European Catalogue of ICT

Water Standards and Specifications

ict4water.eu

A study prepared for the European Commission
DG Communications Networks, Content & Technology with support from

Digital Single Market

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with acknowledgement to Svetoslav MIHAYLOV (DG CONNECT) for his contribution and support

Internal identification

Contract number: LC-00823983

EUROPEAN COMMISSION

Directorate-General for Communication Networks, Content and Technology

H5 - Smart Cities & Sustainability

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ISBN:

978-92-76-17850-7

Catalogue No: KK-03-20-234-EN-N

doi: 10.2759/39178

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European Catalogue

of Information and Communication Technologies Water Standards and Specifications

Abstract: The aim of the European Catalogue of Information and Communication Technologies (ICT) Water Standards and Specifications is to support the Action Plan for Water Services in the context of the Digital Single Market as well as the Rolling Plan of the European Commission for digitalisation of the water management. More specifically, the objectives include mapping of the existing Water Management Platforms, architectures and standards, gap analysis, priorities and feasibility of the integration, interoperability, and convergence of different technological solutions. The document contains: 1. Analysis of the water digitalisation level in Europe; 2. Principles for standard and specification assessment; 3. Coordinated efforts of the relevant stakeholders and end-users through different projects that could be used as use-cases for standards' development; 4. Proposed changes to the European Commission Rolling Plan for ICT standardisation in smart water management. The European Catalogue of ICT4Water standards and specifications also presents the adoption of priorities, feasibility of integration, interoperability recommendations and specifications in due consideration of the ICT Standardisation Priorities for the Digital Single Market.

How to Read the European Catalogue of ICT Water Standards and Specifications?

This document presents the state of the art in the field of ICT water standards and specifications. The document starts with requirements settings that are based on the stakeholders' and end-users' expectations. More than 50 projects in the sector are analysed and specified. The standardisation organisations are presented with stress on the interoperability and possibility to be integrated worldwide and at European level. The gaps analyses are explained both on projects and standards separately for the convenience of the reader. The conclusions present also the priorities in two, four and six years term in the sector that should be taken into consideration.

The catalogue includes many references to different articles, white papers, web pages, projects and standards that are listed alphabetically at the end of the document. Citations follow so called Harvard style using the name of the first author or a keyword from the page as well as the date of publication and/or access. All figures are reprinted after written approval from the authors and publishing organisations. There is a list of abbreviations and specific terms at the end of the document.

1. Introduction and State of the Art

WATER is one of the many natural resources that are considered critical for the existence of life on the planet [ENVI Council, 2018]. Nature has kept the equilibrium in water resource management that is proven to be effective for millions of years, i.e. the vast use of the World Ocean for wastewater regeneration was sufficiently effective [UN Water, 2018]. However, in the last 200 years, the industrialisation processes in society have introduced technologies that could poison Earth's water and surface in hours. Therefore, there is a need for new recycling technologies that will not only prevent the contamination of water but will also allow the reuse of water and water in circular economy in different scale.

The role of the European Commission in the process of horizontal and vertical harmonisation and standardisation of the water use, reuse, water in circular economy, and mitigation of contamination has world–wide impact on the economic development, innovations, regulations, and management of natural resources. The experience gained in smart grids, smart cities, smart and green energy management, smart health care and living, smart houses and buildings as well as the implementation of Internet of Things (IoT) and other Information and Communication Technologies (ICT) are a good starting point for the technological convergence of water management [World Bank, 2018].

The ultimate goal of this activity is to demonstrate the process of technological upgrades, integration and interoperability support for existing and new water management platforms through new and existing European and global standards. The process of technological harmonisation has a long way to go and depends on many different factors like political will, motivation, investment, administration, maintenance, management capabilities and many others. The ICT4Water (ICT for Water) standards and specifications catalogue tries to show the entire value chain from raw data to end-to-end services during the technological transition towards water digitalisation and green technologies support in Europe. The experience collected within the scope of smart cities standardisation and market digitalisation is widely used [EC Smart Cities, 2019; Mihaylov, 2018].

Gaps in the ICT standards related to the water management are already identified by the ICT4Water cluster thanks to the work of multiple teams and projects in the field in the last years [Anzaldi Varas, 2018; Ict4water, 2018]. This catalogue continues the analyses of the standards' and platforms' gaps and disambiguates trying at the same time to point out important technological steps and priorities for reaching the objectives of the Digital Single Market (DSM) in the field. The aim is to provide circumstances for:

a) Better access for consumers and businesses to online smart water related products and services across Europe.

b) Creating the right conditions for digital networks and services to flourish in the sector.

c) Maximising the smart water sector growth potential of the European Digital Economy.

The main idea in this work is to promote the digitalisation of the water management through the use of smart meters, data collection, data abstraction and cloudification. This allows the collection of raw data relevant to smart water management in real-time, near-real-time and non-real-time and the development of micro and macro services on the top of the raw data [Trossen at al., 2019; 5g-ppp, 2018; ETSI TR 118 524, 2016].

The raw data and services are related to the end-users and stakeholders. They are defined at regional, national and international level and correlated to the appropriate legislation locally and internationally. The digitalisation in water sector has started with the implementation of different devices and services locally. The business models are fragmented and there is a lack of clear strategy for further integration and interoperability. The gap analysis and prioritisation aim to define a framework for reaching the Digital Single Market objectives in the smart water sector in synergy with other sectors [Sušnik at al., 2018].

The standards' gaps defined in the ICT4Water action plan [Anzaldi Varas, 2018] are related to issues that are also common to other listed smart IoT systems including:

- Limited interoperability between existing and new technological solutions having in mind that the proprietary platforms are not favoured any longer and the new trends of open, modular and interoperable systems are encouraged. This is expected to make the market more flexible and competitive while keeping the prices low at the same time.
- Limited data sharing between different parts of the platforms, which leads to local monopoly and local management of the data, creates difficulties in service delivery and in the control of data by different bodies, as well as with platform scaling and integration. The lack of data sharing prevents ICT global service creation and development.
- Limited "water smartness", or lack of appropriate sensors and automation in critical places that could, on the one hand, prevent disaster, damage, loss of resources and contamination, and on the other, allow for better management, control, administration, investment continuity, water infrastructure maintenance and water quality.
- Fragmented cyber-security with lack of common vision as to which part of the raw data could be shared and which part cannot be made publicly available, or how to detect and prevent hazardous situations in water supply and management.
- Limited actors' awareness of the situation in water management with respect to local regulations. The water distribution companies are partially obliged to announce information on water supply. The expectation of the society in this regard is very high because end-users like to be informed, to be allowed to take decisions and to be proactive. New policy on the water harvesting and smart homes makes the end-users active players in the water supply and management field.
- Lack of common market policy for making the water smart and platforms digital aiming to create integrated and interoperable systems from one side and identification of new end-to-end services from the other side.
- Lack of common business models that could allow better and cheaper public and private procurement of the platforms and systems at different scales starting from a small household and ending with water distribution companies, sewage companies, national parks, national water resources management bodies, transnational water resources management bodies, research organisations, etc.

The topics mentioned above have also resulted from the work on the roadmaps for water management carried in the framework of the European Initiative Partnership (EIP) on Water during 2015 and 2016 [ICT4Water roadmap, 2015; ICT4Water roadmap, 2016; EIP-WATER, 2018; Eip-water market, 2018]. After year 2016 the roadmaps are part of the Action plan [Anzaldi Varas, 2018]. Figure 1 presents the aim of the EIP on Water to matchmake the industry, suppliers and end-users.

The stakeholders' collaboration is important to open the water sector for innovation. Many projects have been working to test in real environment different aspects of this aligning. The EIP Water Marketplace collaborates interested colleagues and allows for products and services development. Specific water-related topic could be filtered, recent news on water innovation could be extracted automatically and published onto desktop via Really Simple Syndication technique (RSS).

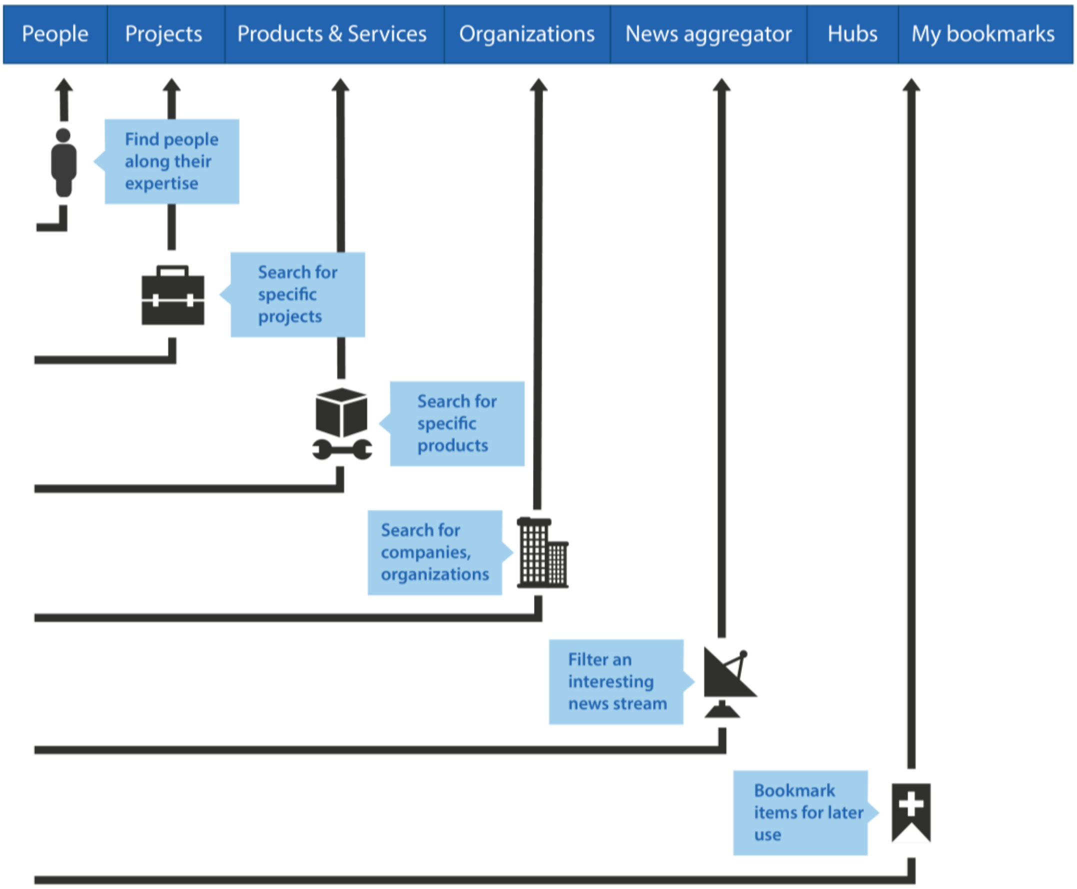

Figure 1. EIP on Water stakeholders' collaboration [EIP-WATER, 2018; Eip-water market, 2018]

Table 1 presents the main technological, social and organisational challenges addressed by EIP on Water as well as main standardisation gaps. The cost/benefit analysis is related to the efficiency and effectiveness of the existing platforms and have to be mapped also to the sustainability and continuity of the business in infrastructure development. Links to the smart cities as well as aligning between the water, food and energy increases the synergy between sectors and efficiency of the platforms. Big data management, cloudification and data sharing are considered to be essential solutions of the new systems. There are many existing field trials and most of them are still fragmented and specialised as many of the running and recently finished projects specified in the next sections.

There is a lack of Key Performance Indicators (KPIs) definitions to allow better requirements specification and analysis of the existing smart water platforms. A good starting point for KPIs definition is done in the scope of the CITYkeys project [CITYkeys KPIs, 2017; CITYkeys, 2017] for smart cities whereas the smart water management KPIs definition is still a pending task and is highly connected to the standardisation process.

The work done by ICT4Water sector and EIP on Water is a good starting point for selection of good use-cases for the further development of the standardisation in the sector and selection of better business practices. The smooth convergence process and appropriate business models for doing sustainable transition in smart water management are still not mature enough. There is a Pre-Commercial Procurement for Digital Single Market (PCP for DSM) announced by the DG CNECT of the European Commission (EC) aiming to stimulate the development of the innovative solutions for the public sector. Identification of the main problems and adequate scheduling of the standardisation activities is important for appropriate technological development in the water sector in general. This is reflected in the updates proposed in the EC rolling plan for ICT standardisation. There is a need for identification of the short, medium- and long-term priority steps, i.e. one to two years, up to four-five years and beyond.

Table 1. Comparison of roadmaps for water management

Roadmap 2015	Roadmap 2016
• Cost/Benefit analysis of ICT • Synergies across sectors • Data sharing • Interoperability • Standardisation • Indicators	• Big data • Data infrastructures • Link with smart cities • Nexus, water–food-energy • Standardisation • Lack of reliable field trials

More than fifteen different standardisation organisations are working worldwide and are active in Europe providing for ICT technologies implementation. Most of them are also in the position to provide significant input to the standardisation process in smart water management. The analyses of the water digitalisation level in Europe, North America, Japan, Korea, China, India, Africa, Australia, i.e. world-wide [World Bank, 2018] are clearly showing the fragmented picture of the water sector. The gaps and priorities in the standardisation, as well as the next technology implementation steps are identified with the strong support of the end-user and stakeholders' as follows:

- The ICT standards and business solutions should allow platform scaling, modular development and deployment in incremental steps and support business continuity.
- The level of use of IoT, cloud computing and communication infrastructures in recent water management architectures leads to the necessity to look for a heterogeneous solution that is capable to integrate different implementations.
- Different architectures, data models, hardware, software, communication structure, possibility of cloudification should allow integration and interoperability in different scales.
- The data sharing and data analysis should also be possible throughout different interfaces and protocols and allow customised and generic services definition and offers.
- The interoperability and synergy between the smart water, smart utilities, wastewater, waste management, but also smart cities platforms, energy, health, agriculture, transport etc. should provide cross-domain smart services and data sharing.

The European Commission Rolling Plan for ICT Standardisation [Rolling Plan, 2018, Rolling Plan, 2019] only partially touches upon the smart water sector. The policy and the strategic plan in water management are still in preparation. This catalogue defines the principles of comparison between the smart water management platforms and related supportive standards. The identified gaps allow for better standardisation planning, technology development, platforms procurement, platforms deployment, scaling, sustainability support, etc. More specifically this catalogue includes:

- Assessment of the existing projects and innovative specifications that could become use-cases in the standards development and coordination. The water sector use-cases types as seen in next sections are different starting from the river basins and national parks going through water distribution and wastewater management and ending with water in circular economy. This is the reason why more than 50 different use-cases have been selected in the next sections of the catalogue.
- Assessment of existing standards and their potential impacts in the sector that could support the integration, interoperability and cloudification in the smart water sector. The main standards existing in the field have been analysed with the support from multiple EU projects and clusters.
- Identification of short-term and long-term standards with priorities in development and implementation that could enable the technology and the market to grow towards sustainable smart water management.
- Data sharing at different levels of the architectures and specifically at southbound and northbound interfaces supporting the interoperability and platform integration. Data sharing needs also to be linked to data from other sectors like energy, weather, air, flora, fauna, soil, industry, agriculture as well as shared satellite data at EC level and world-wide.
- Analysis of the possible gateways to integrate and make legacy architectures interoperable even when they have heterogeneous parts and highly customised proprietary local implementations at different scales [Datta and Bonnet, 2014].
- Identification of the privacy of the water related data and transparency to the public bodies, national and international bodies through proper data sharing regulations, protection of the end-user's data while keeping the end-users well informed.
- The coordination steps between the relevant stakeholders and end-users allowing continuous definition and integration of existing and future services through the cloud, IoT systems and using big data analytics through their wide representation in the standard development.
- Smart water management at regional, national, and international levels by restructuring/ functional development of different agencies, governmental and international bodies.
- Clear view of the aligning of Anything-as-a-Service (AaaS) and Water-as-a-Service (WaaS). As a general rule the WaaS is considered as part of the AaaS because the AaaS is related to smart cities, agriculture, industry, health etc.
- Definition of the Water-as-a-Service micro and macro services at cloud, fog, dew, and smart dust computing levels as well as the level of water awareness for different actors and the transparency levels of the water related information. Fog, dew and smart dust computing levels refer to the distributed nature of the cloud at different scales.
- Focus on more specific tasks in the Action and Rolling Plans with possibility to update them when applicable.

2. Requirements to the Water Management Platforms

The first task in the evaluation of smart water development standards and platforms is to define the assessment principles from technological, social, administrative, and business point of view while taking consideration of the difference in information and communication services, models, requirements, processing, persistence, sustainability, protocols, interfaces and so on. The definition of requirements could not be done without the support of the relevant stakeholders and end-users as they form the group of main actors of the platform [Wsstp Stakeholders, 2015; Al Mahdi, 2017]. The role of the smart water management stakeholders is shown in the ITU Focus Group [ITU Focus Group, 2016] report. KPIs for smart cities are defined in [ETSI GS OEU 019, 2017].

Security issues in critical infrastructures are demonstrated in [ETSI TR 103 303 V1.1.1, 2016]. End-users and stakeholders work at different scales, i.e. locally, regionally, internationally, having a Small-Scale Implementation (SSI) in households, a Medium-Scale Implementation (MSI) in local water providers and a Big-Scale Implementation (BSI) in regional water distribution companies. New trends in water reuse, harvesting and water in circular economy are changing drastically the understanding of water sources management and water production. Experience gained in smart grid implementations using local and remote utility sources could be easily transferred to the digital water management.

The methodology for requirements' analysis of communication infrastructure demands the solutions to be:

- Open
- Hierarchical in layers and planes
- Based on standard interfaces and protocols
- Encapsulating data
- Ensuring separation between management, monitoring and control levels
- Interoperable by means of data sharing through gateways at different layers
- Integrated through gateways at different layers
- Heterogeneous by default allowing synergy between different systems
- Capable to define services based on the end-user and stakeholder requirements
- Capable to support short-term and long-term plans for standardisation
- Customised for water management, as water flows are different from water data flows

The methodology for requirements' analysis of cloud platform includes:

- Notion, idea, positive and negative implementations impact allowing further classification identification
- Features, i.e. specific aspect or attribute specification
- Generic features, i.e. common or high-level features extraction
- Abstraction, i.e. presenting the feature formally excluding the background details identification
- Interoperability definition

- Possibility to be integrated definition
- Classification of features
- New features definition
- Feature dependencies identification

These features lead to the ontology's implementations.

In some sectors like living environments [Autexier at al., 2017] the end-users are divided into primary, secondary, and tertiary users. Using the same analogy, the definition of main actors in smart water sector could also be defined in three groups as follows (Figure 2):

- Primary end-users and stakeholders that are directly related to the smart water management like house owners, water distribution companies, water providers, industries and agriculture farms using water in production, national parks, municipalities, water basins management companies, sea watching companies and research labs. They usually use the smart water services. End-users often are the driving force in the creation of the synergetic services for the citizens (Tables 2 and 3).

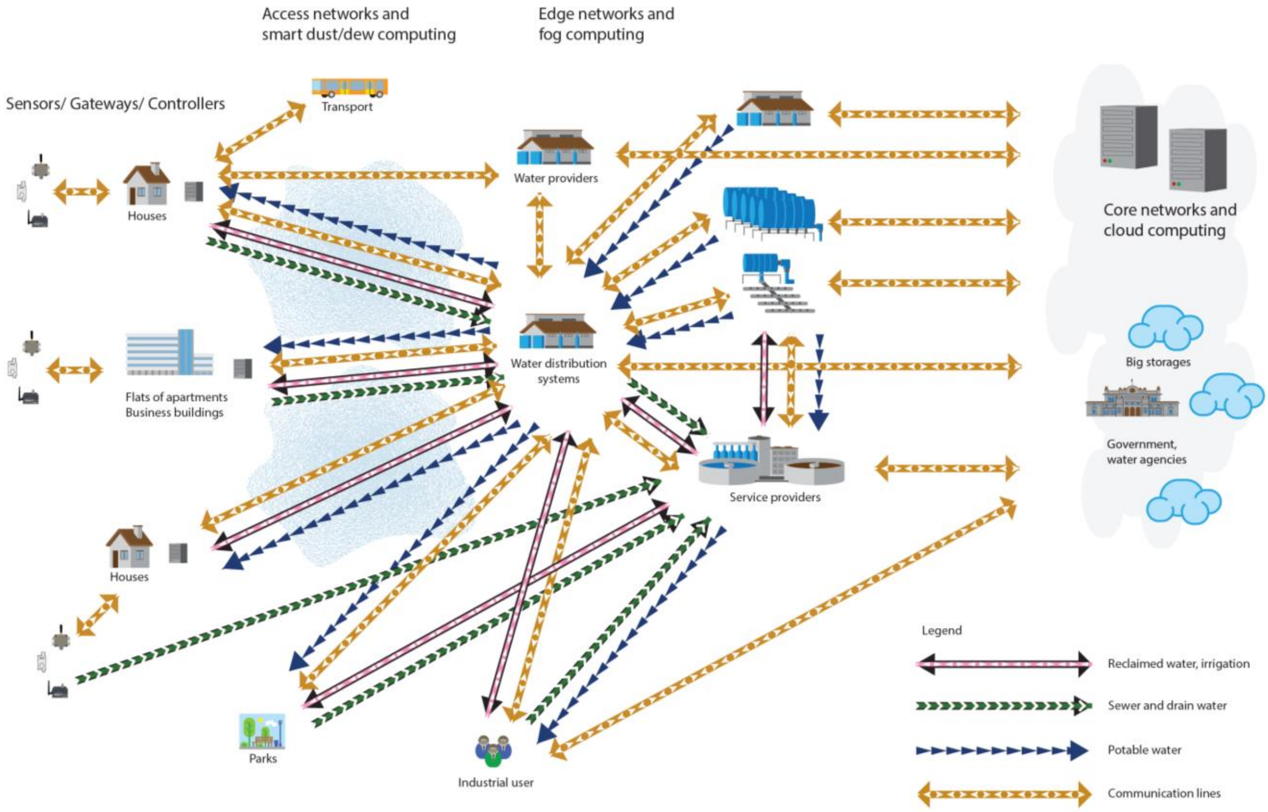

Figure 2. ICT-based water standards and specification end-users and stakeholders collaboration

- Secondary end-users and stakeholders that are indirectly related to the smart water management like water service providers, sewage companies, water information providers, Non-Governmental Organisations (NGOs), International Governmental Organisations (IGOs), public and private agencies, industrial partners producing equipment and consumables, utility companies. They usually provide the smart water services (Table 4).

- Tertiary end-users and stakeholders that build their activities on the collected data indirectly like ministries, regulation bodies, local legislation committees, municipality and municipality contracted companies, other smart service companies providing services for energy, heating, transport, gas, i.e. smart cities related companies, universities and other research organisations, labs, international organisations, etc. They use and create value-added services or share the data with smart water management primary and secondary bodies (Tables 5 and 6).

Table 2. Definition of primary smart water management stakeholders' and end-user's requirements. Part A

No	Primary stakeholders and end-users	Requirements of the direct clients of the water services
1.	House owners	House owners expect to have the capabilities to measure the use of different types of water, i.e. potable water, reclaimed water, water for irrigation, rain water, sewer and drain water. House owners also need to know the purity, possible contamination in water, possibilities to manage water locally in the house, local legislative obligatory measures. They can share optionally the locally measured data.
2.	Water distribution companies	Water distribution companies expect to collect data on water consumption per house, per district, per region, per type, to measure wastewater, reclaimed water, to be capable to estimate water losses, to measure the streams and flows as well as pipes in order to detect and prevent failures in water supply, leakages, hazardous situations, water contamination, to have data from water suppliers on the quality and quantity of supplied water, to collect data on billing, to support local legislation obligations to share data with end-users and other water-related bodies, as well as many other functionalities.
3.	Water providers	Potable water providers expect to be capable to measure the quality and quantity of the water sources in the process of extraction, delivery and processing, the level of contamination and all necessary subsequent processing of the water before delivery to the users. They also collect, check and store appropriate probes and accompanying information, detect, and possibly prevent damages in the equipment by using different sensors and filters through automation of water delivery. Part of the collected information is reported to the local authorities.
4.	Industries using water in production	The companies using water in their production process use potable and/ or reclaimed water and may produce wastewater of different type and level of contamination. All water flows during the industrial processes need to be qualified and quantified, including the level of contamination. The companies also need to have information allowing them to detect and prevent failures in water related production process. They share part of the locally measured data pursuant the local legislation.
5.	Agriculture farms using water in production	Farms use potable, reclaimed and wastewater for their activity in different scales, quality and quantity, depending on the type of their production, i.e. animals, vegetables, industrial crops. They expect to be capable to measure the use and reuse of water, to detect and prevent losses, damages, leakages and congestions operationally. They also need information for accounting and reporting purposes. Farms share locally measured data on water use and reuse depending on the local legislation.

Table 3. Definition of primary smart water management stakeholders' and end-user's requirements. Part B

No	Primary stakeholders and end-users	Requirements of the direct clients of the water services
6.	Sewage companies	Sewage companies of different scales need to measure the flows and contamination of the reclaimed water and the wastewater. It could be done in houses, companies, farms, regionally. Options for ICT services for those companies are calculation of the water reuse percentage, recipiency of the reclaimed water, coordination with the companies and houses using reclaimed water. Sewage system is also supported by means of detection of losses, leakages and damages, as well as potential prevention of congestion and failures. They share the data for the percentage of the reclaimed water use.
7.	National parks	National parks (or just parks), forests, lakes, river basins, meadows and aquifers might be a subject to proactive or preventive control to avoid flooding and contamination. They may use the automation through sensors and satellite data to control the activities concerning smart water management. ICT water related services could support recreational activities, such as fishing, boat riding, swimming and water-related entertainment. National parks have to publish and share the data and related measures on the water quality.
8.	Water basins management companies	In many countries there are national-based or transnational companies and bodies managing big water basins like rivers, big lakes, coastal line. Like national parks, they could use ICT for water management services to control the water levels, flows, congestions, contamination, potential flooding, for ship management etc. They could also use them to create additional value-added services for logistics and citizens awareness.
9.	Sea watching companies and labs	All countries with a lake/ sea coastal line are obliged to control the purity of the sea water and shores by taking probes regularly and sharing this information with other national and international bodies. This business could be combined with open access satellite data and fully automated through computing and sensor networks.
10.	Municipalities	Smart cities need to have supportive information that allows them to plan the infrastructure, to control the investments, water contamination levels, the use, reuse of water, the capacity of the households to automate and use local sources, etc. Water harvesting is a good starting point for the creation of additional value-added services for the municipalities that could be partially publicly available. Cities and regional bodies need information to be integrated in their synergetic services for raising citizens awareness. Smart cities are big consumers and providers of the shared data depending on the level of smartness in their activities.

Some of the end-users and stakeholders can be classified as primary and secondary users or as secondary and tertiary users at the same time depending of the role played in the smart water services. The important requirements to the end-users and stakeholders related to smart water management services are summarised in Tables 2, 3 and 4. The market is also demanding classification and profiling of the end-users and stakeholders. As seen from the tables, it could be done in a similar way in different sectors, i.e. the synergy also could be defined. Consequently, the profiled end-users and stakeholders could be mapped to the multi-stakeholders' platforms and supported by standards.

Table 4. Definition of secondary smart water management stakeholders' and end-user's requirements

No	Secondary stakeholders and end-users	Requirements of the direct providers of the service
1	Water service providers	Water service providers are the companies that supply water and perform billing, accounting and end-user management. They could use the ICT and other utility company resources to make the services cheap and user-friendly. In general, there are opportunities for the creation of value-added services related to the water management automation.
2	Water information providers	Water information providers can be information agencies managing the satellite data and other water management information that could be shared publicly or on demand. The information allows the creation of the value-added services for the citizens and serves to raise water management awareness.
3	Sewage treatment plants	Similarly to the water service providers, sewage treatment plants are both providers and consumers. Their role in water in circular economy is becoming more and more important and is related to the provision of information on reclaimed water, wastewater, water for irrigation and water for industrial purposes. The complexity of the process should be supported by the appropriate pipes, measurements, actuators, communication lines and specific data models.
4	Non-Governmental Organisations	NGOs are specialised bodies that use publicly available and shared data and may collect their own data independently to control the levels of contamination, water flows, water use and reuse. Depending on their interests and financial support they could build multiple value-added services on top of data on a continuous basis.
5	International Governmental Organisations	IGOs collect and share data concerning smart water management. They share the data publicly or privately in different scales depending on the local and international legislation. Appropriate data processing could feed new ICT services for the citizens in a synergetic way. IGOs services have a big potential to support the citizens awareness policy of the European Commission at European level.
6	Public and private agencies	Many public and private agencies also deal with smart water management, as well as smart energy, smart heating, smart electricity supply management, etc. They control and often enforce coordination between multiple governmental bodies in a synergetic way.
7	Industrial partners producing equipment and consumables	A huge group in the Digital Single Market for smart water management is the group of the industrial companies producing equipment for automation, ICT devices, consumables for the water management, creating sewage and purifying systems, building, and rebuilding the infrastructure. They need ICT services to enhance their planning and investment activities, as well as for identification of potential problems and shortages of spare parts, consumables or equipment, etc. The industry follows closely the policy of the authorities and the market requirements and aims to propose short to medium-terms solutions. They continuously analyse the market data.
8	Utility companies	A special type of stakeholder is a utility company that could be used for the distribution of the ICT water management services including billing, accounting, administration, maintenance. Water management data is needed for business process development.

