11 pumping plant that take the water directly from a well with input directly to the network*

Facilities such as those in Figure 11 [67] have certain advantages. For example, they eliminate large tank sand autoclaves, have lower operating costs, save energy, display increased pump life, and do not require the construction of additional tanks or installation flexibility.

At the household level and so more interesting for Thermi pilot, there are also intelligent sensors that can control pumps according to consumption in domestic water supply and booster systems. One such sensor is the Pressure Manager[68] which is also example of an intelligent sensor. It works well with domestic water supply pumps – including other pump brands for use in home environments. It is suitable for applications where automated

[67] See "Elettropompe a velocità variabili nella gestione delle acque – OMRON"
[68] http://www.grundfos.com/products/find-product/pressure-manager.html#brochures – accessed December 2014

start/stop of pumping equipment, based on current water consumption is required. The Pressure manager sensor allows pump start from 1.5 or 2.2 bar (typical house water pressure). The pump is started when the designated start pressure is reached, and keeps running as long as there is flow. This intelligent device provides dry-running protection and a cycling alarm for increased safety. It can be equipped also with an internal pressure tank to minimise starts and stops in the event of leaks in the installation. In addition, the smart device can be optimised for operation with a large external pressure tank by enabling at 1bar differential pressure function. This can minimise the pump operating for the pressure tank.(www.grundfos.com,

The reported features and benefits are (as reported on the manufacturer's webpage, www.grundfos.com):

- User-friendly interface
- Free choice of installation position
- Flexible power supply
- Internal pressure tank
- Pump running indication
- Alarm indication
- Dry-running protection
- Rotary outlet connection


*Figure 12: Pressure Manager*[69]

At the water network level (for example for Linate pilot where all the water network is piloting) too higher pressure may damage pipes or fixtures, which can be a risk to workers and operators. High water pressures waste water, so only with a pressure reduction we can reduce water consumption, reduces the excess energy required for water flows through the system. There are two types of water pressure reducing valves, direct acting and pilot operated. Direct acting valves are used more often. These have a spring that with pressure equalizing mechanism for the valve for precise water pressure control. (www.watts.com)

[69] http://www.grundfos.com/products/find-product/pressure-manager.html#brochures – accessed October 2014

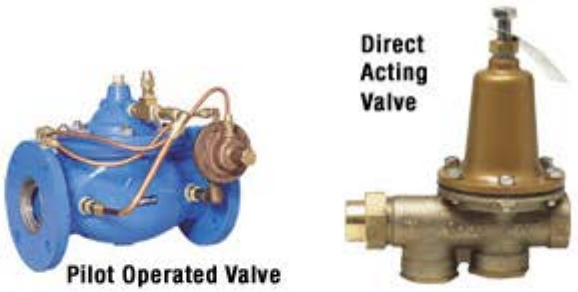



*Figure 13 Direct Acting Valve and Pilot Operated Valve for reducing pressure in a water distribution networ (www.watts.com)*

A water pressure reducing valve (PRV) automatically reduces the pressure from the water supply main to allow a more stable pressure for the water network to achieve water and energy saving. . One example of installation of a PRV is in Linate pilot where we have a water network set up to 5 bar pressure, this pressure value, particularly in an area in which there are only low buildings (one or two floor at least) is a very high pressure value. The consequence of the high pressure are: higher leakages in water network, higher pumps energy consumption, higher probability of pipes rupture, high probability to damage fixture, higher amount of water wasted. The installation of a PRV allows to avoids these problem achieving a more efficient water network. (www.watts.com)

Intelligent valves adjust or block the flow of water in pipes based on environmental conditions. They can be used as part of pressure management strategies or leak detection activities. For example at the household level (Thermi pilot) or at scholar users level (NUIG pilot) smart water valves such as LeakSmart[70] can detect irregularities in home's water flow and notify your Smartphone preventing water wastage. The intelligent water valve has two components;(i) a Wi-Fi-enabled valve, and (ii) a square sensor that connect directly to a home's main water pipe. The device also has applications for shut off water flow remotely.


*Figure 14 LeakSmart*

[70] http://www.tomsguide.com/us/leaksmart-prevents-flood-damage,news-18184.html – accessed October 2014

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