The identification of the level and type of data sharing between stakeholders and end-users and all items in the water management infrastructures is not necessary for every type of end-user and stakeholder. It depends on local, national, and European level legislation. Sensor-to-cloud solutions as well as the main end-users and stakeholders are presented in Figure 2. This scheme of the IoT platform presents the flows of water and data through pipes and communication lines. ICT infrastructure is used to create an overlay of the water supply network. Part of the lines are not shown for simplicity reasons. As seen from the legend to the figure, the water types are supplied and managed through different stakeholders. The flows colour coding in this catalogue uses well known standards as:

- blue for the potable water
- green for drain water
- purple for the reclaimed water and water for irrigation
- orange for communication lines

Table 5. Definition of tertiary smart water management stakeholders' and end-user's requirements. Part A

No	**Tertiary stakeholders and end-users**	**Requirements of the indirect users of water management related data**
1.	Ministries and governmental agencies	Many ministries and governmental agencies are working with water related data and are responsible for water management. They also have an obligation to regulate, raise the citizen awareness, control the use of water locally and report the processes to the international organisations. This could be automated through ICT value-added services based on the raw and processed data collected from the households, water distribution companies, water suppliers, sewage treatment plants, satellite data etc.
2.	Regulation bodies	Regulation bodies act locally, nationally, and internationally. They collect and process raw data from all water management bodies, analyse it and create new smart water management policies. This process could be even more complicated, so the smart and artificial intelligence based value-added services could help to analyse the relations between policy rules and processed data, as well as to identify the gaps or misinterpretation of the data and the policy.
3.	Local legislation committees	Local legislation bodies try to adapt the international and national regulations and policies to the local circumstances. They need all the information to perform the policy aligning with the real-time and non-real-time data in order to control and analyse services.
4.	Municipalities	Municipalities are the main players in smart water management as they are required to supply the citizens with water and to develop the infrastructure through contracts with companies. They need to collect all the information necessary to reach the DSM objectives, i.e. to contract, process, control and receive support for effective and efficient operation. As the municipalities also develop the infrastructure and are responsible for energy, heating, construction works management they need to synergistically share and map the information from many sectors [AIOTI, 2018].
5.	Municipality contracted companies	The municipalities support and develop the infrastructure and supply the citizens with energy and water through contracts and licences with different companies locally and internationally. The transition to the DSM goes through transparency of the data related to the business for all players including the citizens.

Table 6. Definition of tertiary smart water management stakeholders' and end-user's requirements. Part B

No	**Tertiary stakeholders and end-users**	**Requirements of the indirect users of water management related data**
6.	Other smart service companies providing energy, heating, transport, gas services, i.e. smart cities related companies	The smart water management could not be isolated from other utility companies including telecoms and Internet Service Providers (ISPs), as they provide similar services. The workload could be shared and coordinated efficiently and effectively between them. The competition between different utility suppliers is a driving force for the Digital Single Market implementation. Smart service companies rely on the shared data and additional data processing while developing their services.
7.	Universities and other research organisations	Many universities, public and private research organisations work on the smart water management or ICT related services and platforms world-wide. The driving force for them is the availability of open data like satellite data, the importance of the water supply business and the vast development of the sensor, automation, ICT services and technologies in the last five decades. The new circumstances of doing business require changes in business processes of the water companies to meet new citizens' expectations in water supply. All research organisations use broad amount and types of information, analyse it and try to develop the technologies step-by-step. Raising awareness of such organisations in the field of smart water management leads to better and faster technology development and increase of innovations in the sector.
8.	Labs	Many labs are acting locally, regionally, nationally, and internationally to control the water purity worldwide. They report at different levels and this information could be shared with other players in the field of smart water management. The transparency of measurement and control is also important as contamination measurement is a changing technology and labs might share not only the data but also the information related to the technology of measurement and data acquisition. Transparency of data sharing allows the labs to increase their efficiency, to correct their measurement and control methods, to compare their results and to use the ICT infrastructures of other organisations as a backup points for their business.
9.	International organisations	The digital society has created in the last five decades many different bodies working in smart water management. There are international public and private research labs, pilot labs, smart cities experimental districts, smart agricultural institutes, satellite data analysing companies, environmental organisations of different types etc., that collect and analyse water management information and endeavour to influence the policy and legislation nationally and internationally. The process is supported by data sharing and data processing.

On the other hand information and communication platforms could play local, regional, and international role depending on the specific business case of collection, storage and processing of the water related data. Starting from the left part of the figure:

- Sensors for data collection and actuators measure the data of importance.
- Raw data is collected, time stamped, position stamped and sent.

- Raw data acquisition and harmonisation is performed at different cloud layers.
- Data storage is supported at local, regional, national and world-wide level.
- Data processing is virtualised, i.e. performed in any place and at any time through any device.
- Southbound interfaces at access/edge networks could support multiple standardised protocols and interfaces.
- Northbound interfaces at edge/core networks could also support standardised interfaces and protocols as well as data structures for data sharing.
- Micro and macro services in the cloud layers could be:
    - Smart dust computing level correlated to the access network like home controllers and small-scale Supervisory Control and Data Acquisition (SCADA) systems.
    - Dew computing level correlated to the access network like home servers.
    - Fog computing level correlated to the edge network like regional storages and server farms.
    - Cloud computing level correlated to the core network like regional/ national/ international server farms and storages.

A lot of experience in smart water management has been gained last decade and many documents and analyses appeared recently thanks to smart cities research [ICT Standards, 2017]. The standardisation process in the field of smart cities and smart grids is intensive and could be a good starting point for smart water management analyses as well. The work done is still fragmented per sector but the process of unification is going intensively. There is no big difference between smart water management and smart energy management, especially smart grid management. The convergence cannot be done in a few years and will take decades of changing policies, providing intensive investment, changing the infrastructure and citizens perception of smart water management. This is evidenced by the smart grid, which was a smart idea 10 years ago and is slowly becoming a reality in different isolated regions.

Data sharing and intensive use of open data support the convergence of the smart water sector. By changing policy and companies' motivation to raise the citizens' awareness and to make their work more transparent to the public, the infrastructure development process based on the Digital Single Market is on the right path. This is the reason why the European Commission decided to open the satellite data to the public allowing globalisation of the market and creation of vast amount of ICT-related services based on the satellite data worldwide. The process suppresses proprietary solutions that have no global or at least wide enough significance.

The smart water management ICT services built on top of raw data are classified as:

- Macro (monolithic) services that use the processed data for different types of end-users and organisations like agencies, municipalities, ministries, universities etc. Macro services are possible due to the data sharing between different organisations using Application Programmable Interfaces (APIs) [ICT standards, 2017]. These services are specific to the so called northbound interface as defined by European Telecommunication Standardisation Institute (ETSI) [ETSI TR 118 524, 2016]. Monolithic services use the data in synergetic way and are customised.
- Micro (atomic) services that support the process of data collection from different proprietary and standardised platforms through different APIs and are based on different interfaces and protocols. For example, ETSI defines the micro services at

the so called southbound interface for 3GPP Reference model [ETSI TR 118 524, 2016]. Micro services could also harmonise and process data.

- Collection of micro and macro services that is considered a complete set for implementation and focused on the water (also called Water-as-a-Service or Water-as-a-Resource (WaaR)).
- Gateways and APIs for smart water management business integration that allow aggregation and scaling of fragmented, proprietary platforms with proprietary services. This specific service aims at integration of the systems through data sharing and possibly through defined interoperability at southbound or northbound interfaces.
- Gateways and APIs for integration of many existing proprietary and generic services that are highly customised in smart water management due to the local legislation or just local requirements. Data sharing is possible at southbound and northbound interfaces after appropriate data acquisition and pre-processing.
- Specific services allowing better customisation of many common and generic services towards local legislation. The lack of flexibility in customisation, the lack of adaptivity of the service to the local requirements and expectations is a common ICT service creation problem. Experience gained in this field, specifically in smart living and smart cities sectors, could be used in smart water.
- Smart cities platform with horizontal overlays for smart water, smart living, smart energy, smart housing etc. allowing independency in the development of different sectors.

The definition of the principles of a methodology for analysis starts from the end-users and stakeholders and goes through the technological, societal, administrative and business requirements’ analyses. In this sense, there is a need to compare ICT water management related standards, specifications and platforms at technological level, societal level and administrative/ business level. The technological level is divided into cloud level and communication infrastructure level that are also related to the devices.

As stated in the [Anzaldi Varas, 2018], the aim of the ICT smart water management catalogue is to allow better access for consumers and businesses to online goods and services across Europe by creating the right conditions for digital networks and services to flourish. The identification of the standard gaps and definition of the priorities in standardisation aim to maximise the growth potential of European Digital Economy.

Main principles of ICT water related standards are defined in the [Anzaldi Varas, 2018] as being:

- Digital by default
- Open
- Cross-sectoral by default
- Interoperable
- Capable to build a capacity
- Secure and trustful
- Focused on people
- Open for innovations
- Mature
- Connecting Europe facility deployments

- Politically relevant
- Allowing previous endorsement of formal platforms
- Allowing water cycle support and key indicators

All the listed principles could be considered also as Key Performance Indicators. There are multiple attempts for KPIs definition in the last decade and most of them are related to smart cities [EIP SCC, 2017], being at the same time too generic but still allowing the definition of the new KPIs as:

- Integration level of the platforms and supportive standards
- Facilitation level of players cooperation
- Level of scalability
- Level of replicability of the solutions
- Level of correspondence to the legislation and policy makers
- Necessity of standard adoption towards the integration policy and openness

Many different projects adopted the KPIs from the CITYkeys project [CITYkeys KPIs, 2017]. They introduce additionally the following water related criteria:

- Quality of Service support
- Access to other services
- Diversity and social cohesion of services
- Green economy support
- Attractiveness and competitiveness of the solutions
- Multi-level governance
- Propagation, continuity, and sustainability
- Factors of success support
- Water in circular economy level support
- Efficiency in use
- Share of reclaimed water
- Reduction in potable water consumption
- Self-sufficiency level
- Water exploitation index, green water (rain water), blue water (surface and ground water), grey water (reclaimed water)
- Water loss and leakage

Many of the listed KPIs could be mapped. The report also includes definitions, specifications, explanations how to calculate KPIs with reference values. Some of them could be explained in more details when applicable [ISO/DIS 37120, 2018]. The colours used to mark the type of water is not standardised yet. The use of colours in different documents is different. Therefore, along this catalogue the legend in Figure 2 is used when possible.

Project ESPRESSO (Espresso – systEmic Standardisation apPRoach to Empower Smart citieS and cOmmunities) developed further part of the KPIs for ICT-related water management [ESPRESSO, 2017; ESPRESSO D4.4, 2016]. The analyses of water digitalisation level in Europe are done at technological level and are based on:

- The use of IoT, cloud computing and communication infrastructures in recent water management architectures.
- The level, maturity, deployment of different architectures including technologies used, data models, hardware, software, communication structure, possibility of cloudification etc. at different scales.
- The data sharing level, smartness of the water, cyber-security issues, actors' awareness level, policy at different scales and business/ procurement models.

Coordination between the relevant stakeholders and end-users is done by considering their requirements and the level of satisfaction in the recent projects, platforms, and standards. The aim is to:

- Identify possible existing and future services for citizens through the cloud-based, IoT and big data analysis technologies.
- Define the Water-as-a-Service micro and macro services at cloud level.
- Define the levels of water awareness for different actors and the transparency level of the water related information.
- Create a data models called Water Big Data for the key actors’ collaborative work in the scope of standard frameworks [Anzaldi Varas, 2018].
- Enforce the use of data analytics and visualisation as well as water management process optimisation, governance, and security [Anzaldi Varas, 2018].
- Propose selection of more than 50 use-cases based on the existing good practices to validate the standards developed considering also cross-sectoral interoperability [Anzaldi Varas, 2018].

3. Analysis of Smart Water Management Platform Architectures and Specifications

3.1. Projects on Smart Water Management between 2012 and 2019

The analysis of the existing platforms for smart water management is based on the output from more than 50 projects running between 2012 and 2019. Projects’ abstracts are part of this section aiming to demonstrate the architectures and the level of the ICT use as well as the level of data abstraction, maturity of the development, type of sensing technologies applied etc. While presenting the projects and specifications the emphasis is on the ICT support rather than on the water management level.

Many running or completed smart water management projects in the last decade with similar and overlapping results are analysed [ICT4Water Partners, 2018]. By collaborating the businesses in smart water management, the projects introduced all the important functional, technological, architectural, and business requirements by implementing them partially and getting preliminary results. The important new features of the platforms are the introduction of cloudification, the use of the artificial intelligence in decision making, the implementation of risk analysis, the consideration of water in circular economy, the introduction of water flows simulations, the analysis of the wastewater management, the implementation of sensor networks, the consideration of the water purity awareness, the service security, the smart water service creation based on data analytics etc. All these steps towards digitalisation of the water business aims to allow the end-users to perform self-management of the water services. The platforms should be open by default supporting a better and transparent procurement, system migration, integration, and interoperability.

The European Commission defines a policy towards a Digital Single Market trying to promote the use of standard solutions in smart systems including smart water management. Standard-based solutions should form a mature part of the network leading to a better water services in the entire Europe. The concurrency in procurement based on standard solutions aims to regulate the prices and isolate proprietary implementations [PCP for DSM, 2018].

The projects presented in the catalogue are active players in the ICT4Water cluster.

CENTAUR

CENTAUR (Cost Effective Neural Technique for Alleviation of Urban Flood Risk) project aims to reduce the urban flood risk through an innovative, cost effective, local autonomous sewer flow control system [CENTAUR, 2018]. Computer models are tested in the laboratory and pilot field tests are performed. Sensor data are processed using intelligent fuzzy logic control mechanisms.

Urban flooding is caused by climate change and consequently affects the lives of thousands of citizens. Activation of the existing sewer storage at the local scale applied by CENTAUR project is based on data-driven real-time control (RTC) strategies. Flow control devices are combined with communication modules and sophisticated computational techniques.

The hydrodynamic model of CENTAUR is fully decentralised and autonomous. When the flow patterns change over time the fuzzy logic algorithm adopts to the changing conditions, including climate change, land use or population influence. At the end of the project the system is market-ready.

CENTAIR project could be a good use-case for decentralised flood risk management using fuzzy logic. The implementation is local.

AfriAlliance

The AfriAlliance project aims to prepare Africa for future climate change. The challenges are faced by African and European stakeholders cooperating in the areas of water innovation, policy, capacity development and research [AfriAlliance, 2018]. The project partners do not create new networks but consolidate existing ones working actively with decision makers, scientists, citizens, practitioners and other key stakeholders. They create a knowledge sharing mechanism that is effective and problem-focused.

As a region Africa is a place that is expected to be influenced significantly by climate changes. It needs innovative solutions for tackling with water and water-related challenges. Lack of water in many parts and flooding in other parts of Africa are going together with the lack of water-related skills, institutional fragmentation, limited capacity to tackle problems [AfriAlliance, 2018].

Africa-EU cooperation is non-technological and is focused on local requirements aiming to create practically proven investment opportunities and boosting a sustainable market. AfriAlliance defines short term demand-driven and long-term research and innovation agenda and constraints at different levels.

AfriAlliance project is a good use-case in standard development for the expansion of the implementation beyond Europe, consolidation of legal implementations, stakeholders' engagement etc.

AquaNES

AquaNES project objectives are focused on water and wastewater treatment innovations, processes, management using combinations of engineering and natural technologies [AQUANES, 2018]. Regional, climatic, and hydro geological conditions are considered such as bank filtration (BF), managed aquifer recharge (MAR), constructed wetlands (CW), pre- and post-treatment engineering. Safe drinking water is produced based on AueaNES post-treatment through membranes, activated carbon and ozonation after bank filtration. Soil-aquifer systems with oxidative pre-treatments are combined with constructed wetlands with different technical post- or pre-treatment (ozone or bioreactor systems) for wastewater management. The project demonstrates not only treatment but also storage capacity aiming in reduction of energy consumption and operating costs. The solution is applicable in industrial or near-industrial scale and profiles new market opportunities across Europe.

The ICT part of AQUANES project is not clearly published. The project could be a good use-case in rain water and wastewater treatment.

BlueSCities

BlueSCities project develops a methodology for integration of the water and waste sectors within the EIP Smart Cities and Communities [BLUESCITIES, 2018]. The main project result is the creation of a BlueSCities package and Revised Practical Guidance Manual with an effective, dynamic, and accessible mechanism that allows public administrations and other stakeholders in Europe and beyond the possibility of effecting a long-term sustainable urban roadmap including water and waste. The platform uses many performance indicators related to the urban water and waste cycles. The collected data is analysed by cloud-based tool permitting the target users, both professional and non-professional including municipal administrations to generate a concise, clear, and effective analysis of the situation concerning water, waste, energy, transport and ICT in any given town or city, so that decision makers can truly appreciate the full global picture.

BlueSCities project could be a good use-case for the synergy between smart water and waste sectors. There are no public documents available showing the ICT part of the project.

CYTO-WATER

CYTO-WATER project applies an innovative imaging cytometer platform for detection and quantification of microorganisms in industrial and environmental waters. Quantification of Legionella and Escherichia coli population is performed within 120 minutes from obtaining the sample [CYTO-WATER, 2018]. The time of detection is much quicker in comparison to the traditional methods. Distributed probe automation is also integrated with the proprietary technologies. The fluorescence image cytometer is a new product. A Global Control System (GCS) reads, records, and processes the data from the automatic water concentration cartridge with a microfluidic cell. Two types of environmental water (two business models) with high market importance in smart and sustainable growth are considered: industrial waters and bathing waters.

CYTO-WATER project is a good use-case for microorganism's water management.

EFFINET

EFFINET project addresses three main management problems in urban water system integrated into a software platform: optimal operational control, demand forecasting and real-time monitoring [EFFINET, 2018]. Real-time optimal control deals with the flow and pressure actuators. It minimises the costs of the electricity using the model predictive control algorithm. Real-time monitoring of water quantity and quality assures continuous detection and location of leakage and/ or water quality breaches. Demand forecasting based on smart metering allows the modelling of the consumption patterns. It supports the service to consumers.

EFFINET project is a good use-case for the water management data for monitoring identification. There is no technical data publicly available from the project.

DAIAD Project

Project DAIAD implements innovative solutions in research activity trying to change the water monitoring [DAIAD, 2018]. It is done by acceleration and adoption of efficient water use and reuse aiming sustainable changes in water consumption at a larger scale. Devices and instruments controlling every drop of water are used for self-monitoring of water consumption independently from the water provider. The data is collected and a sustainable water consumption policy is proposed to the users. Real-time monitoring and big data analysis applied support the proactiveness of the users. The DAIAD platform architecture is presented in Figure 3.

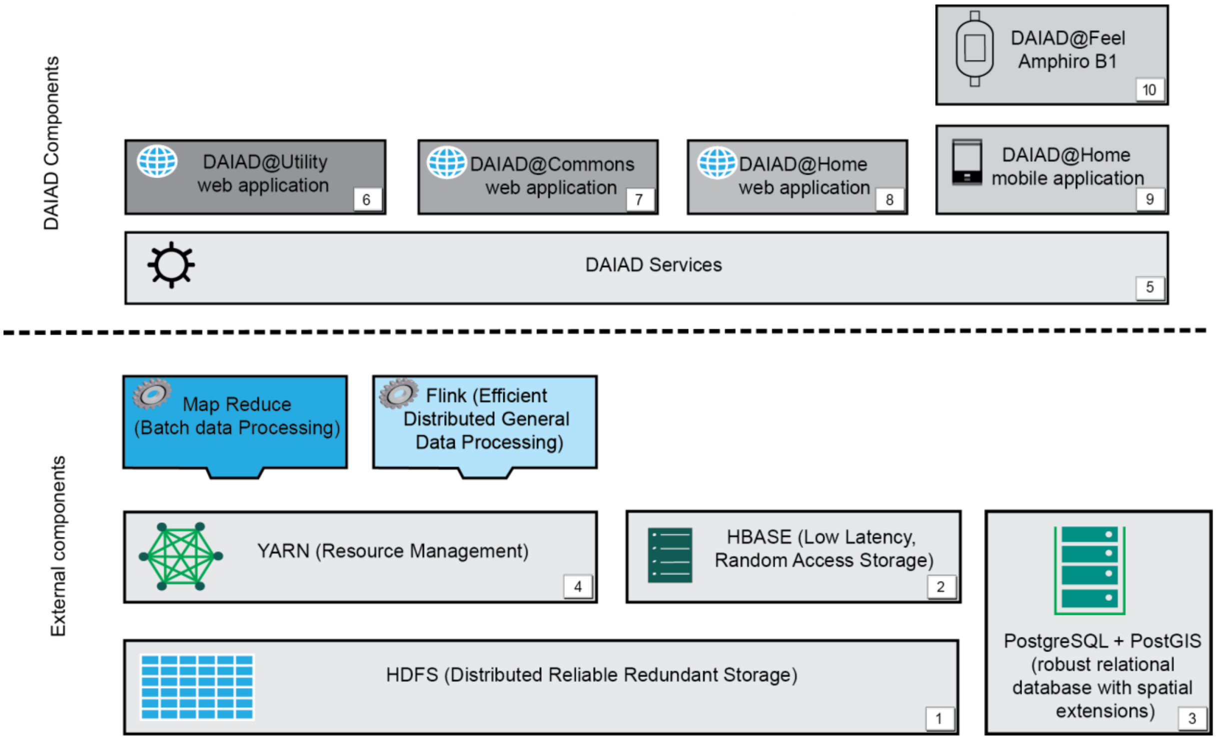

Figure 3. DAIAD project platform for smart water management [DAIAD, 2018]

DAIAD project is a good use-case for standards development as it implements sensor-to-cloud solution using data harmonisation and services definition. It is scaled and cloudified, leverages the consumers to accelerate innovation and implementation of efficient water management by raising the user awareness and engagement.

Ctrl+Swan

A water distribution networks management based on innovative sensors integration is proposed by the Ctrl+Swan Action Group [CTRL+SWAN, 2018]. The main blocks of the platform architecture demonstrate IoT sensor-to-cloud approach.

CTRL+SWAN project is a good use-case for sensor-to-cloud technology development and implementation in different scales.

DIANA

DIANA project developed a commercial service platform for water managers and authorities improving their water management policies and practices, allowing the identification and inspection of non-authorised water abstractions for irrigation and with special care in extreme conditions such as drought [DIANA, 2018]. The Earth observation data provided by Copernicus and other data sources, as well as state-of the-art models for the identification of (illegally) irrigated areas are mapped together. An estimation of abstracted water volumes with a view of offering an affordable and cost-effective value-added suite of data products and services is performed. Demand-driven services are based on data assimilation, integration, and fusion. Web and mobile applications are run over the platform's Service Oriented Architecture and supported by a RESTful API. The API handles the business logic, internal and external interfaces including the related data sources (Figure 4). The platform is modular, secure, integrates multiple data sources, stores, analyses, scales, alerts and presents the data. In Figure 4 MODIS and Sentinel stand for the satellite gathering Earth observation data ESA platform to share the data.

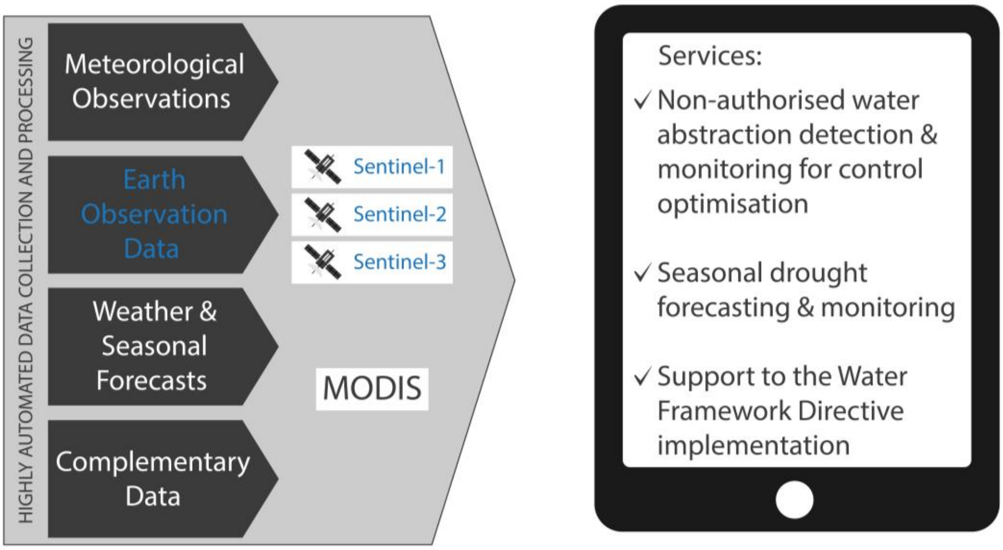

Figure 4. DIANA project framework [DIANA, 2018]

DIANA project is a good example of data integration from satellites and in-situ devices.

ESPRESSO

A sustainable, prosperous, and inclusive future in a Smart City depends on physical, digital, and human systems integration [ESPRESSO, 2017]. For this reason, sophisticated information and communication technologies are used involving not only the technological complexity but also various sectorial services. Many of the issues are still not or are under intensive standardisation. The acceleration of Smart City deployment is promoted throughout reuse of existing open standards. The ESPRESSO (Espresso – systEmic Standardisation apPRoach to Empower Smart citieS and cOmmunities) project developed a conceptual Smart City Information Framework [ESPRESSO D7.4, 2017; ESPRESSO D4.4, 2016; ESPRESSO D3.1, 2016; ESPRESSO D3.2, 2017; ESPRESSO D2.2, 2017] (Figure 5). This framework includes a Smart City platform, data provision and processing services integrating relevant data, workflows, and processes. ESPRESSO framework is based on open standards, technologies, and information models applied in various sectors including smart water management.

The Smart City enterprise application platform and services are defined taking into account detailed engineering requirements and in cooperation with cities, standardisation organisations, administrative bodies, and private industry, aiming integration and interoperability between different sectors at the same time. A very large number of stakeholders was engaged in the process. Cost reduction open market fostering were emphasised by ESPRESSO project looking for a solution to avoid lock-in to proprietary solutions. CityGML is used in conceptual Smart City Information Framework development as a reference data model and for service encoding. Shared semantics was created through open and shared vocabularies aiming data linking and metadata definition based on standards' analysis.

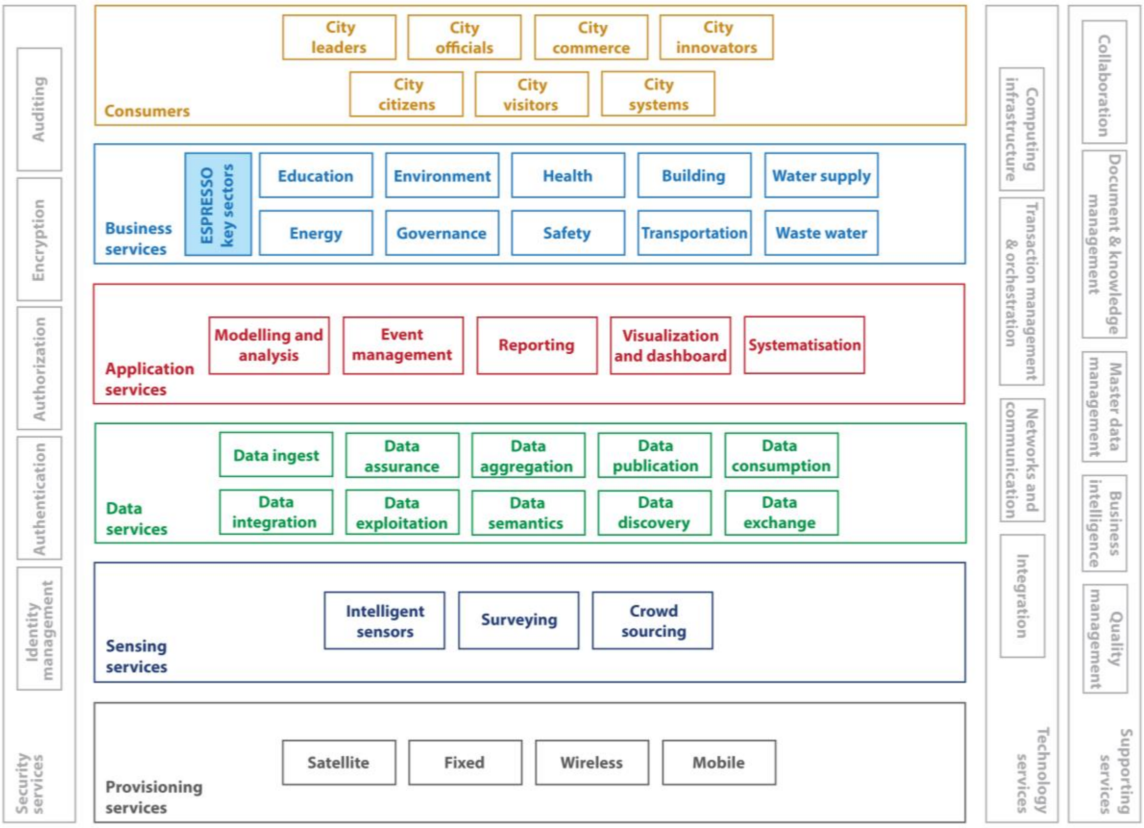

Figure 5. ESPRESSO project platform for smart cities [ESPRESSO D2.2, 2017]

ESPRESSO project is a good use-case for the data models in smart cities including water management, semantic models, standards' mapping, and roadmap for standard development.

FREEWAT

The main goal of FREEWAT project is to simplify the application of the water-related EU Directives by a free and open source GIS-integrated modelling environment for simulation of quantity/ quality of surface water and groundwater with an integrated water management and planning module [FREEWAT, 2018]. The advanced time series analysis is implemented in the tools for the analysis, interpretation, and visualisation of hydrogeological and hydro chemical data. The hydrological cycle and water resources management are simulated including flow models, crop growth models, transport models, management, and optimisation models. An Observation and Analysis Tool (OAT) is applied for input data and post- data processing.

Designing scenarios for the proper application of water policies in relation to the stakeholders as engineering and geo-environmental companies, river basin authorities, water authorities, environmental protection agencies, universities, and research institutions are mapped.

FREEWAT project is a good use-case related to the surface water management, geospatial data, location system and related legislation.

Ground Truth 2.0

Project Ground Truth 2.0 demonstrates an analysis of the observations and technological feasibility of different solutions, aiming at ensuring sustainably, citizens' engagement, societal and economic benefits, i.e. the global market uptake of the concept and the enabling technologies [Ground Truth 2.0, 2018]. The civil engagement by means of observations and new data stream provision through the mobile devices complements the existing systems and data sources. Therefore, the citizens are performing decision making and cooperative planning. The thematic focus of Ground Truth 2.0 is on flora and fauna, as well as on water availability and water quality for land and natural resources management. Citizens are enabled to share data about the environment.

Ground Truth 2.0 project could be used as a good example for citizens' engagement in data sharing.

HYDROUSA

HYDROUSA project sets up, demonstrates, and optimises on-site innovative nature-based solutions (NBS). It is done for a variety of water streams management as rainwater, groundwater, wastewater, atmospheric vapour water and seawater. The aim is to produce the so called valuable resources used to enrich not only the domestic water supply but also to increase agricultural production and create economic activities in the water-scarce Mediterranean areas [HYDROUSA, 2018]. The project introduces innovative, regenerative, and circular solutions for nature-based water management, based on circular value chains (Figure 6). The Mediterranean islands face significant challenges in terms of water management and conservation. Water reserves are scarce, while the high touristic activities during the summer months put a strain on the limited water reserves. HYDROUSA ressurects a water resilient economy, mitigates climate change and reforms the agro-food system. Water loops, low energy footprint, integration to the local market, comprehensive business models, valorisation of non-conventional water resources are also addressed.

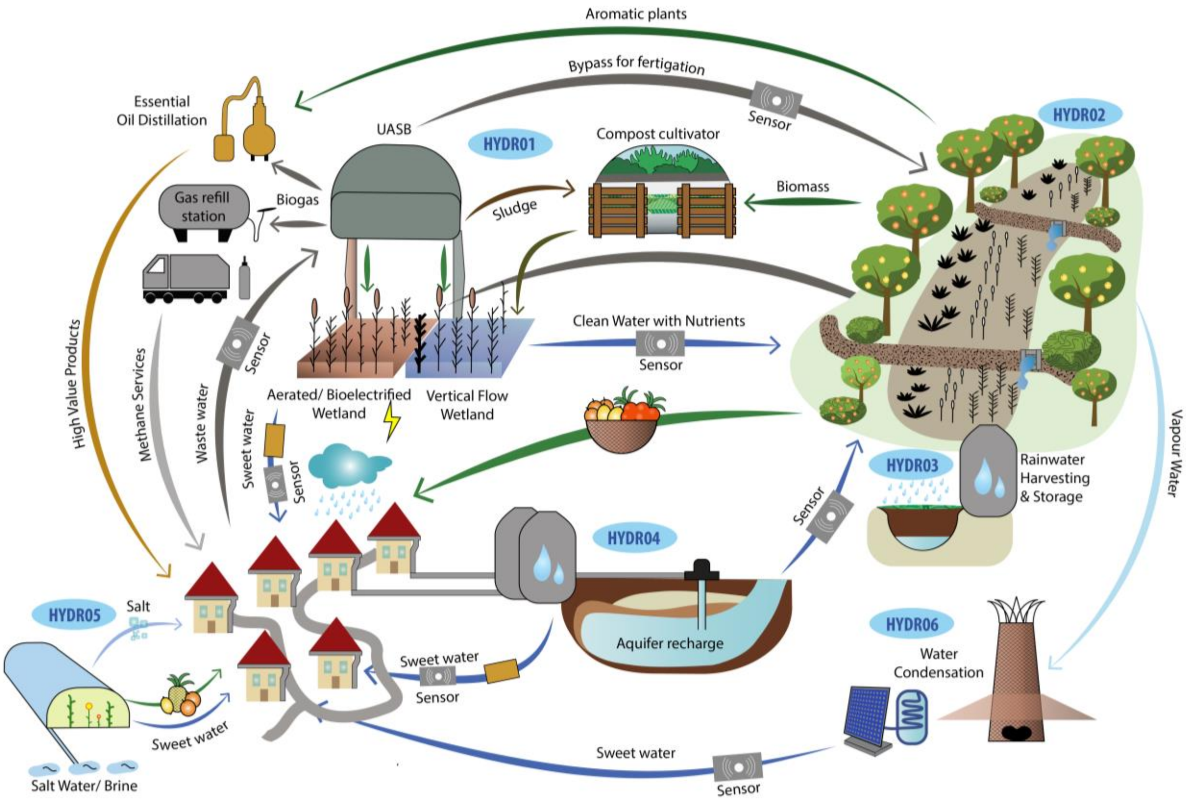

Figure 6. HYDROUSA project structure [HYDROUSA, 2018]

HYDROUSA project is a good example for circular water chain introduction and variety of waters management.

ICeWater

ICeWater project adjusts the water supply to the actual consumption in urban areas taking into consideration the stability of freshwater supply to citizens. It is integrated to the smart grid to minimise energy consumption and detect leakages [ICEWATER, 2018].

ICeWater project could be a good use-case for smart water and smart grids integration. No data is publicly available.

INCOVER

INCOVER changes the wastewater treatment towards a bio-product recovery industry in contrast to the primarily sanitation technology. This is the way the water suppliers introduce water recycling [INCOVER, 2018]. A Decision Support System methodology for holistic wastewater management is tailored to the INCOVER technologies providing data under selection criteria. Three case-studies of value-added plants treating wastewater are implemented. The use-cases target the wastewater from municipalities, farms and food and beverage industries.

INCOVER project worked on the following three wastewater recovery solutions of value-added plants: 1) Use of bio-plastic and organic acids chemical recovery based on algae/bacteria and yeast biotechnology; 2) Use of pre-treatment and anaerobic co-digestion systems with near-zero-energy plant providing upgraded bio-methane; 3) Use of adsorption, biotechnology for wetlands systems and hydrothermal carbonisation in bio-production and reclaimed water treatment. Optical sensing and soft-sensors are implemented to improve the efficiency and added-value of the production.

The ICT part of the project is not publicly available. Nevertheless, INCOVER project could be a good use-case for wastewater management data sharing, circular economy introduction, market collaboration between end-users and water providers.

INTCATCH

INTCATCH platform changes the way in which current river and lake water quality monitoring is implemented [INTCATCH, 2018]. Efficient, user-friendly water quality monitoring strategies and systems are developed and demonstrated. Innovative autonomous boats with sensors, DNA test kits and a Decision Support System (DSS) are applied. The stakeholders and citizen scientists are empowered and engaged with water quality management (Figure 7). The platform incorporates socio-economic drivers in the development process while DSS is based on end-user and stakeholders demands. The platform is capable to be integrated, supports interoperability with other systems, shares data, could be scaled and cloudified.

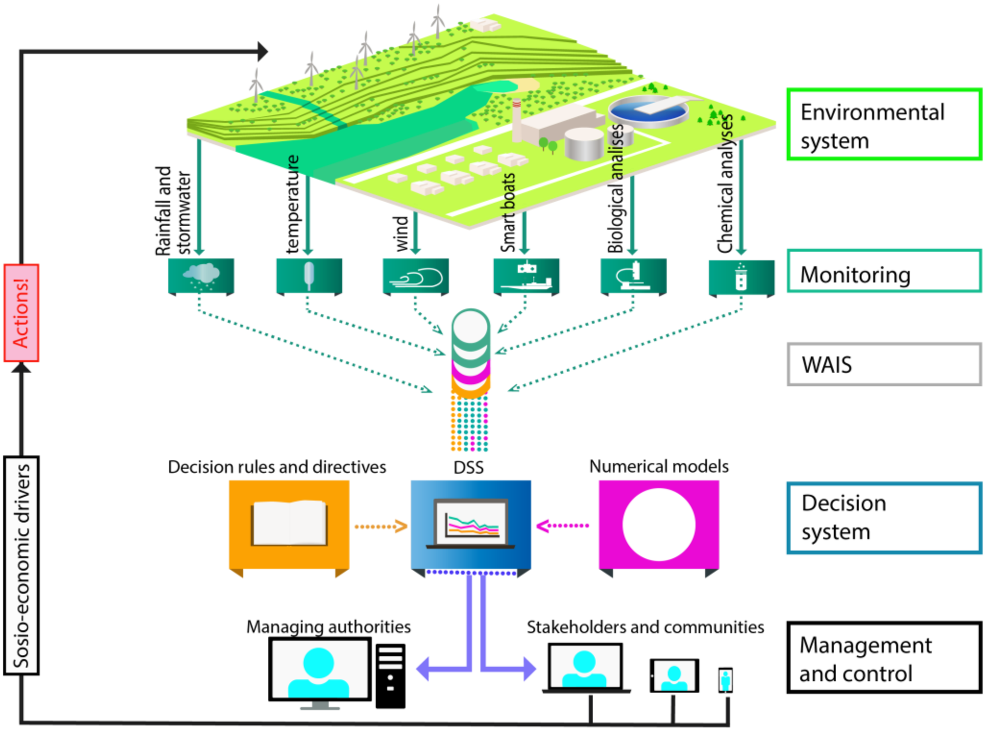

Figure 7. INTCATCH project platform for smart water management [INTCATCH, 2018]

INTCATCH revolutionises the way water monitoring and decision-making is implemented through a Water Information System (WAIS). The lab is brought into the field decreasing the cost and resources of water monitoring. Citizens, NGOs and water regulators are engaged in water monitoring activities for the benefit of society. New innovative approach towards monitoring and managing water bodies is developed aiming to prove sustainability and effectiveness. The cloud-based system stores and visualises data in a format accessible to the regulators, community groups, NGOs and citizens while bringing to the market the complete INTCATCH service for water monitoring that potential customers can acquire.

A special experiment is conducted using novel DNA test kits which are already used in the biomedical sector.

The project is an excellent use-case for river and lake water management with IoT implementation and mobility through drone-boats as well as good combination between environmental data and socio-economical drivers.

INNOQUA

INNOQUA project proposes an innovative ecological on-site sanitation system for water and resource savings. It integrates the biologically-based water sanitation technologies for complete water treatment aiming to obtain solutions that are scalable, low cost, sustainable and adaptive to different configurations, local contexts, and markets [INNOQUA, 2018]. The growing need for protection and improvement of natural water resources is taken into consideration. INNOQUA acronym is patent protected, award winning, innovative, and scalable ecological sanitation solution. The purification capacity of earthworms, zooplankton, and alternatively microalgae and sunlight exposure as natural cleaning processes are reinvented. The sustainable performance of the water sector is reached through an optimised environmental performance that is based on eco-design and optimal solutions for reduced water consumption, increased resource efficiency, reduced carbon footprint, etc.

The ICT part of the project is not publicly disseminated. The project could be an interesting use-case for ontology development for wastewater management after careful study.

INTEGROIL

The INTEGROIL project addresses the development and demonstration of a robust and flexible integrated solution for treating water flows generated in the activities of the Oil&Gas industry, making them of reusable quality and reducing the dependency on water availability [INTEGROIL, 2018]. Innovative treatment technologies are effectively operated by the Decision Support System that optimises the process of high quality water reuse. The solution, although demonstrated only for the Oil&Gas sector, can be easily implemented in other water-intensive industries. Oil&Gas industry requires high volumes of water in oil extraction and refining, thus generating large amounts of wastewater. Since water is a finite resource, technologies associated with the reuse of industrial wastewater enable the turning of low quality wastewater into high quality process water. The main goal of INTEGROIL is to develop and demonstrate a robust but flexible integrated solution for treating water flows with variable compositions in order to be reused.

The project is a perfect use-case for water intensive industries implementations.

iWIDGET

iWIDGET project proposed an interesting roadmap for standardisation and water sector development [iWIDGET, 2018]. Novel ICT technologies for integrated supply-demand side management are improved for the optimisation of the water efficiency. The solution is sustainable aiming to minimise wastage in the supply chain. Data sharing is possible through multiple southbound and northbound interfaces. The integral building blocks of the platform are data mining, analytics, decision support, scenario modelling, data management, standards interfaces, visualisation, water conservation modelling and social simulation. ICT4Water standards gaps analysis is performed [Vamvakeridou-Lyroudia at al., 2015]. Standard recommendations are proposed. WaterML definitions and ontology are implemented.

iWIDGET project is an excellent use-case for water efficiency management, WaterML and water ontology implementation and data sharing at different interfaces.

ISS-EWATUS

ISS-EWATUS project develops an intelligent Integrated Support System for Efficient WATer USage and resources management as synergy between water specialists and ICT research [ISS-EWATUS, 2018]. Several innovative ICT methods are applied in exploitation of the untapped water-saving potential in the EU. The project platform integrates different solutions and is capable to share data through APIs at northbound interfaces (Figure 8).

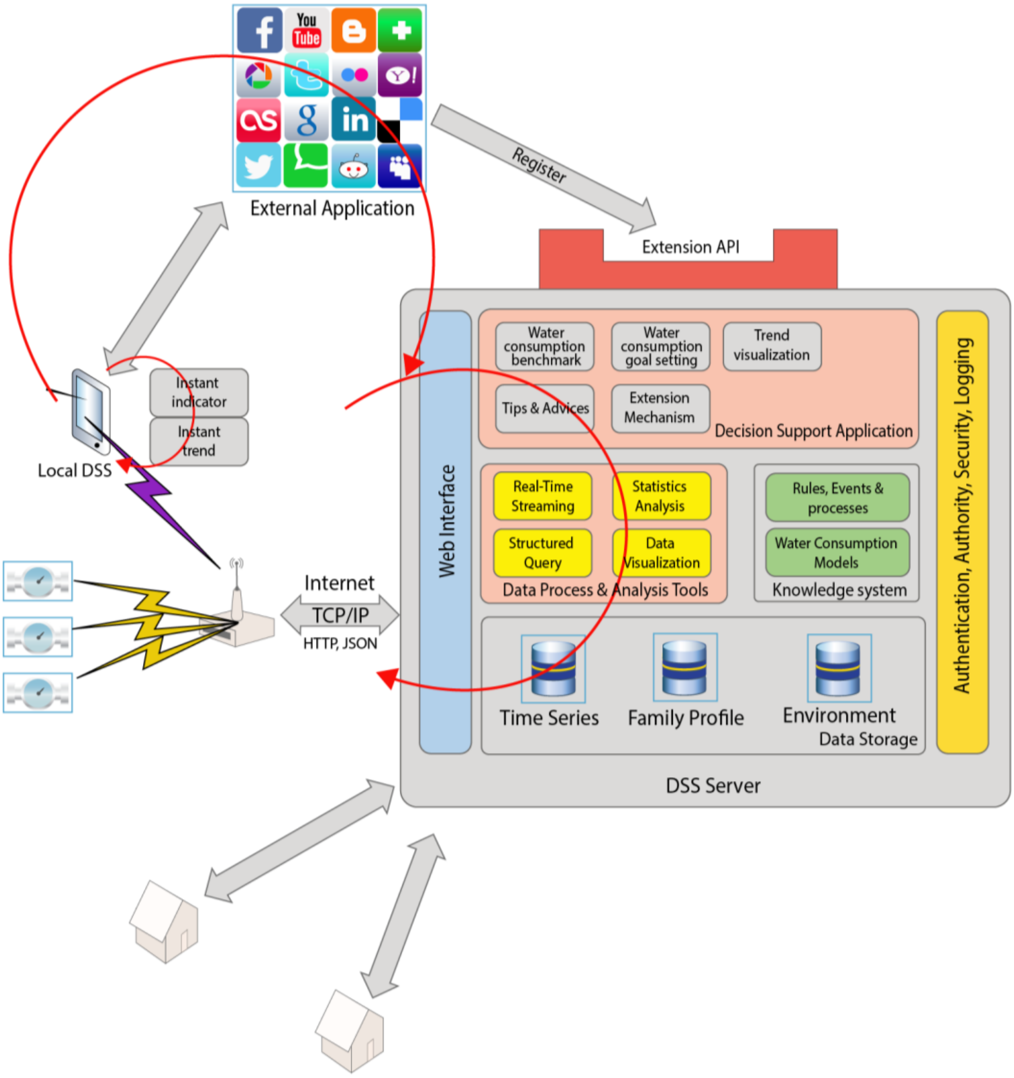

Figure 8. ISS-EWATUS project platform [Yang et al., 2017]

ISS-EWATUS platform could be a good use-case for the integrated system for smart water management and data sharing.

KINDRA

KINDRA project collects the data of Europe's contemporary practical and scientific experience in hydrogeology research and innovation. The collated programmes, activities and research actions are analysed for gaps and potential overlapping [KINDRA, 2018]. The knowledge on groundwater in the European Union is fragmented and the collected data is not standardised. KINDRA project assesses the existing knowledge using a new Hydrogeological Research Classification System (HRC-SYS). The European Inventory of Groundwater Research (EIGR) web-service uses this classification for identification of the relevant research topics, trends and challenges. The process supports synergies analyses, water policy and management optimisation across Europe. The gaps in hydrogeology research are identified in relevance to the Water Framework Directive and Groundwater Directive (WFD and GWD) including a sound understanding of groundwater-surface water interactions, climate change impact and adaptation. The EIGR represents an international access point to national knowledge sources [Water Framework Directive, 2017].

KINDRA project is a good hydrogeology use-case on gap analysis. The direct use of IoT is not published.

LIFE SmartWater

LIFE SmartWater project applies water saving capabilities implemented through Advanced Active Leakage Control and spread along the water distribution network [LIFE SmartWater, 2018]. The water pipe networks are vulnerable to losses due to: the water networks footprint that is geographically widespread; the pipe's material; the many access points; the lack of real-time monitoring of the network condition and flows parameters for the grid operator. These losses can lead to substantial damage to the environment and the entire region because of undetected pipeline damages, illegal withdrawal, and contamination. The management of the water distribution networks is based on mid-term operational planning rather than on the data and efficiency technologies. The processing of occurred leakages is delayed with days due to the lack of automated sensing and bad operational planning. These problems are solved using smart valve actuators with modern sensor technology and the creation of a truly smart water grid. The cost-efficient retrofitting automation of valves and intelligent sensors combines with the innovative wireless and energy-autarkic technologies.

LIFE SmartWater project is a possible use-case for leakage detection, integration of a proprietary solutions through SCADA systems and data integration.

LIFE SWSS

LIFE SWSS creates a decision support platform with innovative management approach that decreases the water leakage, the energy consumption, and the associated greenhouse gas emissions. A reverse-pump in gravity systems for energy recovery (renewable energy) is implemented [LIFE SWSS, 2018]. The project also aims to address energy intensive consumption of water supply systems in respect to EU targets for 2020 as well as water losses in conformance to Flagship initiative of the Europe 2020 Strategy and Water Framework Directive. It is done through an integrated platform for efficient operational management and decision support (Figure 9).

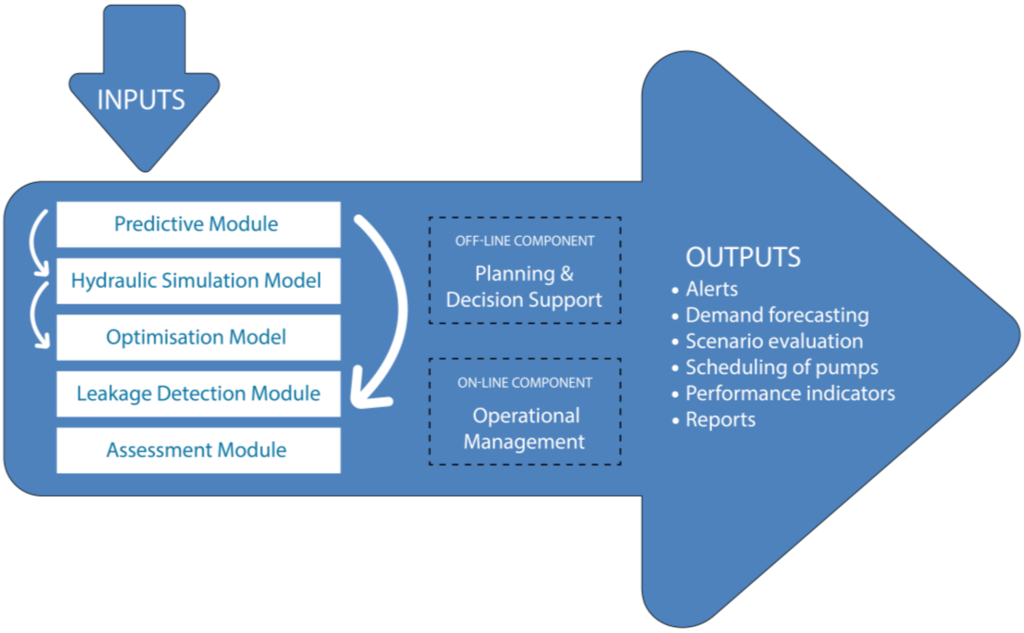

Figure 9. LIFE SWSS project architecture [LIFE SWSS, 2018]

LIFE SWSS project is a good example for the green water pumping, the energy saving, the water simulations.

NextGen

The NextGen project analyses transformational circular economy solutions for resource use in the water sector that are supported by innovative embedded thinking and practices [NextGen, 2018]. Within the scope of the project, a new estimation of the European water and allied sectors in the context of global circular economy is performed. It is based on new understandings of the ways to recover, refine, reuse, repurpose, capture value from and extend the use-life of water and water-related resources and products. Nature-based storage, optimal management strategies, advanced treatment technologies, engineered ecosystems are reused at multiple scales. In addition, the approach to the combined water-energy management, treatment plants as energy factories, water-enabled heat transfer, storage and recovery for allied industries and commercial sectors are studied. A thorough analysis, profiling and sharing of business models and services for water solutions in the circular economy could support the creation of data sharing models and micro/ macro services for other projects and sectors.

NextGen project could become a good use-case of circular economy water management as well as integrated approach towards materials and energy use. ICT infrastructure is not publicly available.

NADIRA

The aim of NADiRA project is to apply digital farming solutions that are capable to transform African agriculture. NADiRA uses the industrialisation of earth observation products, sensors, IoT data and mobile devices. The project looks for a solution with high transparency, inclusiveness and efficiency through real-time monitoring and innovative job market development. The consideration for security of investment is an interesting approach towards stakeholders, including smallholders. Details on the players, building blocks and functions aligning are presented in Figure 10, whereas the abbreviations are well explained in [NADiRA, 2018].

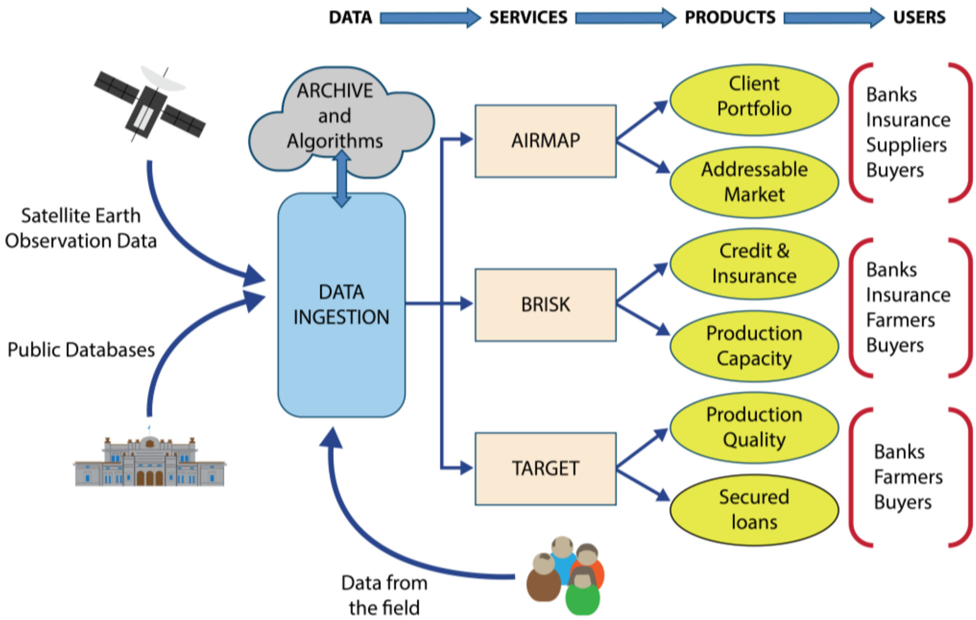

Figure 10. NADIRA project structure [NADIRA, 2018]

NADIRA project could be a good use-case for stakeholders' engagement and diverse data ingestion.

POWER

The Project "Political and sOcial awareness on Water EnviRonmental challenges" (POWER) sets up a user-driven Digital Social Platform (DSP). It expands the governance of existing water networks. Large-scale platforms with stakeholders are evolved in the co-creation and delivery of digital products and services to citizens involving awareness-raising, new policy initiatives and deployment [POWER, 2018].

POWER project could be a good use-case for raising social awareness. The ICT part is not published.

Project Ô

Project Ô developed local, small loops of water management aiming to make it beneficial. This is a step towards a circular economy vision of the resource "water" and may reduce the pressure over a water management system [PROJECT Ô, 2018]. The results are achieved with support from stakeholders taking into account their requirements. The objective is to demonstrate circular and sustainable water management systems, their efficacy and applicability of new innovative processes. Project Ô shows that a circular and integrated use of water is a key component for the success of the circular economy. Molecular separation membrane, capacitive deionisation, and advanced adsorption are only but a few of the technologies that are employed for the development of circular water systems.

Project Ô could be a good use-case for stakeholders' engagement in the process of circular economy management, including water, as well as decentralisation of smart water management. The ICT part is not publicly available.

PROTEUS

PROTEUS project delivers an autonomous, highly multifunctional MEMS and nano-enabled microfluidic sensor node for adaptive and drink & wastewater quality monitoring [PROTEUS, 2018]. The integration between chemical sensors with carbon nanotube, MEMS, a cognitive engine that is reconfigured on the fly are core parts of the smart system. PROTEUS creates a synergy between integrated smart systems area, Internet of Things, cloud-based computing, and long-range wireless sensors in the field of water utilities. Energy autonomy is based on harvesting technology.

PROTEUS project could be a good use-case for nano sensors implementation and flexible configuration techniques.

RESCCUE

RESCCUE project delivers innovative models to the smart cities to allow them to offer services and recover quickly from climate change related events, including flooding. Cities and urban areas are becoming more resilient to climate changes by using RESCCUE innovative models and tools. Cities' authorities could plan and make a continuous analysis of the situation while taking decisions on the services [RESCCUE, 2018].

RESCCUE project could be a good use-case for studying the influence of climate change and humanitarian operations on the smart cities. The ICT infrastructure is not public.

RTWQM Action Group

The Real-Time Water Quality Monitoring (RTWQM) Action Group fosters solutions for online water quality monitoring aiming also to optimise the water management systems [RTWQM, 2018].

The action group is formed from multiple different projects and many of them could be used as use-cases in smart water management monitoring.

Run4Life

A radical new technological concept for nutrient recovery and wastewater treatment is proposed by Run4Life project [Run4Life, 2018]. Every flow of wastewater from the house is collected separately and is treated optimally aiming to recover and reuse it safely (Figure 11). For the task related to the Run4LIFe platform, different data from meters and sensors located in the tank, digester, and membranes, as well as the air quality are integrated in a single platform. Parameters include levels, pressures, flows, pumps operating status, pH, temperature, Redox, etc. The data allow a continuous monitoring of the plant, establishment of thresholds for alarms, reports, etc. The information obtained in the demo-sites is used for process simulation in order to conceive a unified Run4Life model which could be applied for particular conditions (flow, source separation, nutrients concentration, etc.), allowing new business opportunities. For tasks related to model development, performance data are collected including influent and effluent composition and flowrate, electricity consumption, consumption of chemicals, and, if applicable, sludge and biogas production rates. These data are stored in a specific database and used to calibrate and validate the mathematical models of the different processes.

On-line monitoring of key performance indicators allows the smart decentralised platform to maximise the nutrient recovery and improve the process efficiency. Segregation of black water (toilet wastewater), grey water (other domestic wastewaters) and organic kitchen waste within the scope of Run4Life project demonstrates an alternative strategy in comparison to the existing one. Possibilities for agricultural application are determined in collaboration with fertiliser producers. End-users and other stakeholders are a fundamental part of this evaluation to achieve institutional, legal, and social acceptance.

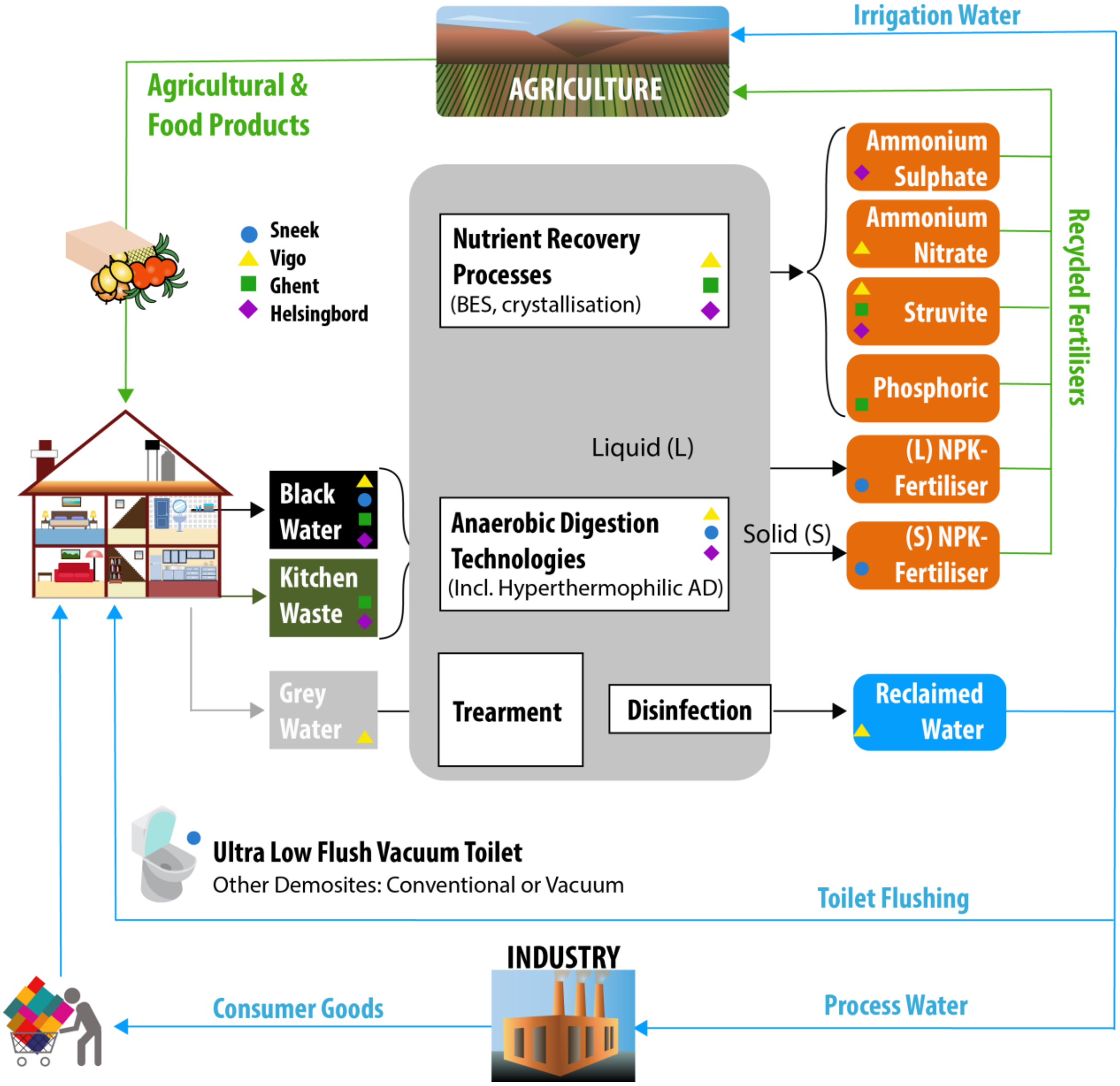

Figure 11. Run4Life project structure [Run4Life, 2018]

Run4Life project is a use-case for house level wastewater management.

SAFEWATER

SAFEWATER project develops a comprehensive and pragmatic platform for management of the safety and the security of drinking water. It reduces the time to react and effectively respond to crises [SAFEWATER, 2018].

SAFEWATER project is a good use-case for sensor implementation, safety, and security.

SIM4NEXUS

A resource-efficient and low-carbon economy transition is integrated with the Nexus concept in SIM4NEXUS project platform [SIM4NEXUS, 2018]. Knowledge and technology gaps are bridged with policies, design, and innovative methodologies to boost the sustainability of the concepts implemented in water-land-food-energy-climate chain under climate change conditions. The SIM4NEXUS coherent system (the 'Nexus') interconnects the water, land, food, energy, and climate taking into account also the complexity and feedback. The dependency between parameters are considered seriously as the change of one part of the Nexus can create pressures on the others. The efficient use of scarce resources within the management of the Nexus is considered critical. SIM4NEXUS aims to predict society-wide impacts of resource use and relevant policies on sectors such as agriculture, water, biodiversity, and ecosystem services through a model-based analysis. A Knowledge Elicitation Engine (KEE) and a serious game interface are applied in GeoPlatform development integrating data and metadata sources on all themes and allowing decision and policy-making (Figure 12). The data models and dependencies are defined in an ontology aiming to link the data from different domains and to specify data correlation (Figure 13).

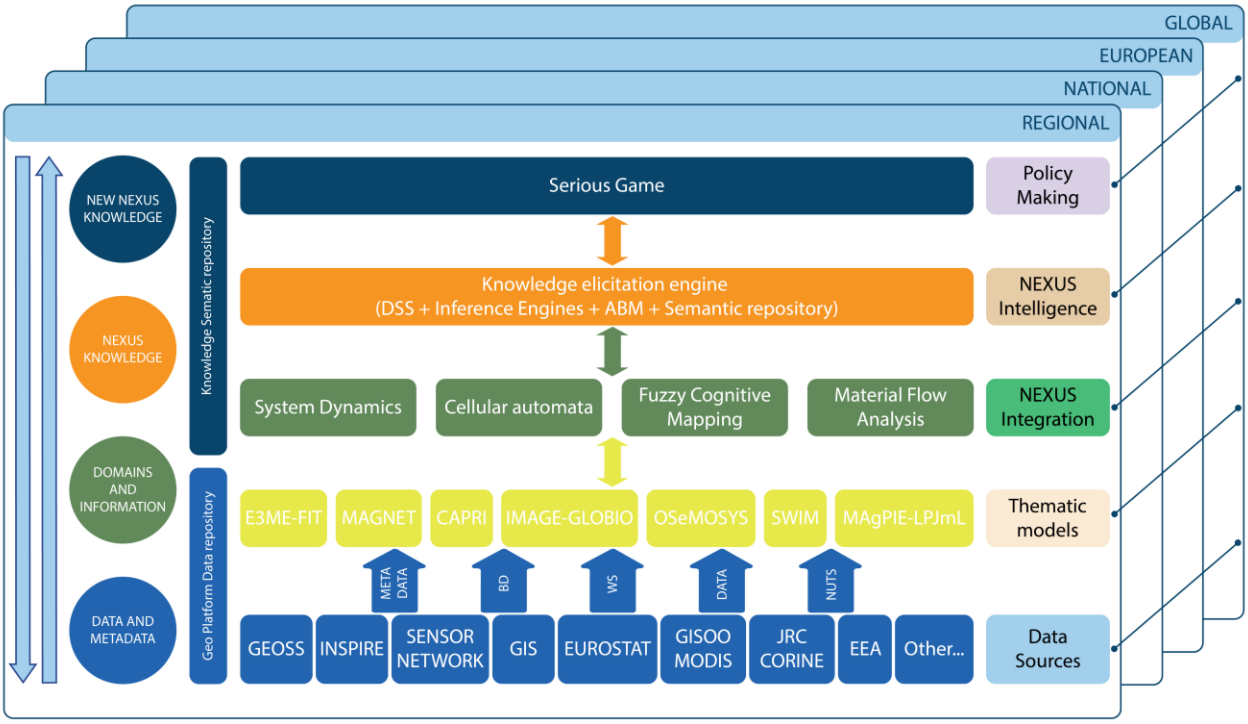

Figure 12. SIM4NEXUS project architecture [SIM4NEXUS, 2018]

Figure 13. SIM4NEXUS project ontology [Susnik, 2018]

SIM4NEXUS project is an excellent use-case for ontology use, gamification, simulation and synergy between different domains and stakeholders.

Smart.met

Smart.met project supports Pre-Commercial Procurement (PCP) with technical assessment, procurement procedure and dissemination [Smart.met, 2018]. An effective, efficient, interoperable solution is reached by implementation of smart metering of (drinking) water based on an open standard. The metering capabilities are provided by the public water utilities whereas the project methodology is capable to improve customer service, optimise the supply of water and identify performance issues. Smart water metering presents itself as an effective solution to the challenges faced by the majority of European water utilities today, from extreme events induced by climate change to the need to replace an ageing infrastructure. Indeed, providing access to accurate data in real-time can help decrease operating costs and prioritise infrastructure investments, while also improving the daily management of networks and customer services.

The Pre-Commercial Procurement procedure is becoming a driving force for the utilities to seek for demand-driven research and new innovative smart meter solutions that increase data readability, battery lifetime, interoperability. These shortcomings explain the need for an advanced water meter technology, able of tackling the challenges of technology lock-in, interoperability, two-way communication, battery lifetime and radio signal coverage, to name a few. In addition, safety issues and people's acceptance of local wireless network emissions are also crucial questions to be addressed.

Smart.met project is a good use-case for smart water procurements and metering management.

SmartH2O

SmartH2O project defines an open extensible framework for building smart water applications [SmartH2O, 2018]. The framework is shown in Figure 14. It uses heterogeneous data sources, social computation interfaces, the deployment model and data sharing through APIs for reaching an interoperability with other platforms. The platform has its own decision support system, classifies and profiles the customers.

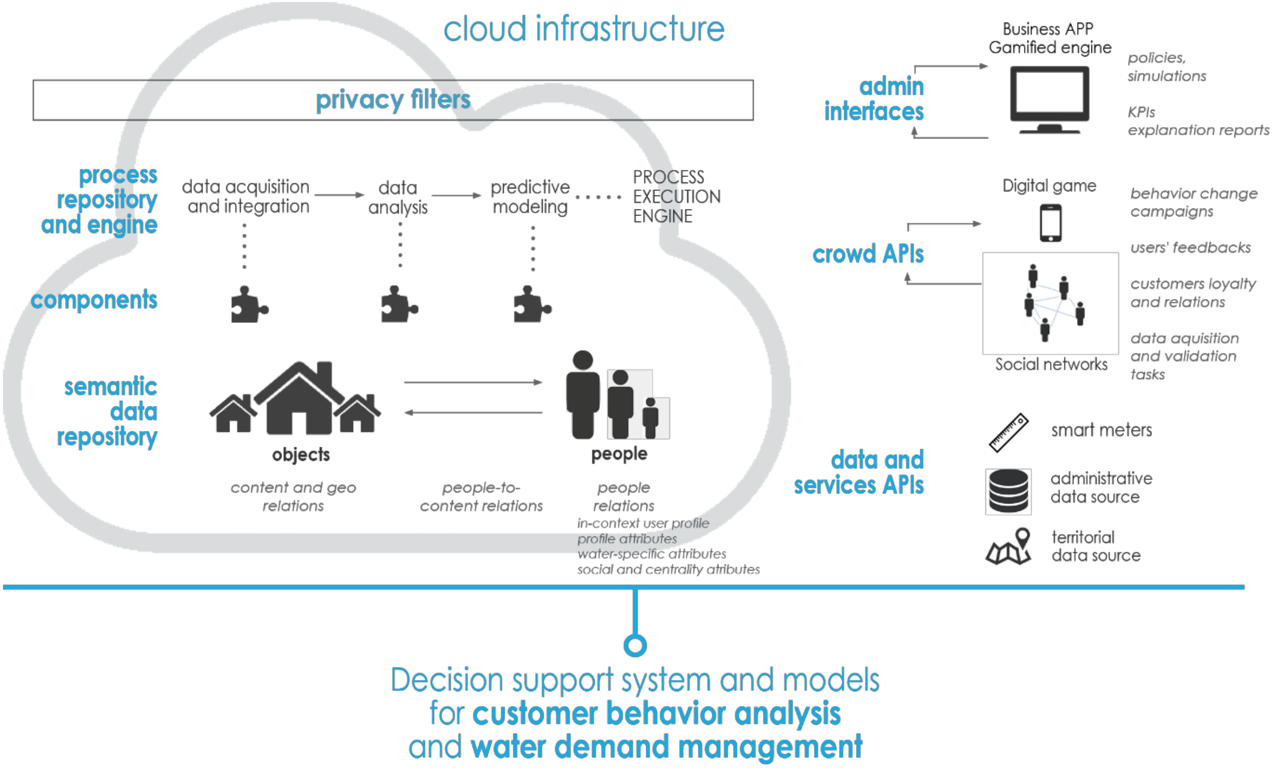

Figure 14. SmartH2O project platform for smart water management [SmartH2O, 2018]

SmartH2O project could be a good use-case during standardisation supporting the classification, ontology definitions and services specification.

SMART-Plant

SMART-Plant project provides a solution for the existing wastewater treatment plants to renovate and change towards efficient wastewater bio-refineries. This is achieved through a portfolio of SMARTechnologies [SMART-Plant, 2018]. Low carbon and energy footprint are continuously assessed through real-time monitoring of greenhouse gas emissions, energy consumptions and process parameters. SMART-Plant scales-up in real environment eco-innovative and energy-efficient solutions to renovate existing wastewater treatment plants and close the circular value chain by applying low-carbon techniques to recover materials that are otherwise lost. New public-private partnership models are explored connecting the water sector to the chemical industry and its downstream segments such as the construction and agricultural sector, thus generating new opportunities for funding.

SMART-Plant project is a good use-case for the use of reclaimed water. The ICT part is not published.

SmartWater4Europe

The business case of the smart water supply networks around the world is analysed by the SmartWater4Europe project [SmartWater4Europe, 2018]. The new industry solutions could save efforts of the global water operators in managing their business. These solutions are based on data and experience sites collected under different circumstances across Europe, as well as analysis and knowledge-gathering of smart water data on an unprecedented scale. The project defines innovative solutions, possibility for integration, standardisation aspects, business cases, deployment potential and market uptake routes. The aim is to define an instrument for prioritisation and optimisation of investment while implementing the European directive on drinking water.

SmartWater4Europe contributes to the EIP Water by speeding up innovations in work priorities that contribute to solving societal challenges, enhance Europe's competitiveness and support job creation and economic growth. Furthermore, the demand and supply are bridged accelerating the uptake of innovations and speeding up their market introduction.

SmartWater4Europe project is a good example of smart water management at water distribution level using SCADA.

SPACE-O

SPACE-O (Space Assisted Water Quality Forecasting Platform for Optimised Decision Making in Water Supply Services) project uses space observation for water management decisions [SPACE-O, 2018]. It integrates satellite technology and in-situ monitoring systems with state of the art hydrologic and water quality modelling using advanced ICT tools for generating real-time, short to medium-term forecasts of water flows and key water quality parameters (e.g. turbidity, algae) in reservoirs. Decision making systems use the collected data in water supply services while enabling proactive solutions at operational level [SPACE-O Infographic, 2018].

Continuous provision of safe and clear water is possible thanks to reliability of the infrastructure, water quality monitoring, efficient performance of the water utilities. Underestimation of the environmental and financial impacts on the continuity of the business is considered seriously. Limited freshwater resources and issues as drought, flooding, pollution, population growth, and competition from other uses, such as ecosystem protection, agriculture, energy production and recreation increases the price of the water management. Electricity and chemicals in water treatment operations should be used efficiently, in a sustainable way and in conformance to the resources protection and sectorial policies.

Agriculture and industry depend on climate change, energy, and water management. The need of stakeholders’ adaption to the social and environmental concerns in large hydrologic units is growing. Water flows and quality monitoring in real-time, capacity forecasts in short to medium-term are used for better water and plant operations aiming to fill the gap between science and water business sector.

Satellite remote sensing techniques are widely used for the systematic study of the Earth‘s surface. They have many applications in science, including assessing and quantifying changes in water quality. SPACE-O operational service platform is innovative and increases the interoperability between Earth observations and modelled services. The Earth observation sector is raising more and more attention due to its relation to many sectors including the water management. SPACE-O tries to create new products and services for better water supply, addressing the environmental challenges and EU policy at the same time.

Space-O project is an excellent use-case for using satellite and non-satellite data in decision-making and service creation process. Description of the ICT part is not publicly available.

STOP-IT

The security of the critical water infrastructures against physical and cyber threats from strategic, tactical, and operational point of view is dealt by the H2020 European research project STOP-IT [STOP-IT, 2018]. The team identifies risks and co-develops an all-hazards risk management framework for the physical and cyber protection of critical water infrastructures. STOP-IT results in an integrated, modular platform that supports the strategic/tactical planning, the real-time operational decision making and the post-action assessment for the key parts of the water infrastructure. It is scalable, adaptable, and flexible.

STOP-IT project is a good use-case for the smart water security and data protection implementation.

SUBSOL

A robust, effective, sustainable, and cost-efficient solution for the freshwater challenges in coastal areas worldwide is established by the SUBSOL project [SUBSOL, 2018]. It is a market breakthrough subsurface water solution achieved by developing a practical approach which accelerates acceptance of subsurface water systems and enhances the market reach and uptake. A set of innovative and practical concepts have been developed to protect, enlarge, and utilise the freshwater resources in coastal areas. The work is based on national, regional, and European research and innovation programs in the past five years. These subsurface water solutions (SWS) allow advanced groundwater management and maximum control over freshwater resources by combination between innovations in water design and configuration management. The SWS capacity is demonstrated through the full-scale pilots that support the sustainable freshwater supply in coastal areas, energy reduction, food production, and financial savings. Demonstration, market replication, standardisation, and commercialisation of the SUBSOL SWS breakthrough aim to reach the market for freshwater resources in coastal areas.

The project does not stress on ICT solutions. However, at ontology level it could be an example how to present the data in the circular economy at coastal regions.

SYNCHRONICITY

Synchronicity is a global IoT marketplace where cities and businesses create and trade common digital services to improve the lives of citizens and grow local economies [SYNCHRONICITY, 2018]. The SynchroniCity IoT Large-Scale Pilot aims to define a platform and services that are simplified, open, agile, cross-border. The solution is transparent and scalable, it is based on agile city standards and optimised for the marketplace.

IoT innovation based on common, open standards is implemented towards a smart-city environment in different reference zones (RZs). SynchroniCity Architecture Reference

Model (ARM) is presented in Figure 15. It implements macro services, southbound interfaces, data management, northbound interfaces, security, privacy, uses current IoT implementations and legacy IoT architectures.

The architecture of the SYNCHRONICITY has decoupled & distributed components, is interoperable, open, scalable, legacy compatible, heterogeneous, resilient to failure.

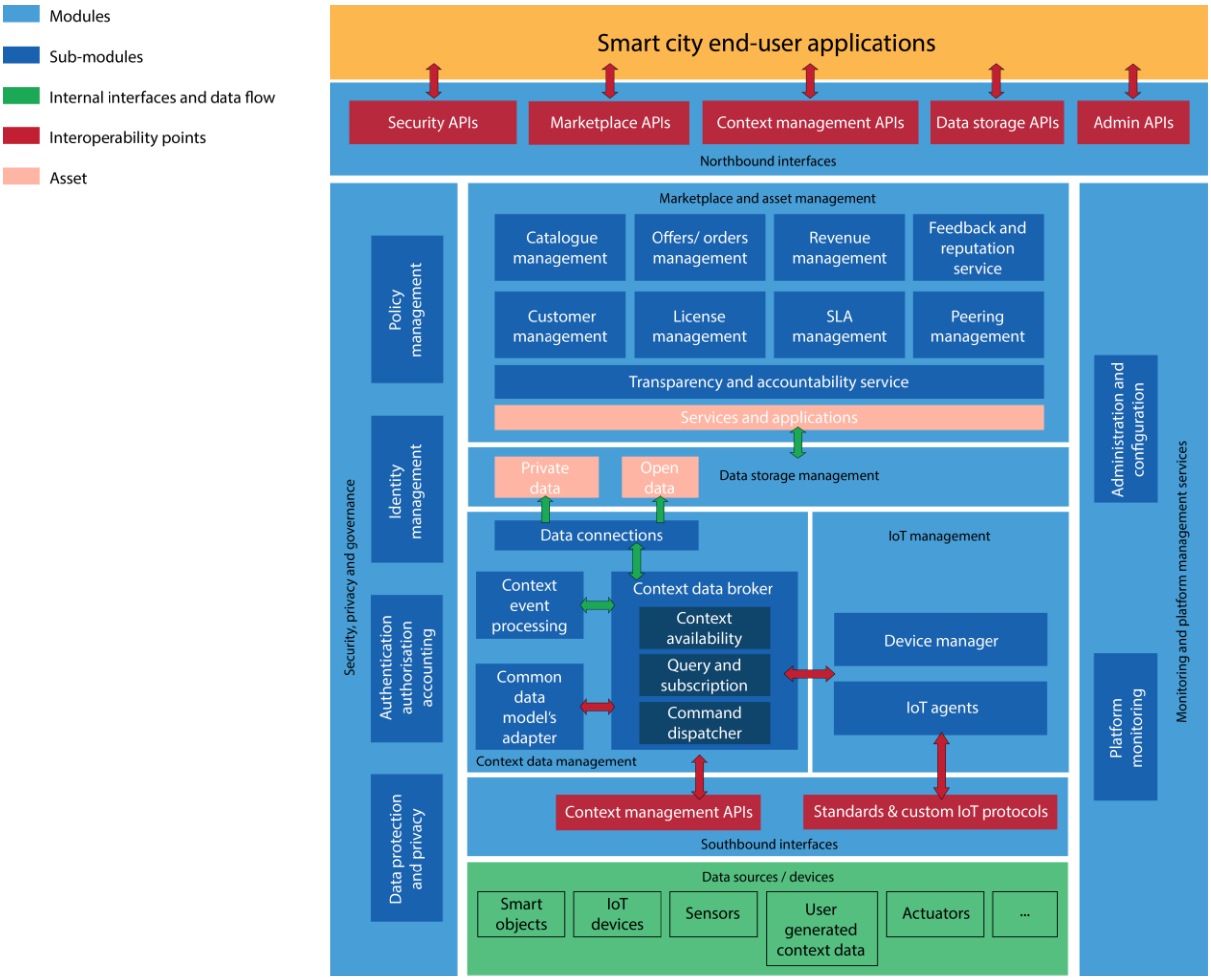

Figure 15. SYNCHRONICITY project platform for smart cities [SYNCHRONICITY, 2018]

Implementation of FIWARE [FIWARE, 2018] and Next Generation Service Interfaces (NGSI) in SYNCHRINICITY pilot is a good use-case in standard development.

SWAMP

A precision irrigation domain is addressed by the SWAMP project that develops an IoT-based smart water management system [SWAMP, 2018]. Data fusion, data analytics, and autonomous drones combined with mobile applications are integrated into the SWAMP solution targeting analyses of the exact need of water, the situation at the farm, matching the irrigation and water delivery. The technology developed and deployed senses the level of water needed by the plantation and for flowing the water to places where and when needed. The project also aims to reduce the efforts in software development for IoT-based smart applications, to automate advanced platforms and integrate different technologies and components, to integrate heterogeneous and advanced sensors, particularly flying sensors (drones) providing precision in the water supply for irrigation, and to use the platform together with technologies such as IoT, Big Data, cloud/fog and drones for the deployment of pilot applications for smart water management and replicability of the solutions. SWAMP system for high-precision smart irrigation optimises the irrigation, the water distribution and the consumption based on a holistic analysis that collects information from all aspects of the system including even the natural water cycle and the cumulated knowledge related to growing of the particular plants.

SWAMP project is a good use-case for smart irrigation and beginning of the fog computing implementation.

UrbanWater

UrbanWater project improves the efficiency of water management in Europe. The UrbanWater platform incorporates weather prediction, surface water reserves data (e.g. reservoirs), household consumption data, includes water distribution data like pressure and leakages, additional information and statistics coming from other sources [URBANWATER, 2018]. The platform uses solutions for advanced metering, data for real-time consumption and new technologies for data management with real-time forecasting on demand, analysis of the consumption, decision support systems, price adaption, and user empowerment solutions. The platform is open to ensure interoperability with energy and water management schemes and further enhance collaboration between key partners.

URBANWATER project is a possible use-case for end-to-end water management.

WADI

WADI project proposes a reduction of losses and the related energy consumption in water transmission systems for water supply, irrigation, hydropower [WADI, 2018]. A surveillance service for water leak detection is developed to provide water utilities with information on leakages in the water infrastructure outside urban areas. Off-the-shelf optical remote sensing devices (multispectral and infrared cameras) are coupled with the two complementary aerial platforms (manned and unmanned) in an operational environment making the WADI’s concept innovative and cost-effective. Strategic infrastructure monitoring at long distance in areas with difficult physical access is provided as a result.

WADI project is a good use-case in water distribution management and distant monitoring of the sources.

WatERP

A web-based “Open Management Platform” (OMP) is developed by the WatERP projects to increase the visibility of the entire water distribution system [WatERP, 2018]. It is supported by real-time knowledge on water supply and demand. The visualisation is customised and integrated with additional data.

WatERP project could be a use-case for web-based solution using data sharing.

WIDEST

WIDEST project has the vision of establishing and supporting a thriving, interconnected ICT for water community to promote the dissemination and exploitation of EU funded activities and results in this area [WIDEST, 2018].

WIDEST project could be a good coordination use-case in smart water management.

WISDOM

WISDOM project functional architecture is open, collects and harmonises data for the water [WISDOM, 2018]. The project defines data ontology to build data models appropriate for the services created. Service layer is based on the collected and processed data, data analysis, rules for processing applied. The cloud is used for data delivery to the customers.

WISDOM project is a good use-case for the ontology definition in further standardisation process.

WaterInnEU

EU funded ICT models, tools, protocols, and policy briefs related to water are used by the project WaterInnEU to create a marketplace for enhancement and exploitation of results in suitable conditions, i.e. to create new market opportunities [WaterInnEU, 2018]. The support of the implementation of the Water Framework Directive is promoted through aggregates and screens of the outcomes, dissemination and exploitation of previous European funded projects. The assessment of the level of standardisation and interoperability of projects is performed looking for a mechanism to integrate ICT-based tools, incorporate open data platforms, generate a palette of interchangeable components capable to use the water data, introduce the data sharing processes, stimulate data models preparation using initiatives as the INSPIRE directive. A forum named Marketplace-as-a-Service (MaaS) is created from projects representatives, stakeholders, and companies in the water domain, (in particular SMEs) to move the current products into the market and offer them at different levels (Figures 16 and 17). Open virtual marketplace defined in the scope of the project includes a user feedback facility and a success stories portfolio with tools and links to water data and metadata.

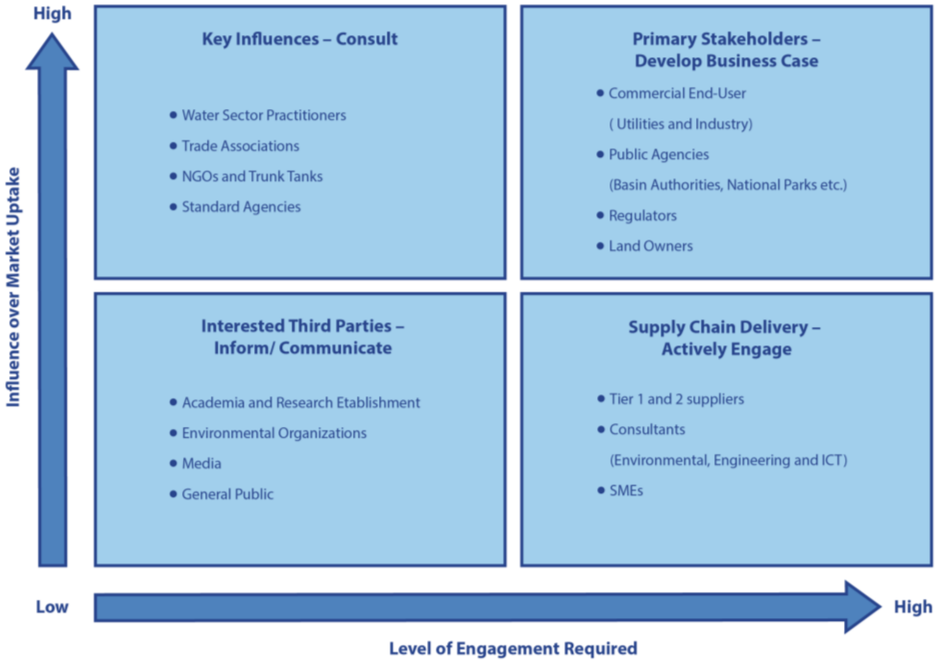

Figure 16. WaterInnEU project market uptake [WaterInnEU, 2018]

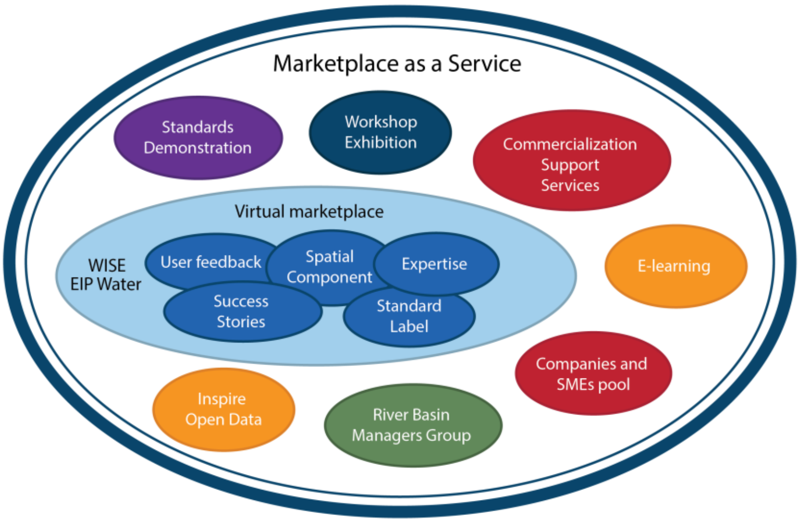

Figure 17. WaterInnEU Marketplace-as-a-Service [WaterInnEU, 2018]

WaterInnEU project is a good use-case for the water models in basins including the transnational rivers and lakes as well as the stakeholder engagement and management services.

Weam4i

Weam4i platform is developed for irrigation [Weam4i, 2018]. It is cloudified, shares data and is interoperable to similar systems. There is also a decision support system working locally, gathering data for water for irrigation, spatial data, other environmental data, correlating the smart water management with the energy market. The platform is presented in Figure 18.

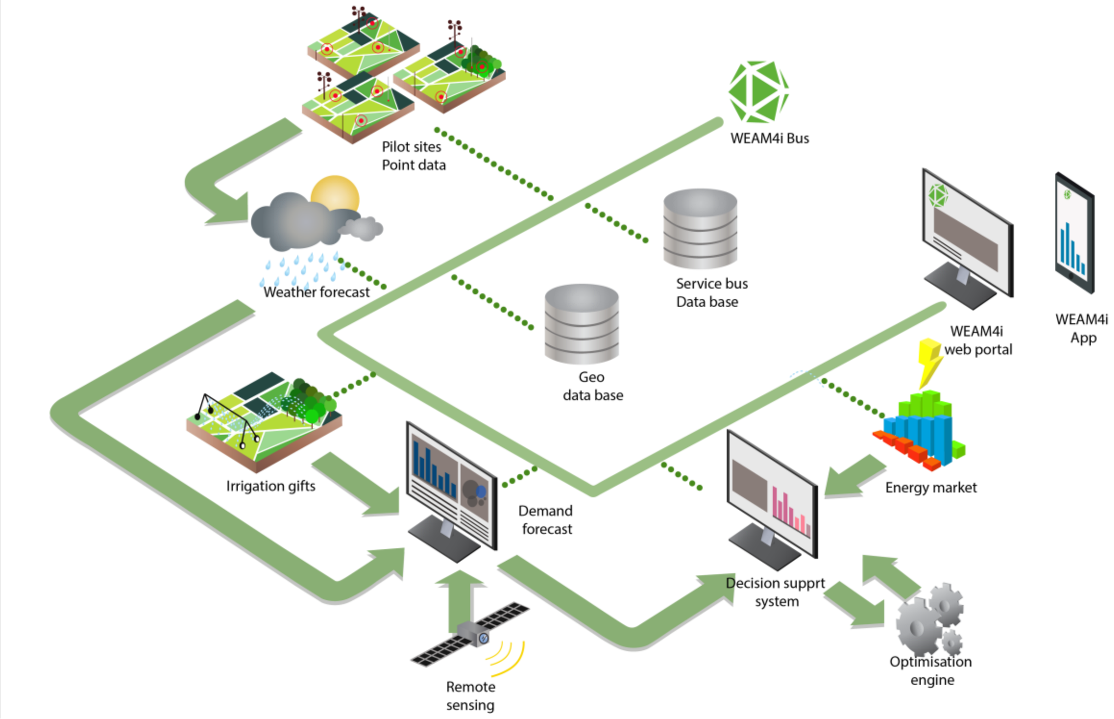

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Figure 18. Weam4i project platform for smart water management [Weam4i, 2018]

WEAM4i platform is a good possible use-case for standardisation support for irrigation and data management.

WATERNOMICS

A platform for water information, management and decision support is developed by the WATERNOMICS project. It shows meaningful and personalised information about the use, the price, and the availability of water to the end-users interactively [WATERNOMICS, 2018]. This introduces limitations in the efforts to manage Water-as-a-Resource. The Waternomics project enables the detailed and real-time measurement of water flows and usage, supports analyses of water consumption patterns, and provides key recommendations on how to increase water efficiency (Figure 19).

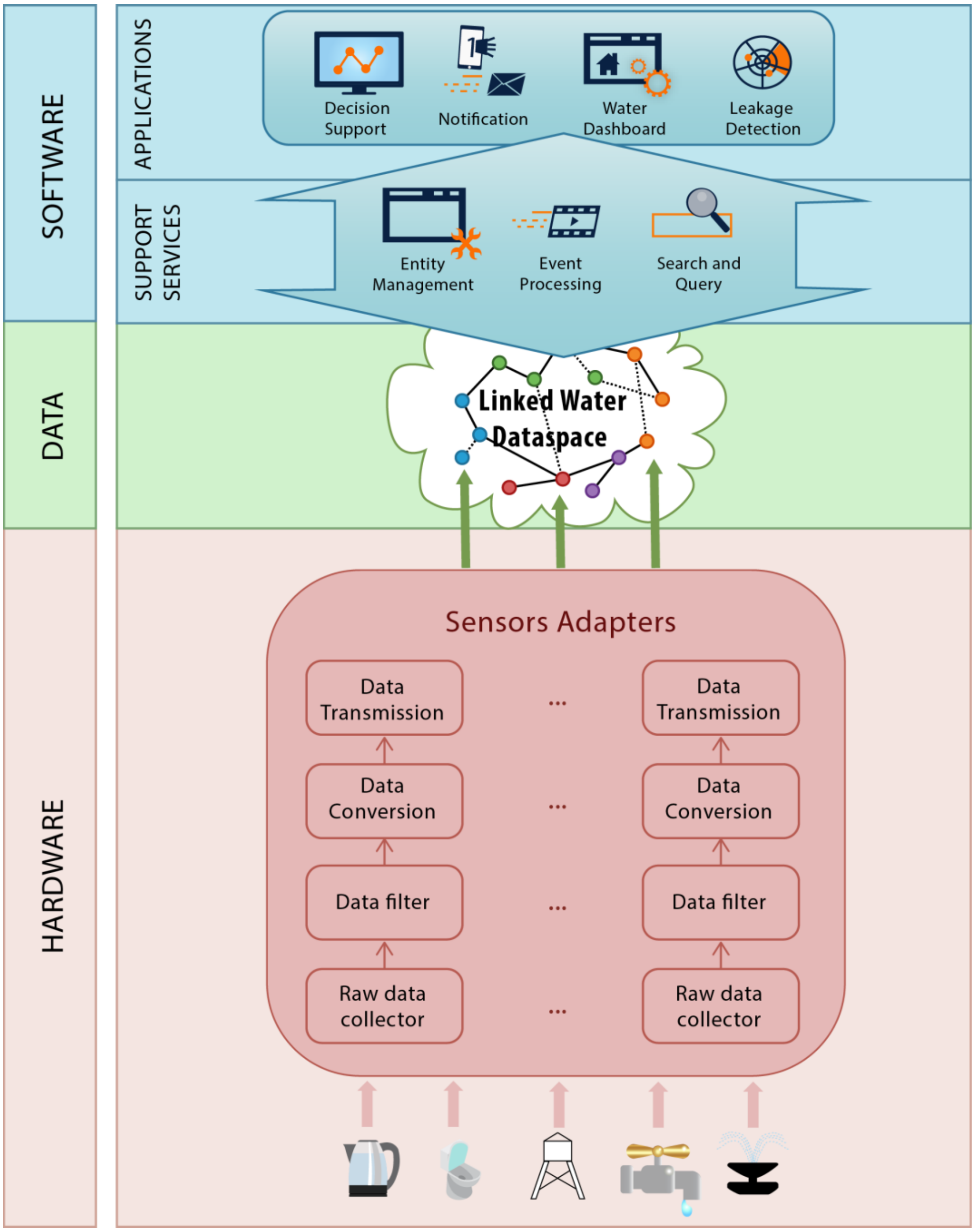


Figure 19. Waternomics project architecture [Waternomics 2018]

WATERNOMICS project is a good use-case for Water-as-a-Resource definition.

3.2. Mapping the Platforms and the KPIs

The analysis of the existing platforms and specifications for smart water management is based on the outputs from more than 50 projects running between 2012 and 2019. The requirements from the end-users and the stakeholders have been collected and simplified in Tables 7 to 22. The acronyms of the projects are used in the table's rows and KPIs are presented in the tables' columns. Tables 7 to 14 are more technology-oriented whereas Tables 15 to 22 are more business-oriented. The gaps identified are explained below the tables.

Specifications from running projects are proposed to be used as a list of possible use-cases and stakeholders' identification in standards' development. The gaps identified are marked in the tables in:

- Blue – short term gaps needed to be solved within the next two years.
- Violet – medium term gaps needed to be solved within four years
- Green – long term gaps needed to be solved within six years

Many of the platforms are still not open or the interoperability and possibility for integration are limited. Scalability and cross-sectoral integration also need more attention. Some of the projects and specifications need to be more focused on security issues.

Many of the specifications do not address existing infrastructure integration and interoperability that is critical for the continuous development in the sector. Players do not always understand the importance of connectivity and data sharing. Another aspect important for the platform development is the need of clear aligning between KPIs and ontology in the smart water management including business processes.

Smart water services cloudification aims to make the services transparent and standardised. The water in circular economy in different scales could be estimated and analysed based on the cloud-based services and data collected.

Data sharing is not well defined in many of the existing specifications. It is not clear how the cloud supports existing ontologies to define data relation and dependencies. It is not possible to make adequate service development in a mature and sharable way due to the lack of ontology and data sharing capabilities. Cloudification of the smart water management works towards transparency of the water business and its sustainability.

The process of micro and monolithic service creation needs to be continuous, flexible, adaptive, and leading to the better solutions for the end-users and stakeholders. The use of big data analyses in the water management could lead to better control and understanding of the global and regional processes and support policy makers.

Table 7. Architectural, technological, and functional aligning between the smart water management requirements and the platforms of different projects. Openness, interoperability, integration, scalability, synergy and security analyses. Specifications from A to N

Requirement/ Projects	Open	Cross sectoral	Inter-operable	Integ-rable	Sca-lable	Secure	Focused on people	Open for innova-tions
AfriAlliance	-	-	-	-	-	-	Yes	Yes
AquaNES	No	May be	May be	Not clear	Not clear	Yes	Yes	yes
BlueSCities	May be	Yes	May be	May be	Not clear	Not clear	Yes	Yes
CENTAUR	May be	Possible	Possible	Possible	May be	Not clear	Not clear	Yes
Ctrl+Swan	Yes	Possible	Possible	Possible	Yes	Yes	May be	Yes
CYTO-WATER	Could be	Possible	Possible	Possible	Could be	May be	Could be	Yes
DAIAD	Yes	Possible	Possible	Possible	Possible	Yes	Yes	Yes
DIANA	Yes	Could be	Possible	Possible	Possible	Not clear	Yes	Yes
EFFINET	May be	May be	May be	May be	May be	Yes	May be	Yes
ESPRESSO	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
FREEWAT	Not clear	Could be	Could be	Possible	Possible	May be	May be	Yes
Ground Truth 2.0	Yes	Coud be	Could be	Could be	May be	Not clear	Yes	Yes
HYDROUSA	Not clear	Could be	Could be	Could be	Could be	Could be	Yes	Yes
ICEWATER	Not clear	Yes	Not clear	Not clear	Not clear	May be	Possible	Yes
INCOVER	May be	No	May be	May be	May be	May be	Yes	Yes
INNOQUA	May be	No	May be	May be	Yes	Yes	Yes	Yes
INTCATCH	Yes	Possible	Possible	Possible	Possible	Yes	Yes	Yes
INTEGROIL	Could be	Yes	Could be	Could be	Not clear	May be	Not clear	Yes
ISS-EWATUS	Yes	Could be	Yes	Yes	Yes	Yes	Yes	Yes
iWIDGET	Yes	Possible	Yes	Yes	Yes	Yes	Yes	Yes
KINDRA	Not clear	Could be	Not sure	Not sure	Not sure	May be	Yes	Yes
Life SmartWater	Could be	No	Not sure	Not sure	Possible	Not clear	Yes	Yes
Life SWSS	Possible	Yes	Possible	Possible	Possible	Yes	Indirectly	Yes
NADiRA	Yes	Could be	Yes	Yes	Possible	Not clear	Yes	Yes
NextGen	Possible	Yes	Possible	Possible	Possible	Yes	Yes	Yes

Table 8. Architectural, technological, and functional aligning between the smart water management requirements and the platforms of different projects. Openness, interoperability, integration, scalability, synergy and security analyses. Specifications from O to W

Requirement/ Projects	Open	Cross sectoral	Interoperable	Integrable	Scalable	Secure	Focused on people	Open for innovations
POWER	Not clear	Not clear	Not clear	Not clear	Not clear	May be	Yes	Yes
Project Ô	Could be	Not clear	Not clear	Not clear	Not clear	Not clear	Yes	Yes
Proteus	Yes	Possible	Possible	Possible	Possible	Possible	Yes	Yes
RESCCUE	Not clear	Not clear	Not clear	Not clear	Not clear	May be	Yes	Yes
RTWQM Action Group	Not clear	Not clear	Not clear	May be	May be	May be	May be	Yes
Run4Life	Possible	Yes	Possible	Possible	Possible	Yes	Yes	Yes
SAFEWATER	Yes	Could be	Possible	Possible	Possible	Yes	Yes	Yes
Sim4NEXUS	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Smart H2O	Yes	Possible	Yes	Yes	Possible	Yes	Yes	Yes
Smart.met	Yes	Possible	Yes	Yes	Yes	Yes	Yes	Yes
Smart-Plant	Not clear	Not clear	Could be	Could be	Yes	Yes	Yes	Yes
SmartWater4-Europe	Not clear	Could be	Could be	Could be	May be	Yes	Yes	Yes
SPACE-O	May be	Yes	Possible	Possible	Possible	Possible	Yes	Yes
STOP-IT	Yes	Possible	Yes	Yes	Yes	Yes	Yes	Yes
SUBSOL	Possible	Possible	May be	Possible	Possible	Yes	Yes	Yes
SWAMP	Yes	Possible	Yes	Yes	Yes	Yes	Yes	Yes
SYNCHRONICITY	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
UrbanWater	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
WADI	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
WaterInnEU	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
WATERNOMICS	Yes	Possible	Possible	Possible	Yes	Yes	Yes	Yes
WatERP	Yes	Not clear	May be	May be	Yes	Yes	Yes	Yes
WeaM4i	Yes	Possible	Possible	Possible	Possible	Yes	Possible	Yes
WIDEST	Yes	Yes	Yes	Yes	Yes	Not applicable	Yes	Yes
WISDOM	Yes	Possible	Possible	Possible	Possible	Yes	Yes	Yes

Table 9. Architectural, technological, and functional aligning between the smart water management requirements and the platforms of different projects. Maturity, KPIs support, connectivity, standard support and potable water management. Specifications from A to N

Requirement/ Projects	Mature	Connecting Europe Facility deployments	Endorse-ment of formal platforms	KPIs support	Stan-dards support	Potable water manage-ment
AfriAlliance	-	-	Possible	May be	May be	Possible
AquaNES	No	No	May be	May be	May be	Yes
BlueSCities	No	Yes	May be	May be	May be	Yes
CENTAUR	Not completely	May be	Partially	Some	Some	No
Ctrl+Swan	May be	May be	May be	Yes	Yes	Yes
CYTO-WATER	Not clear	Could be	May be	Yes	Yes	No
DAIAD	Yes	Possible	Possible	Yes	Possible	Yes
DIANA	Could be	Could be	Possible	Yes	Yes	Not clear
EFFINET	May be	May be	May be	May be	May be	Yes
ESPRESSO	May be	Yes	Yes	Yes	Yes	Possible
FREEWAT	May be	Possible	Possible	Not clear	Not clear	Yes
Ground Truth 2.0	No	Yes	May be	Yes	Yes	Could be
HYDROUSA	No	Not clear	Not clear	Yes	Yes	Yes
ICEWATER	May be	May be	Not clear	Not clear	May be	Yes
INCOVER	May be	Not clear	Not clear	May be	May be	Not clear
INNOQUA	May be	Could be	Not clear	Not clear	Not clear	No
INTCATCH	Yes	May be	May be	Not clear	Not clear	Possible
INTEGROIL	Almost	Not clear	Not clear	May be	May be	Not clear
ISS-EWATUS	Yes	Not clear	Not clear	May be	May be	Yes
iWIDGET	May be	Cloud be	Cloud be	Yes	Yes	Yes
KINDRA	Cloud be	May be	May be	Not clear	Not clear	Yes
Life SmartWater	Cloud be	Not clear	May be	Not clear	Not clear	Yes
Life SWSS	Cloud be	Not clear	Not clear	Possible	Possible	Yes
NADiRA	Not clear	Cloud be	Possible	Yes	Yes	Not clear
NextGen	Not clear	Not clear	Not clear	May be	May be	Yes

Smart water service creation is not possible without good cooperation with players. Continuity of the business and accompanying service development is based on the user requirements and expectations. The solutions should be replicable in order to allow the development of the Digital Single Market and systems deployments in incremental steps. Local legislation needs to be harmonised and have to lead to service customisation through licences. The platform development has to conform to the standards. Some of the existing standards need to be mapped and harmonised together leading to the better and smooth platform development.

Table 10. Architectural, technological, and functional aligning between the smart water management requirements and the platforms of different projects. Maturity, KPIs support, connectivity, standard support and potable water management. Specifications from O to W

Requirement/ Projects	Mature	Connecting Europe Facility deployments	Endorsement of formal platforms	KPIs support	Standards support	Potable water management
POWER	Not clear	Not clear	Not clear	Could be	Could be	Yes
Project Ô	May be	Not clear	Not clear	May be	May be	Partially
Proteus	Not clear	Not clear	Not clear	May be	May be	Yes
RESCCUE	Not clear	Not clear	Not clear	May be	May be	Yes
RTWQM Action Group	Not clear	Not clear	Not clear	Not clear	Not clear	Possible
Run4Life	Yes	Could be	Not clear	Yes	Yes	Partially
SAFEWATER	Yes	Possible	Not clear	Yes	Yes	Yes
Sim4NEXUS	Yes	Yes	Possible	Yes	Yes	Yes
Smart H2O	Yes	Possible	Possible	Yes	Yes	Yes
Smart.met	Could be	Possible	Possible	Yes	Yes	Yes
Smart-Plant	May be	Not clear	Not clear	Yes	Yes	
Smartwater4-Europe	Yes	Possible	Possible	Yes	Yes	Yes
SPACE-O	Could be	May be	Not clear	Yes	Yes	Yes
STOP-IT	Yes	Possible	Not clear	Yes	Yes	Yes
SUBSOL	May be	Not clear	Not clear	Yes	Yes	Could be
SWAMP	Yes	Yes	Not clear	Yes	Yes	Partially
SYNCHRONICITY	Partially	Yes	Could be	Yes	Yes	Possible
UrbanWater	Yes	Yes	Could be	Yes	Yes	Yes
WADI	Yes	Yes	Not clear	Yes	Yes	Yes
WaterInnEU	Yes	Yes	Yes	Yes	Yes	Yes
WATERNOMICS	Yes	Yes	Not clear	Yes	Yes	Yes
WatERP	Yes	Yes	Not clear	Yes	Yes	Yes
WeaM4i	Yes	Possible	May be	May be	Yes	Not clear
WIDEST	Yes	Yes	Yes	Yes	Yes	Yes
WISDOM	Yes	Possible	May be	Could be	Possible	Yes

The social aspects of the smart water management are still underestimated in many specifications. The proactive role of the end-users and stakeholders is expected to become a driving force for the platforms' and standards development.

Mapping between the services from different sectors, the service dependencies specification, looking to the green and sustainable solutions are the essential features of the Digital Single Market.

Self-sufficiency level is not always reasonably estimated in many specifications. Digital Single Market solutions should be effective, tested and practically-proven concepts.

Table 11. Architectural, technological, and functional aligning between the smart water management requirements and the platforms of different projects. Stormwater, flooding, sewage, wastewater reuse, IoT implementation and cloudification level. Specifications between A and N

Requirement/ Projects	Stormwater/ flood management	Sewage manage-ment	Wastewater management	Water reuse	Use of IoT and communi-cation	Cloudi-fication
AfriAlliance	Possible	Possible	Possible	Possible	Possible	Possible
AquaNES	Possible	Possible	Yes	Partially	Not clear	No
BlueSCities	Yes	Yes	Yes	May be	Not clear	No
CENTAUR	Yes	No	Possible	May be	Yes	Partially
Ctrl+Swan	May be	Yes	Yes	May be	Yes	Yes
CYTO-WATER	Yes	Yes	Yes	Possible	Yes	Possible
DAIAD	Yes	Yes	Yes	Yes	Yes	Yes
DIANA	Possible	Possible	Possible	Partially	Not clear	Possible
EFFINET	May be	Yes	Yes	May be	May be	May be
ESPRESSO	Possible	Possible	Possible	Possible	Yes	Yes
FREEWAT	Possible	Yes	Yes	Possible	Yes	Possible
Ground Truth 2.0	Possible	Possible	Possible	Possible	Possible	May be
HYDROUSA	Yes	Yes	Yes	Yes	May be	Possible
ICEWATER	May be	May be	May be	Not clear	Not clear	No
INCOVER	Possible	Yes	Yes	Possible	Yes	Not clear
INNOQUA	Not clear	Yes	Yes	Yes	Not clear	Not clear
INTCATCH	Yes	Yes	Yes	Yes	Yes	Yes
INTEGROIL	Not clear	Not clear	Yes	Yes	Yes	Not clear
ISS-EWATUS	Possible	Yes	Yes	Yes	Yes	Yes
iWIDGET	Could be	Yes	Yes	Could be	Yes	Yes
KINDRA	Yes	Not clear	Not clear	Not clear	May be	Not clear
Life SmartWater	No	Could be	Could be	Not clear	Yes	Not clear
LifeSWSS	No	No	No	Not clear	Yes	Not clear
NADiRA	Possible	Possible	Possible	Partially	Not clear	Yes
NextGen	Yes	Yes	Yes	Yes	Yes	Not shown

Efficiency in use is not well presented in many specifications. It is an important aspect of any platform aiming to become a part of the open market. There are more than 50 different projects and specifications that could be used as use-cases in standard development covering different aspects of the smart water management and efficiency analyses.

Table 12. Architectural, technological, and functional aligning between the smart water management requirements and the platforms of different projects. Stormwater, flooding, sewage, wastewater reuse, IoT implementation and cloudification level. Specifications between O and W

Requirement/ Projects	Stormwater/ flood management	Sewage management	Wastewater management	Water reuse	Use of IoT and communication	Cloudification
POWER	Not clear	Not clear	Not clear	Not clear	Not clear	Not clear
Project Ô	Yes	Yes	Yes	Yes	Not clear	Not clear
Proteus	May be	Yes	Yes	Not clear	Yes	Yes
RESCCUE	Yes	Not clear	Not clear	May be	Yes	Not clear
RTWQM Action Group	Possible	Possible	Possible	Possible	Not clear	Not clear
Run4Life	Possible	Yes	Yes	Yes	Yes	Possible
SAFEWATER	Possible				Yes	
Sim4NEXUS	Yes	Yes	Yes	Yes	Yes	Yes
Smart H2O	Possible	Possible	Possible	Possible	Possible	Yes
Smart.met	Possible	Possible	Possible	Possible	Yes	Yes
Smart-Plant	No	Yes	Yes	Yes	Yes	Not clear
SmartWater4-Europe	No	No	No	Partially	Yes	Partially
SPACE-O	Yes	Yes	Yes	Yes	May be	Not clear
STOP-IT	Not clear	May be	May be	May be	Yes	Yes
SUBSOL	Yes	Could be	Could be	Yes	Yes	Not clear
SWAMP	Partially	Yes	Yes	Yes	Yes	Yes
SYNCHRONICITY	Possible	Possible	Possible	Possible	Yes	Yes
UrbanWater	Yes	Yes	Yes	Yes	Yes	Yes
WADI	Possible	Possible	Possible	Yes	Yes	Yes
WaterInnEU	Possible	Possible	Possible	Yes	Yes	Possible
WATERNOMICS	Possible	Possible	Possible	Yes	Yes	Yes
WatERP	Not clear	Not clear	Not clear	Yes	Yes	May be
WeaM4i	Possible	No	May be	May be	Yes	No
WIDEST	Possible	Possible	Possible	Yes	Yes	Yes
WISDOM	Yes	Possible	Possible	Possible	Yes	Yes

Regardless the short-, medium- and long-term features of the specifications existing on the market, other features should not be disregarded and should accompany and support the overall standardisation process. This detailed analysis provides a clear picture on the recent developments in the sector, the trend for next two to three years and the necessary steps in the long run. **Smart water management is broad in scale and has many different faces. In this sense, because of the selection of 50 possible use-cases, satellite data analyses, environmental monitoring, marine and sweet water basins monitoring, small to medium agriculture watering, smart cities potable water supply, sewage and reclaimed water management and finally small and big water in circular economy management are covered by at least 2-3 use-cases each. Attention is paid to the circular economy and more specifically to the water reuse** [Regulation, 2018].

Table 13. Architectural, technological, and functional aligning between the smart water management requirements and the platforms of different projects. Data sharing, service definition, big data, and ontology analyses. Specifications from A to N

Requirement/ Projects	Data sharing	Cloud-based services	Water-as-a-Service, micro services	Macro services	Use of Water Big Data	Ontology defined
AfriAlliance	**-**	-	-	-	-	-
AquaNES	No	No	No	No	No	No
BlueSCities	No	No	No	No	No	No
CENTAUR	No	No	No	Partially	No	No
Ctrl+Swan	Yes	Yes	Yes	Yes	Yes	May be
CYTO-WATER	Possible	Possible	Possible	Possible	Possible	Possible
DAIAD	Possible	Yes	Yes	Yes	Yes	Possible
DIANA	Yes	Yes	Possible	Possible	Possible	Possible
EFFINET	Possible	Yes	Possible	Possible	Possible	Possible
ESPRESSO	Yes	Yes	Yes	Yes	Yes	Yes
FREEWAT	Possible	Not clear	Not clear	Not clear	Not clear	Not clear
Ground Truth 2.0	Yes	Possible	Possible	Possible	Possible	Possible
HYDROUSA	Possible	Possible	Possible	Possible	Possible	Possible
ICEWATER	May be	May be	Not clear	Not clear	Not clear	No
INCOVER	May be	Not clear	Not clear	Not clear	Not clear	Not clear
INNOQUA	Not clear	Not clear	Not clear	Not clear	Not clear	Not clear
INTCATCH	Yes	Yes	Yes	Yes	Yes	Not clear
INTEGROIL	Possible	Not clear	Not clear	Not clear	Not clear	Not clear
ISS-EWATUS	Yes	Yes	Yes	Yes	Yes	Not clear
iWIDGET	Yes	Yes	Yes	Yes	Yes	Yes
KINDRA	May be	Not clear	Not clear	Not clear	Not clear	Not clear
Life SmartWater	Yes	Not clear	Not clear	Not clear	Not clear	Not clear
LifeSWSS	Could be	Not clear	Not clear	Not clear	Not clear	Not clear
NADiRA	Yes	Yes	Possible	Possible	Possible	Possible
NextGen	Possible	Yes	Yes	Yes	Yes	Not clear

Table 14. Architectural, technological, and functional aligning between the smart water management requirements and the platforms of different projects. Data sharing, service definition, big data, and ontology analyses. Specifications from O to W

Requirement/ Projects	Data sharing	Cloud-based services	Water-as-a-Service, micro services	Macro services	Use of Water Big Data	Ontology defined
POWER	Yes	Not shown	May be	May be	May be	Not presented
Project Ô	Not clear	Not clear	Not clear	Not clear	Not clear	Not clear
Proteus	Possible	Yes	Yes	Yes	Possible	Not clear
RESCCUE	Possible	Not clear	Not clear	Not clear	Not clear	Not clear
RTWQM Action Group	Not clear	Not clear	Not clear	Not clear	Not clear	Not clear
Run4Life	Not clear	Not clear	Not clear	Not clear	Not clear	Not clear
SAFEWATER	Possible	Possible	Possible	Possible	Possible	Possible
Sim4NEXUS	Yes	Yes	Yes	Yes	Yes	Yes
Smart H2O	Yes	Yes	Yes	Yes	Yes	Possible
Smart.met	Yes	Possible	Possible	Possible	Possible	Possible
Smart-Plant	Not clear	Not clear	Not clear	Not clear	Not clear	Not clear
SmartWater4Europe	Possible	Possible	Possible	Possible	Possible	Possible
SPACE-O	May be	May be	May be	May be	Yes	Not clear
STOP-IT	Yes	Yes	Possible	Possible	Yes	Not clear
SUBSOL		May be	Possible	Possible		Not clear
SWAMP	Yes	Yes	Yes	Yes	Yes	Not clear
SYNCHRONICITY	Yes	Yes	Possible	Yes	Yes	Not clear
UrbanWater	Yes	Yes	Yes	Yes	Yes	Possible
WADI	Yes	Yes	Possible	Possible	Possible	Possible
WaterInnEU	Yes	May be	May be	May be	May be	Possible
WATERNOMICS	Yes	Yes	Yes	Yes	Yes	Possible
WatERP	Yes	Possible	Possible	Possible	Possible	Possible
WeaM4i	May be	No	Possible	Possible	Possible	Possible
WIDEST	Yes	Yes	Possible	Possible	Yes	Yes
WISDOM	Possible	Yes	Yes	Possible	Possible	Yes

Table 15. Business smart water management requirements aligning. End-users, stakeholders cooperation, replicability, standard adaptation, Quality of Service analyses. Specifications from A to N

Requirement/ Projects	Players cooperation	Replicability	Aligning to the legislation and policy makers	Necessity of standard adoption	Quality of Service
AfriAlliance	Yes	Yes	Yes	Yes	May be
AquaNES	Yes	Yes	Yes	Not clear	Not clear
BlueSCities	Yes	Yes	Yes	Not clear	Not clear
CENTAUR	Yes	Yes	Not clear	Might be	Yes
Ctrl+Swan	May be	Possible	Possible	Possible	Yes
CYTO-WATER	Yes	Yes	Yes	Could be	Yes
DAIAD	Yes	Yes	Possible	Possible	Yes
DIANA	Yes	Could be	May be	May be	Possible
EFFINET	Possible	Possible	Possible	Possible	Yes
ESPRESSO	Yes	Yes	Possible	Possible	Yes
FREEWAT	Possible	Possible	May be	May be	Yes
Ground Truth 2.0	Definitely	Possible	Possible	Possible	Possible
HYDROUSA	Yes	Possible	Possible	May be	Possible
ICEWATER	May be	May be	May be	May be	Possible
INCOVER	Yes	Yes	May be	Not clear	Yes
INNOQUA	Yes	Yes	May be	May be	Yes
INTCATCH	Yes	Yes	Yes	May be	Yes
INTEGROIL	May be	Yes	Could be	May be	Yes
ISS-EWATUS	Yes	Yes	Could be	May be	Yes
iWIDGET	Could be	Yes	Could be	May be	Yes
KINDRA	Not clear	May be	Possible	May be	Yes
Life SmartWater	Yes	Yes	Not clear	Not clear	Yes
Life SWSS	Possible	Yes	Could be	Not clear	Yes
NADiRA	Yes	Could be	May be	May be	Possible
NextGen	Not sure	Could be	May be	Not clear	Yes

Table 16. Business smart water management requirements aligning. End-users, stakeholders' cooperation, replicability, standard adaptation, Quality of Service analyses. Specifications from O to W

Requirement/ Projects	Players cooperation	Replicability	Aligning to the legislation and policy makers	Necessity of standard adoption	Quality of Service
POWER	Yes	May be	Could be	Could be	Yes
Project Ô	Yes	Yes	Could be	May be	Yes
Proteus	Not clear	Yes	Possible	May be	Yes
RESCCUE	Yes	Yes	May be	May be	Yes
RTWQM Action Group	May be	Possible	May be	Not clear	Yes
Run4Life	Yes	Yes	Yes	Could be	Yes
SAFEWATER	Yes	Possible	Possible	Could be	Yes
Sim4NEXUS	Yes	Yes	Yes	Could be	Yes
Smart H2O	Yes	Possible	Possible	Possible	Yes
Smart.met	Yes	Yes	Yes	Possible	Yes
Smart-Plant	Yes	Yes	Yes	Not sure	Yes
SmartWater4Europe	Yes	Yes	Yes	Yes	Yes
SPACE-O	Yes	Yes	Yes	Could be	Yes
STOP-IT	Yes	Yes	Yes	May be	Yes
SUBSOL	Yes	Yes	Yes	Not clear	Yes
SWAMP	Yes	Yes	Yes	Not clear	Yes
SYNCHRONICITY	Yes	Yes	Yes	Yes	Yes
UrbanWater	Yes	Yes	Yes	May be	Yes
WADI	Yes	Yes	Yes	May be	Yes
WaterInnEU	Yes	Yes	Yes	May be	Yes
WATERNOMICS	Yes	Yes	Yes	May be	Yes
WatERP	Yes	Yes	Yes	May be	Yes
WeaM4i	May be	Yes	Possible	Possible	Yes
WIDEST	Yes	Yes	Yes	Yes	Yes
WISDOM	Yes	Possible	Possible	Possible	Yes

Table 17. Business smart water management requirements aligning. Synergy, diversity, competitiveness, sustainability analyses. Specifications from A to N

Requirement/ Projects	Access to other services	Diversity and social cohesion	Green economy support	Attractiveness and competitiveness	Sustainability
AfriAlliance	Not clear	Yes	Yes	-	Possible
AquaNES	No	May be	Yes	Yes	Not clear
BlueSCities	Yes	Yes	Yes	Yes	Not clear
CENTAUR	Possible	Possible	Yes	Yes	Not clear
Ctrl+Swan	Possible	Possible	Possible	Yes	Yes
CYTO-WATER	Could be	Not clea	Yes	Yes	Not clear
DAIAD	Possible	Possible	Possible	Yes	Yes
DIANA	Possible	Possible	Possible	Possible	Possible
EFFINET	Possible	Possible	Possible	Good	Possible
ESPRESSO	Yes	Yes	Yes	Good	Yes
FREEWAT	Not clear	Possible	Possible	Possible	Possible
Ground Truth 2.0	Possible	Possible	Possible	Possible	Possible
HYDROUSA	Possible	Possible	Yes	Yes	Possible
ICEWATER	Yes	Yes	Yes	Yes	Yes
INCOVER	No	No	Yes	Yes	Yes
INNOQUA	No	No	Yes	Yes	Yes
INTCATCH	Yes	Yes	Yes	Yes	Yes
INTEGROIL	Possible	Possible	Yes	Yes	Yes
ISS-EWATUS	Possible	Possible	Yes	Yes	Yes
iWIDGET	Possible	Possible	Possible	Yes	Yes
KINDRA	May be	Yes	Yes	Yes	Not clear
Life SmartWater	Not clear	May be	Yes	Yes	Not clear
Life SWSS	Not clear	Could be	Yes	Yes	Not sure
NADiRA	Possible	Possible	Possible	Possible	Possible
NextGen	Possible	Possible	Yes	Yes	Not clear

Table 18. Business smart water management requirements aligning. Synergy, diversity, competitiveness, sustainability analyses. Specifications from O to W

Requirement/ Projects	Access to other services	Diversity and social cohesion	Green economy support	Attractiveness and competitiveness	Sustainability
POWER	Possible	Yes	Yes	Yes	Not clear
Project Ô	May be	Not clear	Yes	Yes	Yes
Proteus	Possible	Possible	Yes	Yes	May be
RESCCUE	May be	May be	May be	Yes	May be
RTWQM Action Group	Not clear	Yes	Yes	Yes	May be
Run4Life	Not clear	Yes	Yes	Yes	Yes
SAFEWATER	Possible	Possible	Yes	Yes	Yes
Sim4NEXUS	Yes	Yes	Yes	Yes	Yes
Smart H2O	Yes	Yes	Possible	Good	Yes
Smart.met	Possible	Yes	Yes	Yes	Yes
Smart-Plant	May be	May be	May be	Yes	
SmartWater4Europe	Possible	Possible	Possible	Yes	Yes
SPACE-O	Yes	Yes	Yes	Yes	Good approach
STOP-IT	Possible	Yes	Possible	Yes	Yes
SUBSOL	Possible	Possible	Yes	Yes	Yes
SWAMP	Possible	Yes	Yes	Yes	Yes
SYNCHRONICITY	Yes	Yes	Yes	Yes	Yes
UrbanWater	Yes	Yes	Yes	Yes	Yes
WADI	Possible	Yes	Yes	Yes	Yes
WaterInnEU	Yes	Yes	Yes	Yes	Yes
WATERNOMICS	Possible	Possible	Yes	Yes	Yes
WatERP	Possible	Yes	Yes	Yes	Yes
WeaM4i	Not clear	May be	Possible	Good	Yes
WIDEST	Yes	Yes	Yes	Yes	Yes
WISDOM	Possible	Possible	Possible	Yes	Yes

Table 19. Business smart water management requirements aligning. Loss, data awareness, water exploitation and efficiency analyses. Specifications between A and N

Requirement/ Projects	Water losses and leakage	Level of water data awareness	Share of reclaimed water	Reduction in potable water consumption	Self-sufficiency level	Water exploita-tion index
AfriAlliance	May be	May be	May be	May be	Low	May be
AquaNES	May be	No	Yes	Yes	Good	May be
BlueSCities		May be	May be	May be	May be	Yes
CENTAUR	Could be	Could be	Could be	Possible	Possible	Possible
Ctrl+Swan	Possible	Possible	Possible	Possible	Possible	Possible
CYTO-WATER	Could be	Could be	Not clear	Could be	Could be	Could be
DAIAD	Yes	Yes	Yes	Yes	Good	Yes
DIANA	Possible	Possible	Possible	Possible	Possible	Possible
EFFINET	Yes	Yes	May be	Yes	Yes	Yes
ESPRESSO	Possible	Possible	Possible	Possible	Possible	Possible
FREEWAT	Possible	Possible	Possible	Possible	Possible	Possible
Ground Truth 2.0	Possible	Possible	Possible	Possible	Possible	Possible
HYDROUSA	Yes	Yes	Yes	Yes	Yes	Yes
ICEWATER	May be	May be	May be	Yes	Yes	Yes
INCOVER	Possible	Possible	Yes	Possible	Yes	Yes
INNOQUA	Possible	Possible	Yes	Yes	Yes	Yes
INTCATCH	Not clear	Yes	Yes	Yes	Yes	Yes
INTEGROIL	No	Yes	Yes	Yes	Yes	Yes
ISS-EWATUS	Yes	Yes	Yes	Yes	Yes	Yes
iWIDGET	Possible	Yes	Possible	Yes	Yes	Yes
KINDRA	No	Yes	No	Yes	Not clear	May be
Life SmartWater	Yes	Yes	May be	Indirectly	Not clear	Yes
Life SWSS	Yes	Yes	Yes	Yes	Not clear	Yes
NADiRA	Possible	Possible	Possible	Possible	Possible	Possible
NextGen	Yes	Yes	Yes	Yes	Yes	Yes

Table 20. Business smart water management requirements aligning. Loss, data awareness, water exploitation and efficiency analyses. Specifications between O and W

Requirement/ Projects	Water losses and leakage	Level of water data awareness	Share of reclaim-ed water	Reduction in potable water consumption	Self-suffici-ency level	Water exploita-tion index
POWER	Not clear	Not clear	Not clear	Not clear	Not clear	May be
Project Ô	Not clear	Yes	Yes	Yes	Yes	Yes
Proteus	Yes	Yes	Yes	Yes	Yes	Yes
RESCCUE	Yes	Yes	Yes	Yes	Yes	Yes
RTWQM Action Group	Yes	Yes	Yes	Yes	Yes	Yes
Run4Life	Possible	Yes	Yes	Yes	Yes	Yes
SAFEWATER	Yes	Yes	Not clear	Yes	Yes	Yes
Sim4NEXUS	Yes	Yes	Yes	Yes	Yes	Yes
Smart H2O	Yes	Good	Possible	Possible	Good	Possible
Smart.met	Yes	Yes		Yes	Yes	Yes
Smart-Plant	Yes	Yes	Yes	Yes	Yes	Yes
SmartWater4-Europe	Yes	Yes		Yes	Yes	Yes
SPACE-O	Yes	Yes	May be	May be	Yes	Yes
STOP-IT	Not clear	Yes	Not clear	Not clear	Yes	May be
SUBSOL	Not clear	Yes	Not clear	Yes	Yes	Yes
SWAMP	Possible	Yes	Yes	Yes	Yes	Yes
SYNCHRONICITY	Possible	Possible	Possible	Possible	Possible	Possible
UrbanWater	Yes	Yes	Yes	Yes	Yes	Yes
WADI	Yes	Yes	Yes	Yes	Yes	Yes
WaterInnEU	May be	May be	May be	May be	May be	May be
WATERNOMICS	Yes	Yes		Yes	Yes	Yes
WatERP	Yes	Yes		Yes	Yes	Yes
WeaM4i	Possible	Possible	Possible	Possible	Good	Possible
WIDEST	Yes	Yes	Yes	Yes	Yes	Yes
WISDOM	Yes	Possible	Possible	Possible	Good	Possible

Table 21. Business smart water management requirements aligning. Political relevance, use-case applicability, multi-level governance analyses. Specifications from A to N

Requirement/ Projects	Factors of success	Efficiency in use	Applicable use-cases to validate the standards and cross-sectorial interoperability	Political relevance	Multi-level governance
AfriAlliance	-	May be	No	Yes	Yes
AquaNES	Good	May be	Could be	Yes	Yes
BlueSCities	Good	Not clear	May be	Yes	Yes
CENTAUR	Good	Good	Could be	Yes	Yes
Ctrl+Swan	Good	Good	Yes	Yes	Possible
CYTO-WATER	Good	Not clear	Could be	Yes	Yes
DAIAD	Good	Good	Yes	Yes	Yes
DIANA	Good	Not sure	Yes for satellite data use	Possible	Possible
EFFINET	Good	Yes	Yes	Yes	Yes
ESPRESSO	Good	Yes	Yes	Yes	Yes
FREEWAT	Good	Not clear	Yes	Yes	Yes
Ground Truth 2.0	Good	Good	Yes for stakeholder engagement.	Yes	Yes
HYDROUSA	Good	May be	Yes. Sea water management, water in circular economy, water reuse are included.	Yes	Yes
ICEWATER	Good	May be	Yes	Yes	Yes
INCOVER	Good	May be	Yes	Yes	Yes
INNOQUA	Good	May be	Yes	Yes	Yes
INTCATCH	Good	Yes	Yes for river and lake water management	Yes	Yes
INTEGROIL	Good	Yes	Yes	Yes	Yes
ISS-EWATUS	Good	Yes	Yes	Yes	Yes
iWIDGET	Good	Good	Yes	Yes	Yes
KINDRA	Good	May be	Yes	Yes	Yes
Life SmartWater	Good	Yes	Yes	Yes	Yes
Life SWSS	Good	Yes	Yes	Yes	Yes
NADiRA	Good	Not sure	Yes for satellite data use	Possible	Possible
NextGen	Good	Could be good	Yes	Yes	Yes

Table 22. Business smart water management requirements aligning. Political relevance, use-case applicability, multi-level governance analyses. Specifications from O to W

Requirement/ Projects	Factors of success	Efficiency in use	Applicable use-cases to validate the standards and cross-sectorial interoperability	Political relevance	Multi-level governance
POWER	Good	May be	Yes	Yes	Yes
Project Ô	Good	Yes	Yes	Yes	Yes
Proteus	Good	Good	Yes	Yes	Yes
RESCCUE	Good	Not clear	Yes	Yes	Yes
RTWQM Action Group	Good	Not clear	Yes	Yes	Yes
Run4Life	Good	Could be good	Yes	Yes	Yes
SAFEWATER	Good	Yes	Yes	Yes	Yes
Sim4NEXUS	Good	Yes	Yes	Yes	Yes
Smart H2O	Good	Not clear	Yes	Yes	Yes
Smart.met	Good	Yes	Yes	Yes	Yes
Smart-Plant	Good	Yes	Yes	Yes	Yes
SmartWater4Europe	Good	Yes	Yes	Yes	Yes
SPACE-O	Good	Yes	Yes	Yes	Yes
STOP-IT	Good	Yes	Yes	Yes	Yes
SUBSOL	Good	Yes	Yes	Yes	Yes
SWAMP	Good	Yes	Yes	Yes	Yes
SYNCHRONICITY	Good	Yes	Yes	Yes	Yes
UrbanWater	Good	Yes	Yes	Yes	Yes
WADI	Good	Yes	Yes	Yes	Yes
WaterInnEU	Good	Yes	Yes	Yes	Yes
WATERNOMICS	Good	Yes	Yes	Yes	Yes
WatERP	Good	Yes	Yes	Yes	Yes
WeaM4i	Good	Not clear	Yes	Yes	Yes
WIDEST	Good	Yes	Yes	Yes	Yes
WISDOM	Good	Good	Yes	Yes	Yes

4. Assessment of ICT Standards for Water Management Platforms

4.1. Overview of Standard Organisations

ICT-based standards for water management platforms are assessed taking into account all standardisation organisations listed in the Action Plan and a few additional bodies in order to have a worldwide view of the processes in the smart water sector. The standards' analysis is performed against the defined requirements. Tables 23 to 25 present the standard organisations working in ICT for smart cities, smart water management, smart agriculture, smart appliances, smart industry etc. The emphasis in this document is on smart water management.

A functional reference architecture for communication capabilities in smart metering systems is defined by CEN, CENELEC and ETSI [CEN/CENELEC/ETSI, 2011]. The three standardisation organisations cooperate in architecture aiming to create a platform that is open and considers networking of smart utility meters [CEN/CENELEC, 2017]. The interfaces and data exchange formats are standardised at appliance level and allow the development of smart control systems. The standard level is still far from cloudification and integration. The system is difficult to scale. It needs further definition of the main interfaces and protocols for integration, connectivity and service definition at different hierarchical layers. In addition to the reference architecture CEN specifies a guidance TS 17171 for hydrogenic data management that is a good approach towards smart environment studies [CEN TS 17171, 2018].

ETSI tries to cover all communication and information aspects of the IoT implementations by intensive standards development and aligning in different domains. Many coordination and support actions initiated by the European Commission are used to complete the tasks.

ETSI investigation for Water [ETSI, ETSI SAREF Water, 2019] is a new initiative for ontology extension in the water domain. The work is at the phase of requirements analysis and the initial semantic model is based on a set of use-cases as well as the analyses and specifications in other domains like energy, smart appliances, IoT, construction, smart cities [ETSI TS 103 264, 2013; ETSI TS 103 410-2, 2017; ETSI TR 103 411 V1.1.1, 2017; ETSI SmartM2M TR 103 375, 2016; ETSI TS 103 410-3, 2017; ETSI TS 103 410-1, 2017].

The investigation of possibilities to extend the SAREF ontology [SAREF Ontology, 2017] to cover smart water management has also started with a semantic model of the smart water appliances. The aim is to identify possible multiple common interfaces through which the devices could be integrated and interoperability could be supported. The ontology is still at its generic level. Scaling, cloudification, data sharing and collaborating with communication and information infrastructure are still at an initial stage and are validated through few use-cases. The synergy between different domains, data dependencies and data sharing are still being defined. **This European Catalogue aims in fostering SAREF for Water creation and supporting it with many use-cases.**

The use of standards in a replicable solution stack is promoted by the so called Industry Specification Group "City Digital Profile" (ISG CDP) of ETSI. The group accelerates the development of integrated services for the citizens as well as a technology roadmap for smart cities. The activity mostly targets city leaders and decision makers. It is supposed to enable cities to reuse procurement of smart solutions with high level of confidence aiming to reach a platform that is integrated, extended, configured and interoperable with similar services from other cities and domains. The work enhances smart city standards through pilot projects testing the scale of the innovative city services and systems integration. National leaders, stakeholders and industry partners could look for a technology roadmap through the whole technology stack and identify the logical steps for service deployment. At the initial phase the cross domain city applications include health and social care, building management and connected homes, urban lighting, water and waste management, energy, transportation and mobility, environmental issues, infrastructure management [ISG CDP, 2017; ICT Standard analysis, 2016]. The plan is ambitious and depends on the investment, local background and legacy systems.

OGC works worldwide on different aspects of the standard related to geospatial data, including hydrology. The defined HY_FEATURES Reference model for real-world water-objects and their relation to hydro-science domain at semantics and network topology level is a good approach towards ontology definition [OGC Hydrologic Features, 2018; OGC WaterML, 2018].

WaterML2.0, defined by OGC, is a standard information model representing water observations data. This abstraction of the hydrogenic data intents to allow data sharing between information systems based on the OGC standards [OGC WaterML2.0, 2015].

Table 23. ICT-based smart water management standard organisations. Part A

Acro-nym	**Name**	**Description**	**Smart Water Management Analysis**
ETSI	European Telecommunications Standards Institute	ETSI defines communication standards and SAREF ontology applicable in different domains [ETSI, ETSI SAREF Water, 2019; ETSI TS 103 264, 2013; ETSI TS 103 410-2, 2017; ETSI TR 103 411 V1.1.1, 2017].	SAREF extension in the water domain is under definition. Use-cases for standards' testing and validation are important.
CEN/ CENELEC	European Committee for Standardisation/ European Committee for Electrotechnical Standardisation	Definition of a Functional reference architecture for communications in smart metering systems [CEN/CENELEC/ETSI, 2011].	The reference architecture does not include details in smart water management.
INSPIRE	Infrastructure for spatial information in Europe	INSPIRE Directive creates a reference EU architecture for sharing of geospatial data sets between EU countries [INSPIRE, 2007].	The INSPIRE directive creates opportunities for ontology definition related to the environmental policy.
ITU-T	International Telecommunication Union – Telecommunication Sector	ITU-T is a worldwide organisation aiming to develop and map standards in the sector. They address communication and information domains together similarly to ETSI [ITU-T, 2015]	The experience in smart cities domain as well as ubiquitous communication, information sharing, and service definition are a good starting point in ontology development.
OGC	Open Geospatial Consortium	OGC works worldwide on different geospatial standards and activities.	OGC creates a good semantic level for all hydrogenic data including smart appliances and smart cities.
ISO/IEC	International Organisation for Standardisation/ International Electrotechnical Commission	ISO IEC have defined interfaces for generic sensor networks application [ISO IEC 30128, 2014].	Most of the work is related to the industry and production of equipment.
ISO/TC	International Organisation for Standardisation/ Technical Committees	The Technical committees of ISO develop many standards for water measurements and reuse [ISO TC].	The metering systems form the peripheral part of the smart water management platform.

Table 24. ICT-based smart water management standard organisations. Part B

Acro-nym	**Name**	**Description**	**Smart Water Management Analysis**
WITS and PSA	Water Industry Telemetry Standard and Protocol Standard Association	Worldwide Industry Telemetry Standards for water industry telemetry control and monitoring are exploited by WITS Standard Protocol Association [WITS PSA, 2018].	Equipment from different manufacturers is made interoperable by WITS satisfying the specific functional requirements of water industry.
AIOTI	Alliance for Internet of Things Innovation	Alliance for Internet of Things Innovation is a non-profit organisation trying to define the standardisation gaps and priorities in IoT implementations [AIOTI, 2018].	The work group in water management aims to develop the standardisation process towards integration and interoperability based on a High Level Reference Architecture.
W3C	World Wide Web Consortium	W3C and especially the Web of Things committee work at data definition and linking in different domains applying IoT devices [W3C, 2018].	W3C focuses on providing APIs that could enable the semantic interoperability and further integration of different system. APIs are based on the best practices use-cases.
NIST	National Institute of Standards and Technology	NIST is defining all standards and technologies applicable in the USA [Liu at al., 2011] including different types of water measurements and systems networking.	Cloud and fog computing implementation are promoted by NIST and are an interesting approach towards smart water management and data sharing.
BDVA	Big Data Value Association	Big Data Value Association is a new consortium aiming to define technologies for data management including water [BDVA, 2017].	Smart water and synergetic data management promoted by BDVA is important in ontology definition.
oneM2M	oneM2M	oneM2M is a global standards initiative for Machine to Machine Communications and the Internet of Things [oneM2M, 2018].	The approach towards ontology definition and specification is a driving force for the SAREF extension.
FIWARE	FIWARE	FIWARE is a consortium of industry members, stakeholders and end-users aiming to automate smart applications in different domains [FIWARE, 2018].	The involvement of FIWARE in the smart water domain is limited.

OGC issued a draft standard for groundwater called GroundwaterML [OGC GroundwaterML v2, 2018] aiming to map hydrological data in a common type ontology.

Table 25. ICT-based smart water management standard organisations. Part C

Acronym	**Name**	**Description**	**Smart Water Management Analysis**
Industry 4.0	Trend in the industry development	Industry 4.0 specialises in implementing of cyber-physical systems in the process of deployment and implementation of the IoT in different domains, including water management [Industry 4.0, 2018].	The work done in the field by industrial partners could lead to better and more sustainable ontology development.
zWave	Alliance for IoT implementations	zWave alliance is a consortium of many industry leaders in the field of IoT solutions aiming to implement wireless concepts in different domains [zWave, 2018].	Use-cases in smart water implementations are interesting validation drivers for the ontology development.
OpenFog	Consortium for Fog Computing implementation	OpenFog consortium aims to introduce and define standards for decentralised and centralised computing approach known as fog computing [OpenFog, 2018].	Smart water decentralised management could allow local authorities to create customised cloud-based services.
Microsoft Azure	Type of cloud platform	Microsoft Azure is a cloud solution developed by Microsoft applicable for IoT implementations [Microsoft Azure, 2018].	There are many applications of Microsoft Azure in different domains that could be used for references in ontology development.

A standard for generic sensor network applications and sensor network capabilities is developed by ISO/IEC. Intended for the industry and equipment suppliers, the standard specifies the mandatory and optional interfaces between the applications at international level [ISO IEC]. The work is a good starting point for ontology development concerning the water related equipment and infrastructure deployment.

ISO TC works on metering systems worldwide. The water reuse standardisation process is expected to allow better definition of water in circular economy [ISO TC 282, 2013]. ISO/TC 282 takes into account the on-site water reuse, centralised and decentralised reuse, direct and indirect reuse, intentional and unintentional reuse. Many technical, environmental, economic, and societal aspects of water reuse are also analysed. Water reuse comprises of repeated, cascaded, and recycled ways of wastewater treatment after a sequence of up taking, conveyance, processing, storage, distribution, consumption, drainage.

ITU-T defines standards applicable worldwide in different domains like ubiquitous sensor network middleware [ITU-T, F.744]. Requirements for water services in ubiquitous sensor network middleware are defined in F.747.6 [ITU-T F.747.6, 2014].

WITS is an association creating standards for telemetry support in the water sector. It establishes opportunities for data sharing and interoperability.

The Alliance for Internet of Things Innovation (AIOTI) has elaborated an architecture and a semantic data model based on the ISO/IEC/IEEE 42010 standard for IoT entities and services. It is considered multidisciplinary and can map different domains including water [AIOTI, 2018].

Microsoft Azure is listed as one of the many proprietary solutions that exist on the market including Amazon Web Services, Google Cloud etc. Smart water platforms need to integrate also with such solutions. Microsoft Azure, Amazon Web Services, Google Cloud, FIWARE are not standard organisations but big players on the market. There are many other national and international organisations working in the water field as listed in Tables 23 to 25. They could be applied as use-cases for ontology development. Many standardisation organisations also try to customise the solutions toward different sectors.

4.2. Detailed Standard Organisations Analyses

This section includes a detailed analyses of the standardisation organisations. As a result, gaps and priorities are selected and classified. The work is based on multiple references and is limited by size.

EIP SCC

The European Innovation Partnership on Smart Cities and Communities (EIP-SCC) is an initiative of the European Commission to map end-users, stakeholders, investors, industry, developers, research institutions and authority bodies working towards smart cities solutions [EIP SCC, 2017]. The task is to look for sustainable concepts compliant with the city-specific challenges and policy. The ICT architecture of the platform in Figure 20 presents all the aspects that need to be taken into account while building a smart cities platform. The EIP SCC defines standardisation priorities and looks for sustainable building of the environment and the infrastructure. It also tries to integrate infrastructures and processes in different domains, to focus on citizens, to reach integrated planning and management based on regulations, to share knowledge, performance indicators and metrics, to share data, standard solutions, business models, procurement procedures etc.

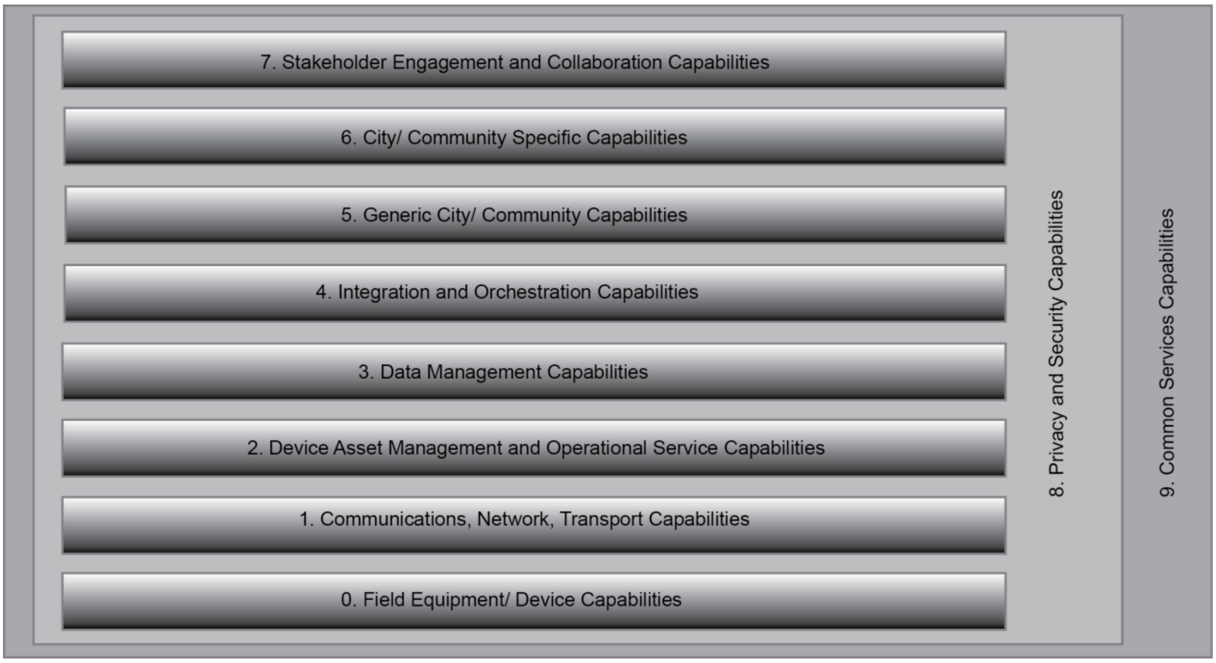


Figure 20. EIP SCC Urban Platform Capability Map [DIN SPEC 91357, 2017]

CEN/CENELEC

CEN/CENELEC works at smart metering and collaboration of devices with ETSI standards. ETSI is specialised in communication and information infrastructure standards and as a result the functional reference architecture for smart metering system of CEN/CENELEC/ETSI has multiple features necessary for a contemporary IoT platform. It is presented in cooperative standard [Figure 2 in CEN/CENELEC/ETSI, 2011] and combines edge computing architecture of ETSI (Figure 25 in this document) with smart sensing. The platform defines home automation systems in a standard way through standard industrial interfaces at low levels. From a communication point of view, it is difficult to integrate such a system to the cloud without a local server or a gateway, data harmonisation and data synchronisation. Network scaling is not feasible from this standard.

However, the reference architecture for smart metering [CEN/CENELEC/ETSI, 2011] prepares the access network for various appliances and their possible interconnection. There is a difference between communication and industrial standards, lack of appropriate gateways and APIs supporting the vertical and horizontal connectivity and data sharing. Systems collaboration and integration, including the type of shared data, need to be defined at different layers. This issue may support the future heterogeneous smart water management platforms by clearing the vision for data access, collection, harmonisation, storing, integration and leading to cloudification.

The standard on the management of hydrogenic data [CEN TS 17171, 2018] is preparing the sector for globalisation. It supports the collection, harmonisation and exchange of hydrogenic data not only for households and in reference to smart cities, but globally, taking consideration of the world water reserves. This standard is a step towards cloudification and globalisation of the business.

A generic report explaining the main steps in the smart grid interoperability analysis [Smart Grid, 2016] is based on use-cases, functional analysis, end-user profiling and testing at device level. The experience collected in smart grids could also be implemented in smart water management. However, the implementation of smart grids is slow and, though being well standardised, the real deployment depends highly on additional investments that are not smooth, incremental and continuous. The smart water sector is confronted with the same problems.

ETSI

While OGC is a global organisation and deals with hydrologic problems and data worldwide ETSI is a European standardisation body which aims to reach world-wide importance. ETSI also tries to cover other important parts of the smart water and smart cities management platforms, such as communication [ETSI TR 118 524, 2016], architecture, security [ETSI TR 103 303 V1.1.1, 2016], and KPIs definition in relation to the end-users and stakeholders [ETSI GS OEU 019, 2017] including interconnection with other platforms [CEN/CENELEC/ETSI, 2011]. The interconnection is performed in cooperation with CEN/CENELEC and is based on smart metering.

The initial semantic model for the water domain is developed after determination of the main requirements based on a limited number of use-cases. Requirements analyses are becoming an essential part of the SAREF for water ontology [ETSI SAREF Water, 2019]. The use of at least 7-8 use-cases per type of ontology implementation will be useful for the stakeholders. Typical implementations like supply of potable water, wastewater management, wastewater reuse, water reuse in industry, water reuse in agriculture, water reuse in construction, flooding management, contamination management, river, lakes, sea water management, water harvesting management should be considered separately. The process is also related to [ETSI SmartM2M TR 103 375, 2016] for landscape systems. The extension of the SAREF towards the water domain is based on SAREF for the environmental domain [ETSI TS 103 410-2, 2017], the building domain [ETSI TS 103 410-3, 2017] and the energy domain [ETSI TS 103 410-1, 2017; ETSI TR 103 411 V1.1.1, 2017]. The basic model is defined in [ETSI TS 118 112, 2016; SAREF Ontology, 2017]. New trends developed for so called Demand Side Flexibility (DSF) in energy sector should be taken into consideration in water sector [Danielle at al., 2018].

ETSI published a report comparing the standards in the IoT domain [ETSI SmartM2M TR 103 375, 2016]. In it the smart water sector is only mentioned by means of supporting standards. The architecture in the document refers mostly to the enterprise and smart cities rather than to the smart water sector directly.

The cloudification process in ETSI standardisation has started and details are published in [ETSI TR 103 528 V1.1.1, 2018]. A High Level Architecture is presented in Figure 21 aligning communication and information infrastructures of IoT platforms.

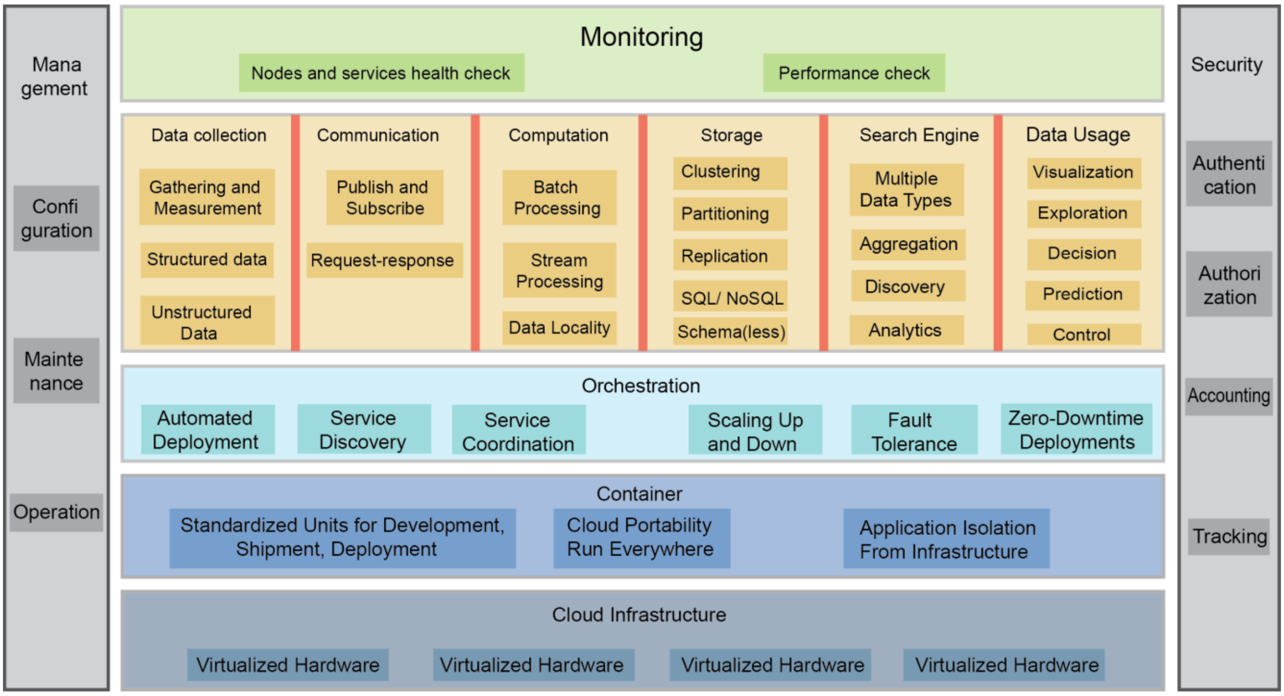


Figure 21. High Level Architecture for IoT virtualisation – generic view [ETSI TR 103 528 V1.1.1, 2018]

A step further is made with the standard [ETSI GS CIM 009, 2019] correlating APIs and Context Information Management (CIM) capabilities in the IoT platforms at cloud level. A home domain abstract information model is finished in [ETSI TR 118 517 V2.0.0, 2016]. Security even at attribute level is defined in [ETSI TS 103 532, 2018].

ETSI based IoT Smart M2M Gateway Architecture for M2M Device and Endpoint Management is defined in [ETSI TS 103 424, 2016]. It allows southbound interfaces at the cloud platform definition as well as access networks heterogeneity. The level of home servers form so called edge networks or fog computing level. The cloud computing level works on the top of the core communication infrastructure using distributed big storages and server farms. Based on this infrastructure there are possibilities to define micro services, monolithic services, data harmonisation, sharing, further and continuous data processing. Coordination with SmartM2M at functional level is presented in Figure 22 [ETSI TS 102 690 V2.1.1, 2013].

ETSI SmartM2M high level architecture maps the communication and information infrastructures. The architecture leads towards cloudification and possibilities for data sharing and data harmonisation. The ontology allows data processing and service creation. The next standards for SmartM2M also define interfaces, service requirements mapped to the end-users/ end-devices, implementation aspects, mobility management etc.

The impact of the smart water on the smartness of the city, the importance of the water infrastructure monitoring and the wastewater management strategy are defined in the standard concerning the impact on the IoT environment implementations on the smart city [ETSI TR 103 290 V1.1.1, 2015]. Flooding prediction and monitoring, wastewater management and necessity of water flows monitoring locally using SCADA systems are shown. The possibility to integrate different parts of the systems is demonstrated in Figure 23.

Integration of the business, information, communication, functional, and components layers is fully developed for smart grid systems [ETSI TR 103 290 V1.1.1, 2015]. The idea is presented in Figure 24.

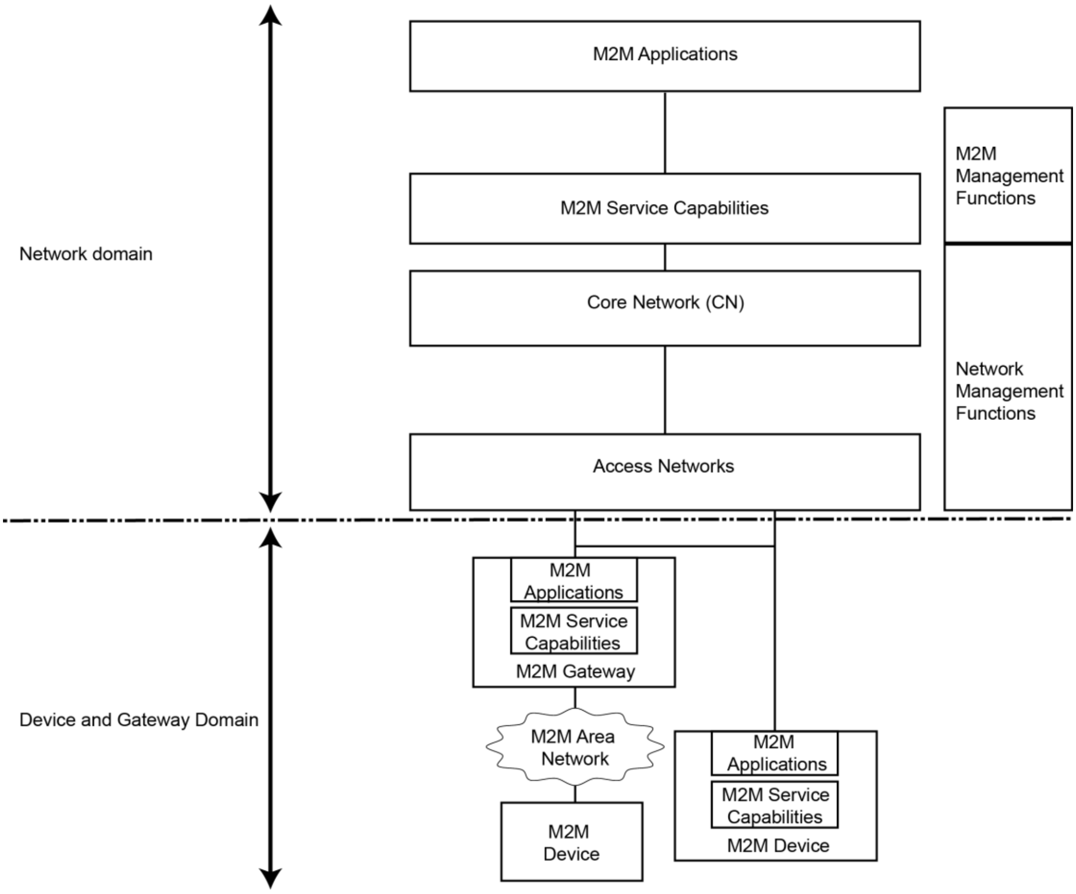


Figure 22. SmartM2M High Level Architecture [ETSI TS 102 690 V2.1.1, 2013]

The smart grid architecture leads to data sharing, cloudification at different levels, data processing and service definition, whereas the data dependencies are defined through SAREF ontology. Smart grid implementation in Europe is delayed due to the high investment needs. A similar smart water architecture could be the possible solution in the water sector. For example, it could be achieved by changing the domains in Figure 24 to potable water sources, sewage treatment plants, reclaimed water providers, water distribution providers and end-user respectively.

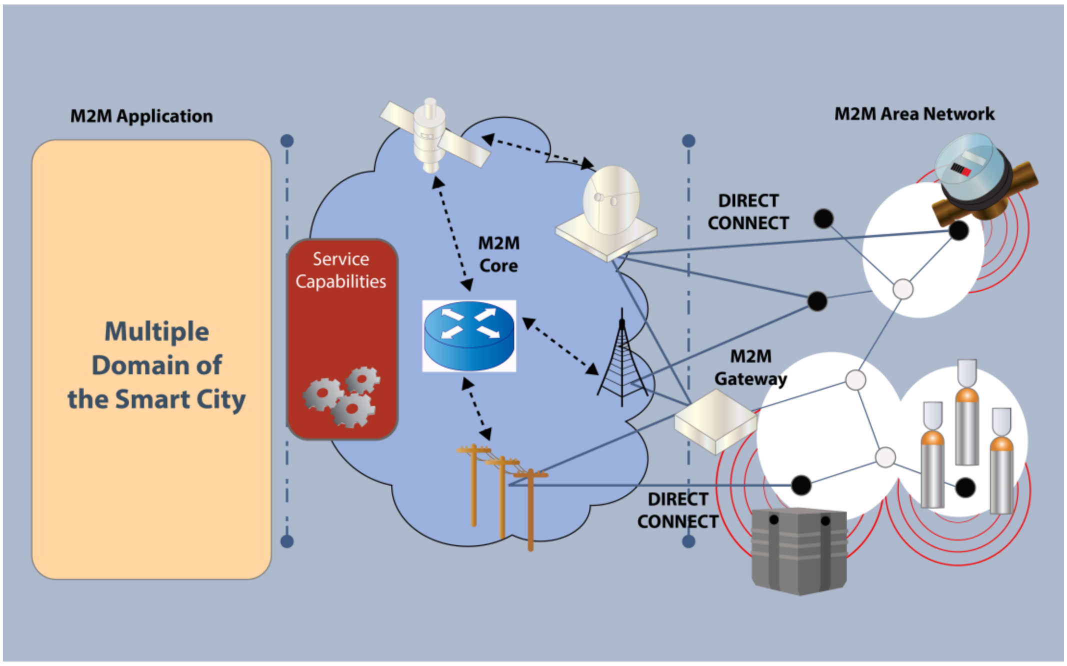


Figure 23. Smart water management in smart cities [ETSI TR 103 290 V1.1.1, 2015]

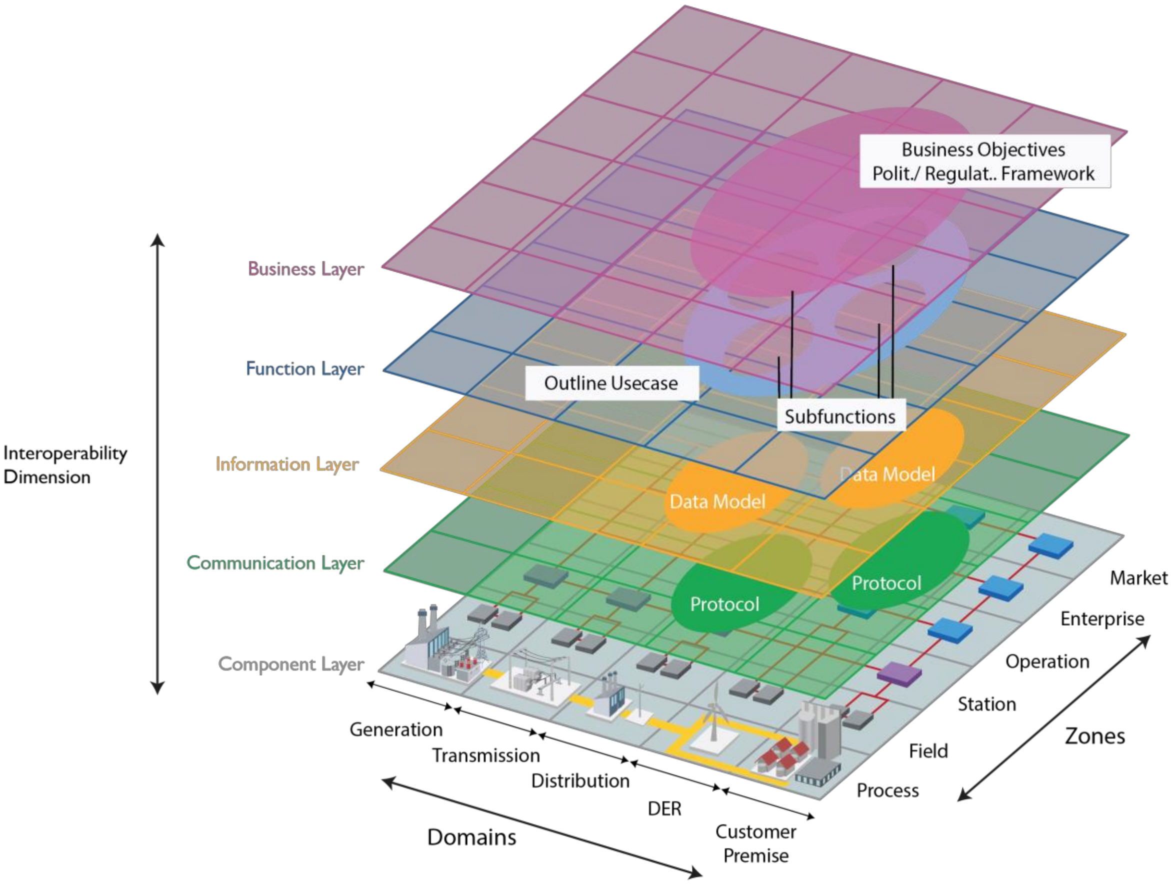


Figure 24. Smart grid architecture of ETSI [ETSI TR 103 290 V1.1.1, 2015]

Such architecture allows complete end-to-end solutions from appliances through aggregators to the providers and is based on the stakeholders and end-users demands. The expected sustainability of the architecture depends on possibility to be integrated and being interoperable with legacy and new platforms through standard interfaces and protocols. The same architecture could be easily applied also in smart cities, smart industry, smart agriculture, smart health etc.

ETSI is active in fog computing definition. The ongoing work on multi-access edge computing is documented in [ETSI GS MEC 003, 2019]. It is mostly based on the 3GPP and allows platform virtualisation. In fact, ETSI provided an infrastructure standard allowing fog computing at edge mobile networks [ETSI GS MEC 003, 2019] (Figure 25).

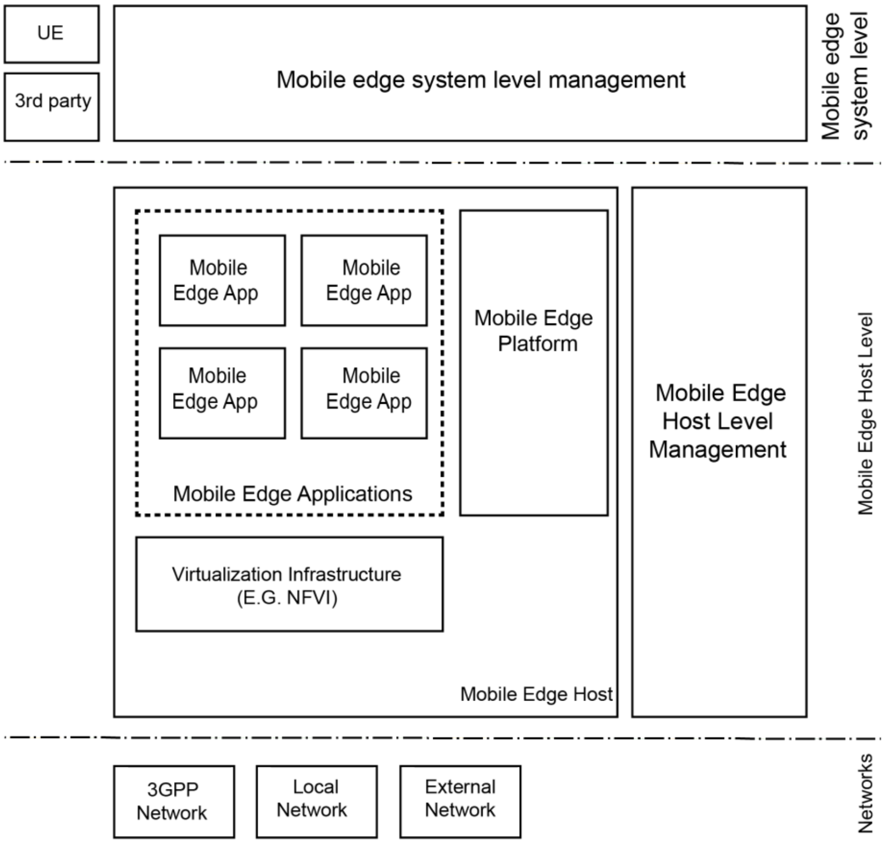


Figure 25. ETSI mobile edge computing framework [ETSI GS MEC 003, 2019]

OGC

OGC is a worldwide level consortium working broadly on platform concepts and semantic layer. OGC standards define data models and data sharing between different water players. The markup language for water [OGC WaterML, 2018] allows definition of data dependencies, encoding and sharing between different parts of the systems. It supports direct development of the APIs for data exchange [OGC SensorML, 2014]. Figure 26 illustrates an UML (Unified Modelling Language) diagram from [OGC WaterML, 2018] document showing the level of details on hydrometric network and the way of data definition and collection. The UML level of specification allows direct work on APIs and does not show directly the scaling of the platforms. However, it is a positive step towards new cloud-based business models. Figure 27 presents an OGC conceptual model for smart cities. It is a semantical platform allowing the development of cloud-based systems and services. The hydrologic data platform could be an extension to this model. OGC Smart Cities Concept diagram is adopted from [ISO/IEC JTC 1/SC, 1990]. It allows integration between systems, addresses security concerns, identifies the business level and the IT services level. The ontology of the OGC needs further correlation with end-users and stakeholders, identification of possible northbound and southbound interfaces, definition of micro and monolithic services on the top of the ontology, data processing and storage requirements. The customisation level of the ontology is not yet implemented.

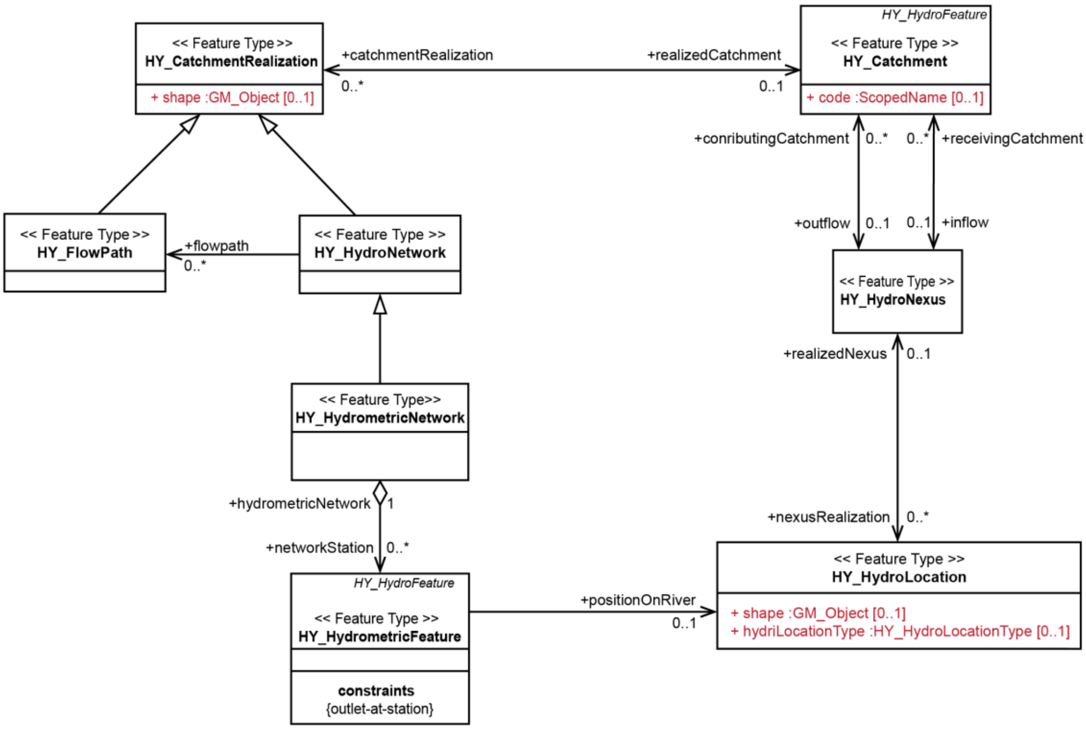


Figure 26. Hydrometric network and hydrometric feature realising a catchment (UML class diagram) [OGC WaterML, 2018]

ISO/IEC

ISO/IEC creates many standards including the sensor network infrastructure reference architecture [ISO/IEC 29182-3, 2014] (Figure 28).

The model supports the integration and interoperability at sensor, network, and service levels through definition of information flows [ISO/IEC 30140-1, 2018; ISO/IEC FDIS 20933, 2019]. The standard is a good starting point in ontology preparation. Functional entities of the sensor network are defined in [ISO/IEC 29182-4, 2013; ISO/IEC JTC 1/SC, 1990] (Figure 29). Different study groups with ISO have been focused on many smart water related topics between 2014 and 2023 as the reuse of wastewater for irrigation [ISO/TC 282/SC 1, 2014], the reuse of water in urban areas [ISO/TC 282/SC 2, 2014], risk and performance analyses of the water reuse systems [ISO/TC 282/SC 3, 2014], reuse of industrial water [ISO/TC 282/SC 4, 2014] etc.

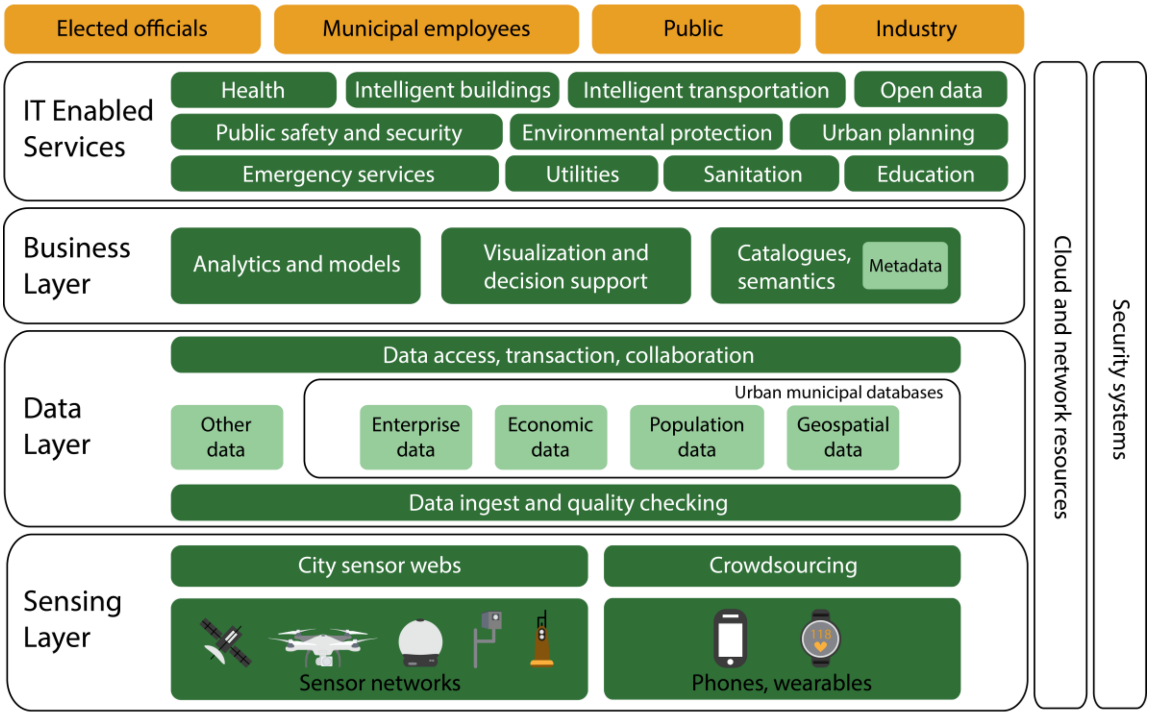


Figure 27. OGC Smart Cities Concept diagram. Source [ISO/IEC JTC 1/SC, 1990]

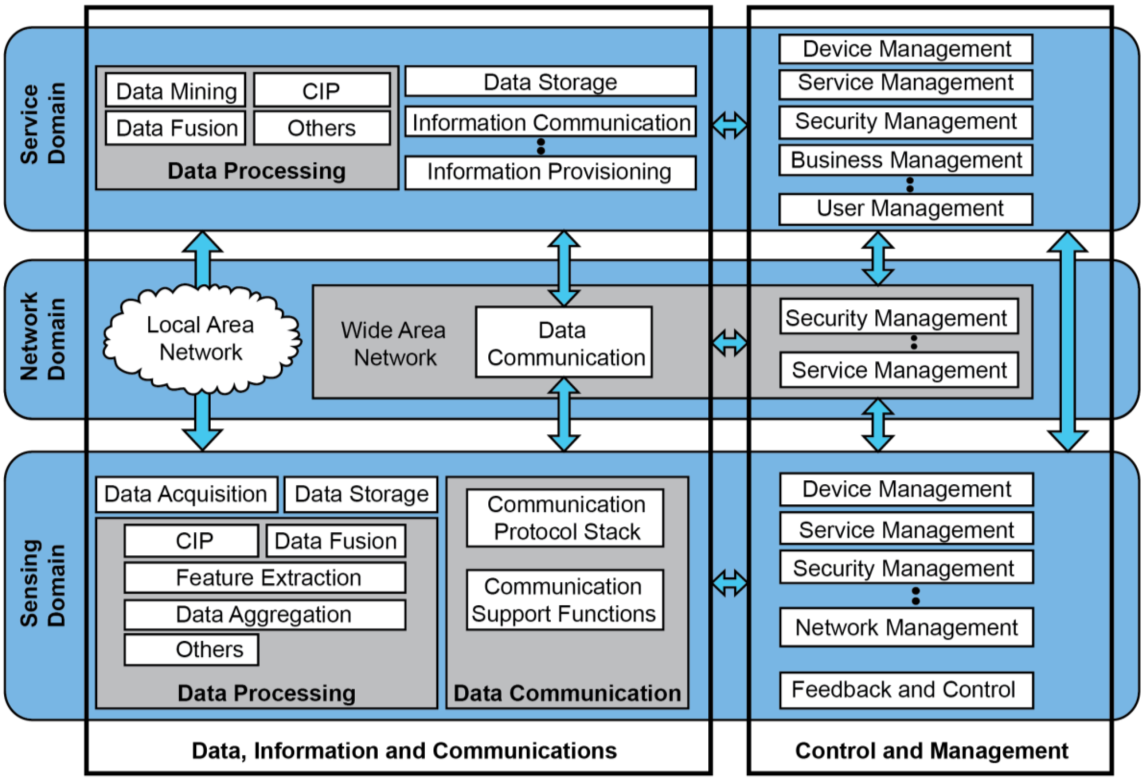


Figure 28. Sensor Network Reference Architecture [ISO/IEC 29182-3, 2014]

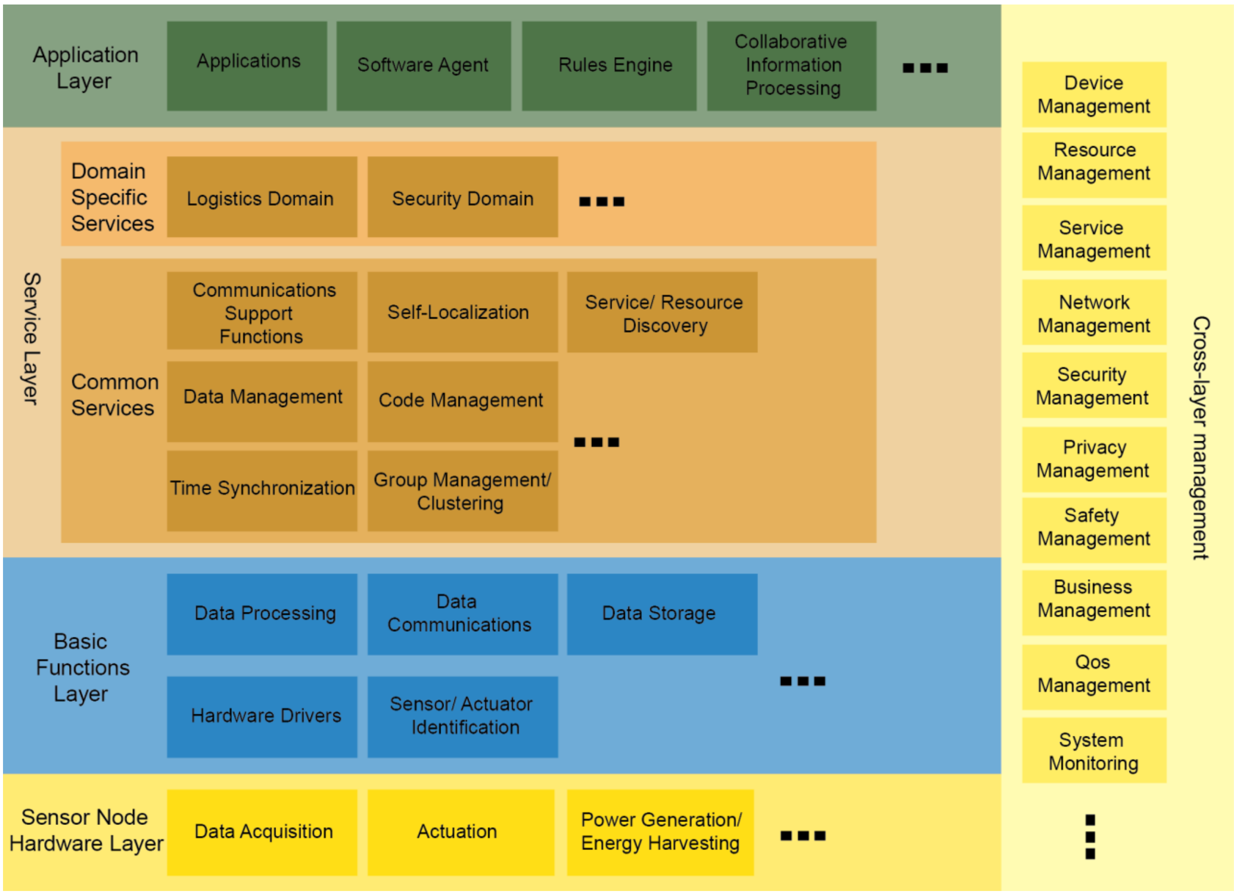


Figure 29. Functional entities of the sensor network [ISO/IEC 29182-4, 2013]

ITU

ITU Focus Group on ICT for water management [ITU Focus Group, 2016] has made an interesting analysis of sensors, protocols, technologies, SCADA implementations, relation to the geographical data, need of real-time monitoring, automation and possible integration. Many aspects of the smart water management as implementations in agriculture, smart cities, industrial use, wastewater management, are mapped. The ideas are not enough cloudified. ITU-T IoT Reference Model [ITU-T IoT Reference Model, 2012; ITU-T F.744, 2009] defines the generic IoT architecture that includes applications and communication infrastructure without definition of the information layer. Security and management functions are well presented (Figure 30). However, cloudification, northbound and southbound interfaces, micro and macro services, data models, data sharing and data processing are not mentioned. The model introduces planes which is good from a structural point of view. Many standards are defined in the IoT domain, but the content is too generic to be directly applied in smart water management. The cloud computing reference model of ITU-T is specified in [ITU-T Cloud, 2012]. The correspondence between the reference model and the cloud infrastructure is presented in Figure 31. Southbound and northbound interfaces are not drawn but could be identified.

AIOTI

AIOTI is the next alliance aiming to force the IoT innovation and implementation. The priorities for smart cities defined by AIOTI aim to map the city planners, researchers, policymakers and providers of infrastructure digitalisation with the platform procurement strategies, IoT technology implementation and deployment. The objectives are to open specific data and data models, to unify APIs, to reuse the components and services of the platforms, to create cross-domain applications, to scale towards business cases, to implement innovations, to reach sustainability of the solutions, to clear vision on heterogeneity and interoperability of the platforms, prevention of the citizens life etc.

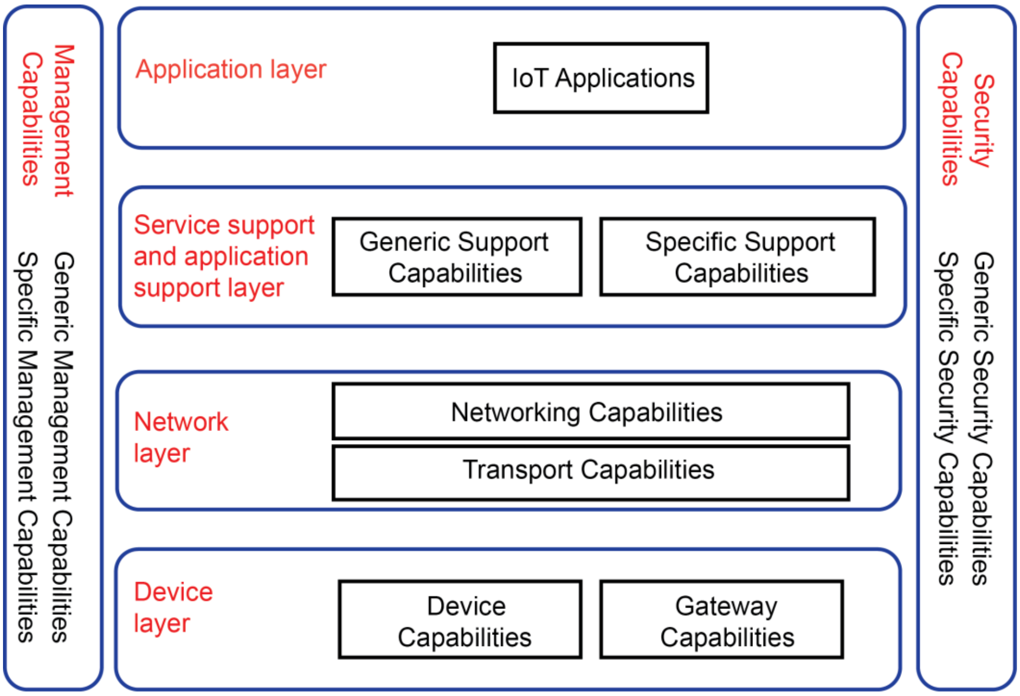


Figure 30. ITU-T IoT reference model [ITU-T IoT Reference Model, 2012]

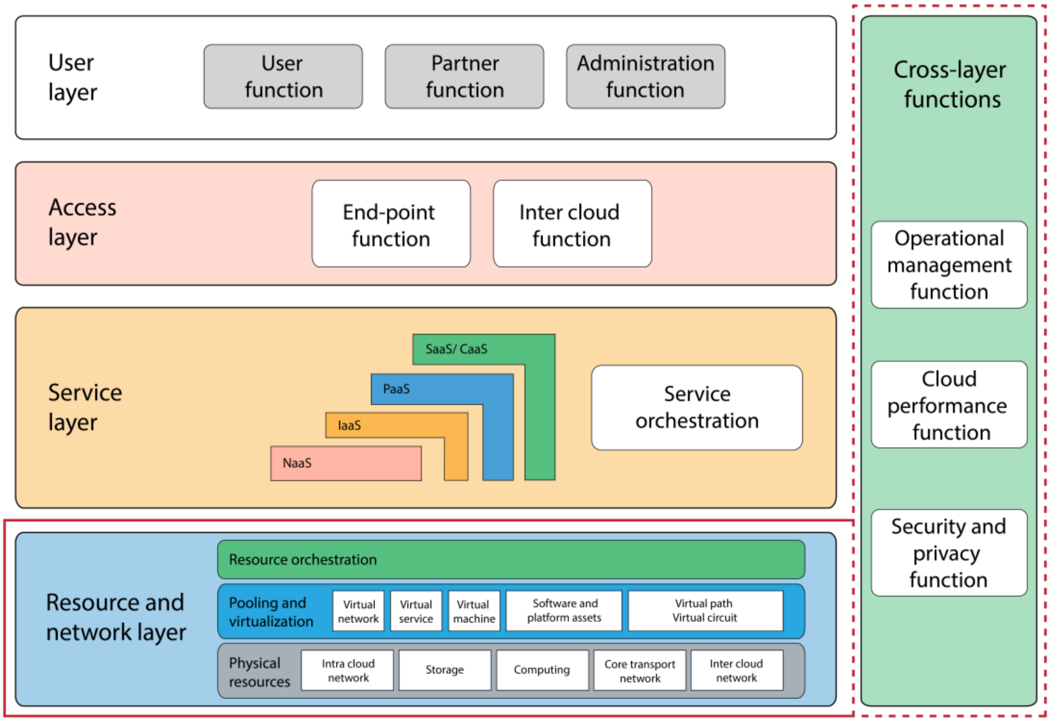


Figure 31. ITU-T correspondence between cloud infrastructure and reference architecture [ITU-T Cloud, 2012]

AIOTI coordinates activities with ITU-T, the European Commission, as well as with ETSI SmartM2M, Context Information Management (CIM) and City Digital Profile (CDP) Industry Specification Groups to fulfil the priority tasks for 2018 and beyond, which include:

1. Definition of the commercially viable cross-application use-cases built on common, interoperable platforms.
2. Data sharing specification allowing the discovery and exchange of data across IoT platforms with respect to the European Union's General Data Protection Regulation (GDPR).
3. Standards-based interoperability being compliant with GDPR.
4. IoT platforms scaling for stream processing, real-time applications etc.
5. Introduction of edge computing aiming prevention of the citizens life and better service customisation.

AIOTI WG 10 is working in smart water management and is identifying the standardisation gaps [AIOTI gaps, 2018]. Many of the gaps are similar to those specified in this catalogue. AIOTI high level architecture functional level is shown in Figure 32 [AIOTI HLA, 2018]. Mapping between platforms is also presented in the same document. CEN/CENELEC, ETSI and AIOTI are working on different architecture layers but aim at having composite set of standards relevant to smart cities.

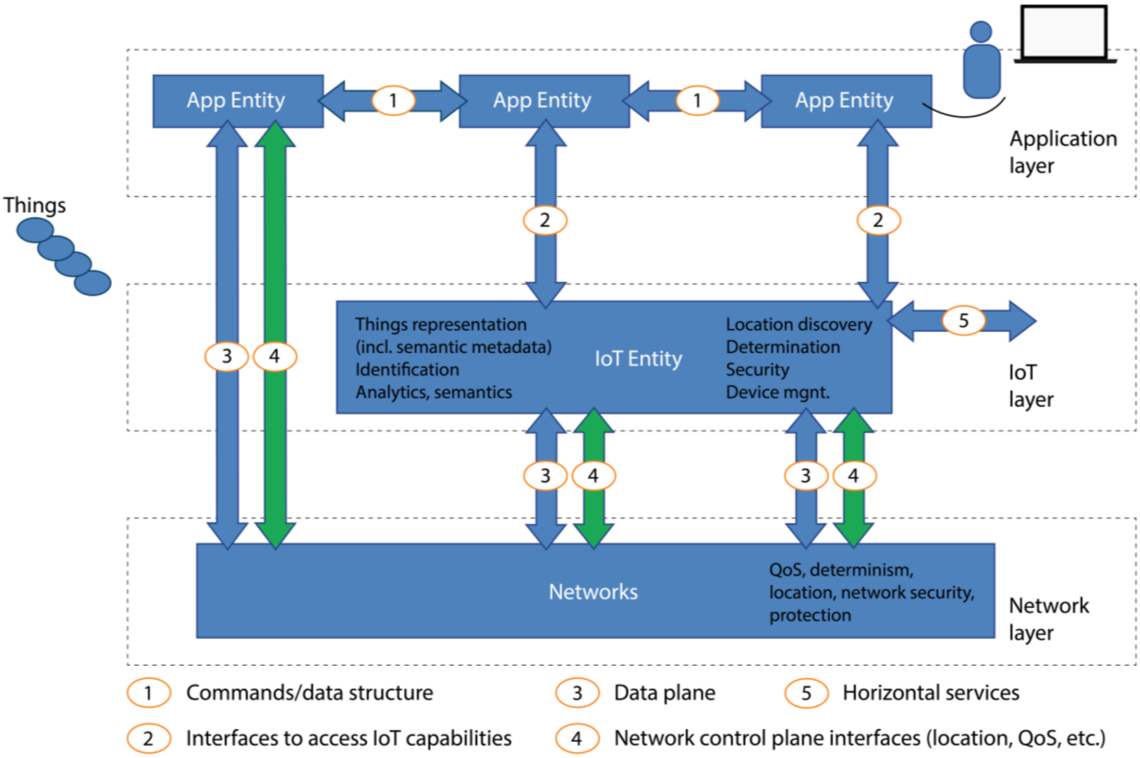


Figure 32. AIOTI High Level Architecture functional model [AIOTI HLA, 2018]

AIOTI members expressed the importance of smart water cyber security in the Digital Single Market [NIS Directive, 2016; Data protection, 2018; iWater, 2018]. Information sharing, information transparency and information protection are closely linked and need to be clearly specified. The equipment procurement procedures and systems development need to follow well defined requirements issued by competent national NIS authorities to facilitate strategic cooperation and the exchange of information. This reflects on serious incident's notification, incidents and risks analyses, end-users, stakeholders, and authority awareness.

NIST

A cloud computing approach is defined by National Institute of Standards and Technology (NIST) [Liu at al., 2011; NIST Cloud, 2011; NIST Fog, 2017] in 2011. It presents cloud consumers, auditors, providers, brokers, carriers. Big data implementation reference architecture is presented in Figure 33. It shows vertical and horizontal scalability of the IoT smart systems in general [NIST Big Data, 2015].

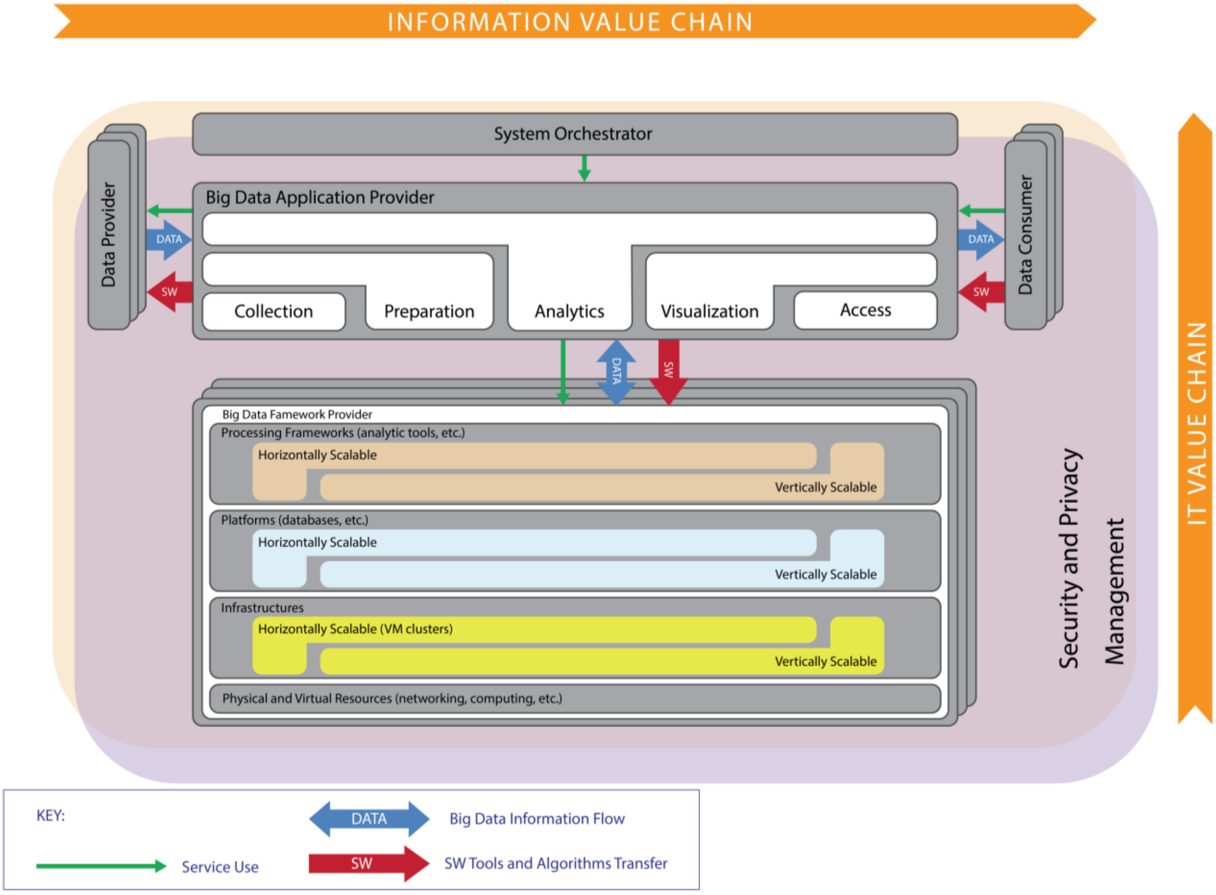


Figure 33. NIST reference architecture [Liu at al., 2011]

INSPIRE

The European Commission supports the analysis and service development through its portal called INSPIRE [INSPIRE, 2007; INSPIRE Infrastructure, 2007]. The service broker is used for service access and provision that allows continuous service development on the top of raw data collected. They support a knowledge database with spatial information obtained from the infrastructure available at European level. The conceptual model [INSPIRE Conceptual Model, 2012; INSPIRE Infrastructure, 2007] report made by the European Commission Joint Research Centre is a good starting point for the data sharing and interoperability study.

WITS

Water Industry Telemetry Standardisation has taken an interesting approach towards SCADA interoperability [WITS, 2016]. The water industry telemetry standards aim at water network integration and data sharing. Distribution Network Protocol (DNP) is defined for the water distribution management and data collection. The documents from WITS also tried to create an ontology on water management.

W3C

World Wide Web Consortium (W3C) defined an open architecture allowing cloudification and data sharing [W3C, 2018] (https://www.w3.org/Consortium/techstack-desc.html). The platform is generic aiming to be applicable in multiple synergetic applications.

BDVA

BDVA is a new association working mainly with infrastructures and architectures that produce big data flows [BDVA, 2017]. The architecture includes data collection, storage, analytics, virtualisation and processing. It is presented in Figure 34. The model demonstrates one step further towards cloudification. The architecture is contemporary and could be extended to fog computing and distributed processing.

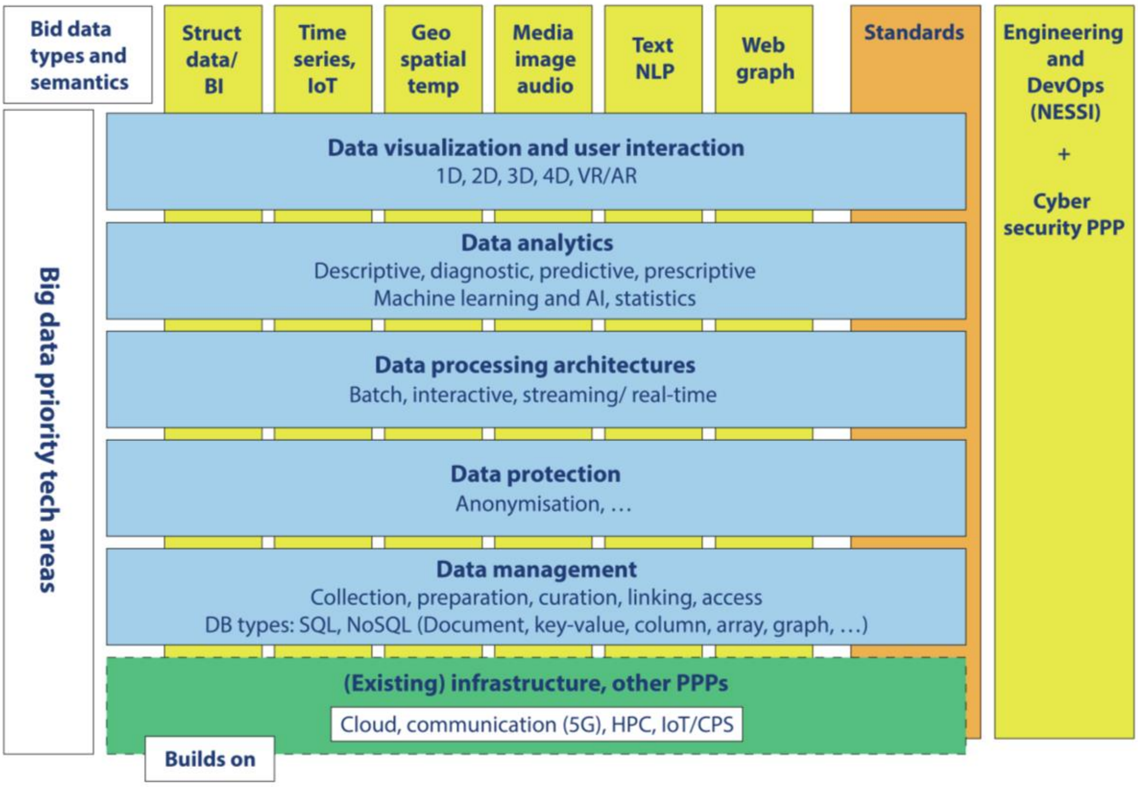


Figure 34. Big data value association reference model [BDVA, 2017]

OneM2M

OneM2M is a worldwide organisation aiming at standardisation in IoT and machine-to-machine communication [oneM2M, 2018]. Most of the partners in the consortium are from the industry. OneM2M is in close coordination with the Intelligent Internet Consortium (IIC). The functional architecture of oneM2M is too generic [oneM2M architecture, 2014]. The document contains different architectures from different aspects of the platforms.

Connections between parts of the systems are defined in Figure 35 [oneM2M use-cases, 2016]. There are several smart water use-cases defined in the specifications.

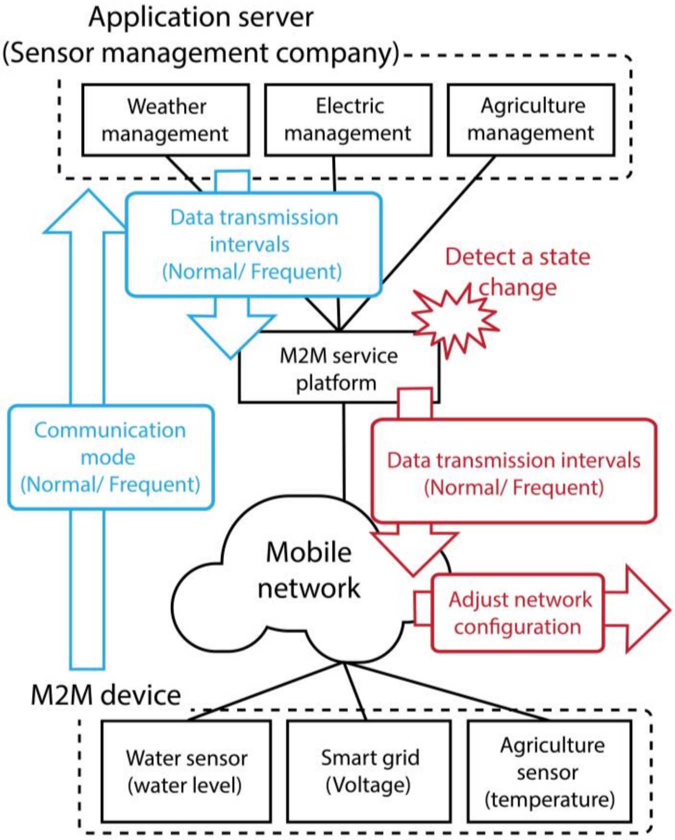


Figure 35. OneM2M high level illustration – optimising connectivity management parameters [oneM2M use-cases, 2016]

The consortium is active in intelligent urban water management systems. A oneM2M ontology is created together with SAREF [oneM2M ontology, 2018]. The use-cases collection includes not only smart meters but communication aspects transferring real-time and non-real-time data, audio and video, environmental sensing, data analytics, traffic analysis, integration and interoperability between different domains including agriculture, irrigation, communication systems etc. [oneM2M use-cases, 2016]. In Figure 36 satellite data are integrated with locally collected data from hydrogenic systems.

OneM2M specifications define the type of sensors used in water measurements and the way to represent the data at sensor level [oneM2M sensor data, 2018]. They support vertical interoperability between different industry products and map them to the ontology [oneM2M ontology, 2018]. The analysis in fog computing is coordinated with NIST, ETSI and openFog consortium [oneM2M fog computing, 2018]. One possible scenario for the smart cities blueprint is presented in Figure 37. The architecture allows the synergy between different systems in the cities [OneM2M Smart Cities, 2018].

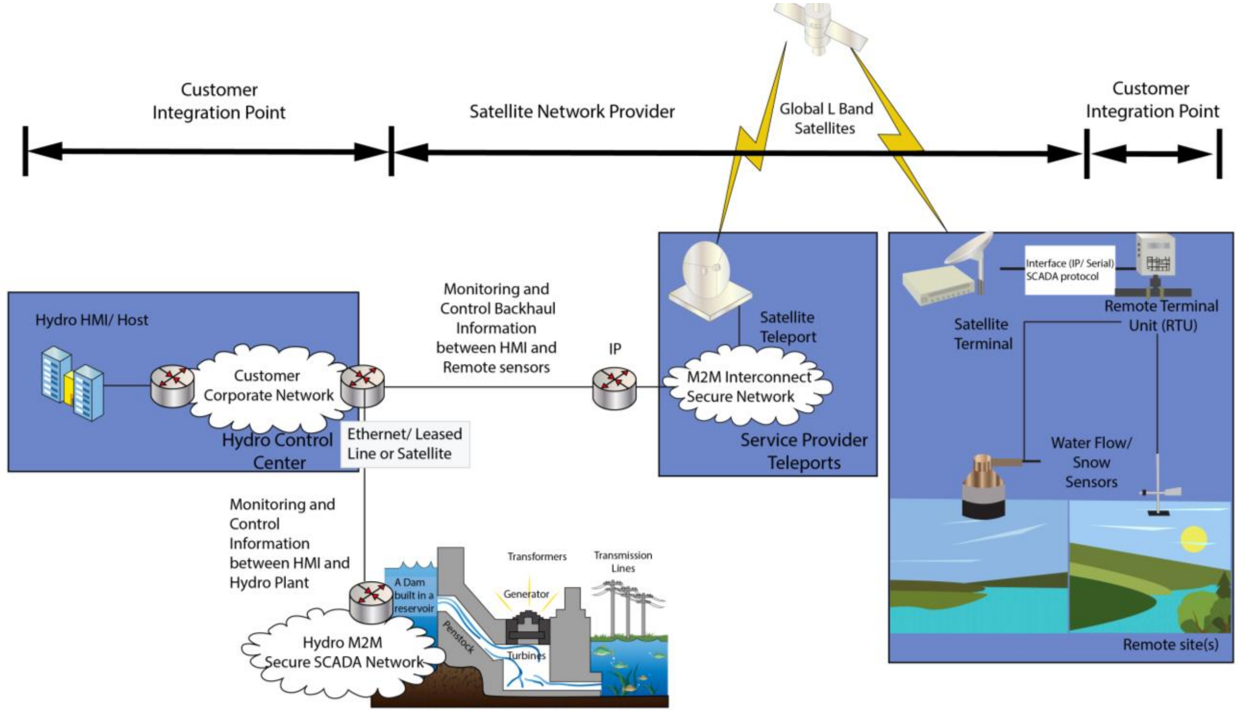


Figure 36. OneM2M high level illustration of environmental monitoring for hydro-power generation using satellite M2M [oneM2M use-cases, 2016]

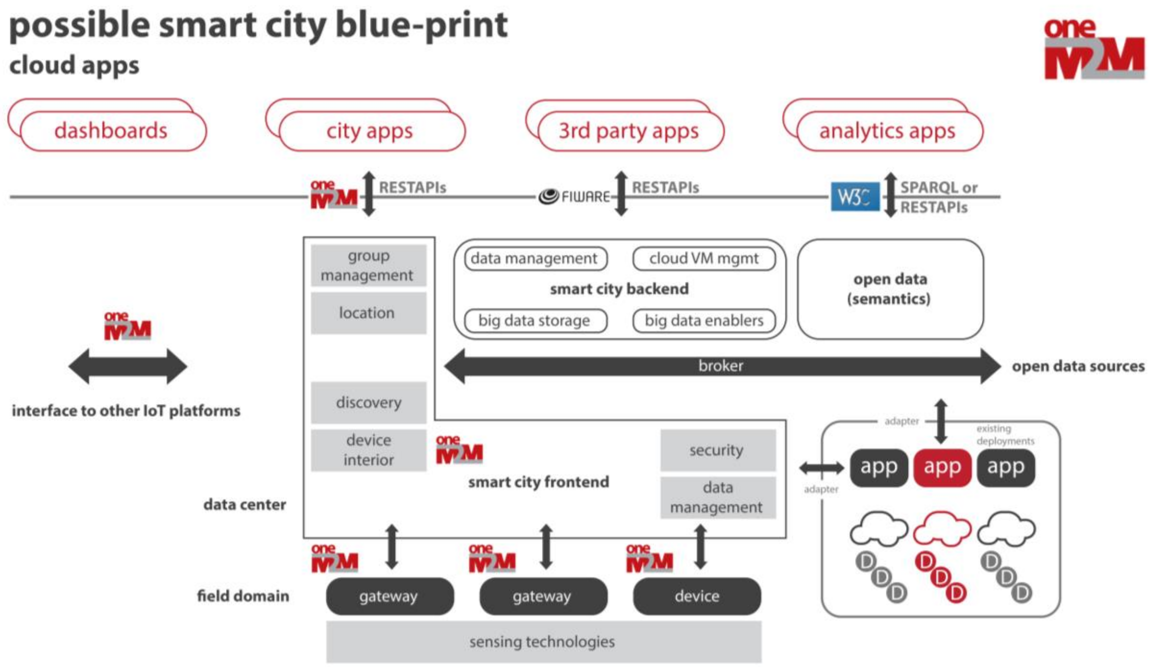


Figure 37. Possible smart city blueprint [OneM2M Smart Cities, 2018]

INDUSTRY 4.0

INDUSTRY 4.0 is a design principle aiming to support manufacturers in technological transformation using Cyber Physical Systems (CPS) [Industry 4.0, 2018, RAMI, 2018]. The architecture has control, process, operations management, company level using object linking and embedding process control, SCADA systems, manufacturing execution system and Enterprise Resource Planning (ERP). Connection to the cloud is performed at company level (Figure 38).

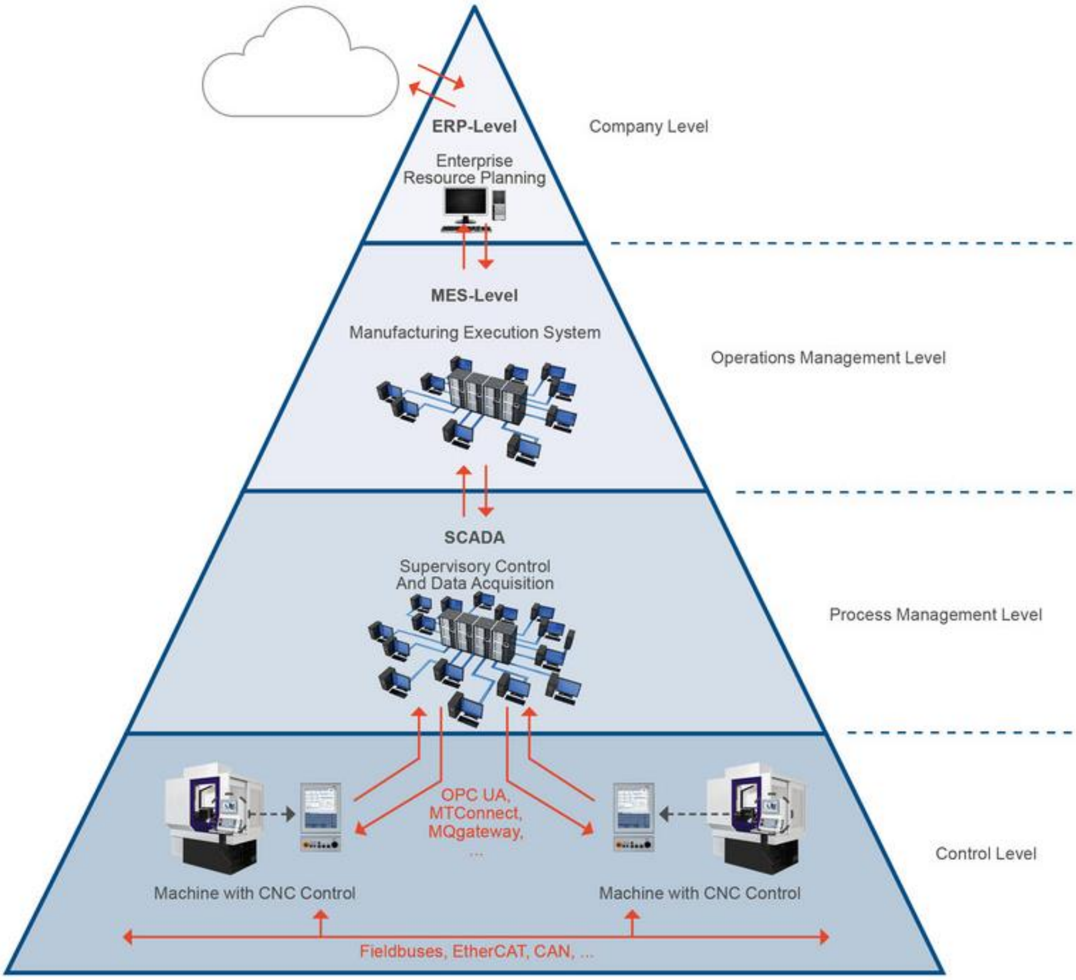


Figure 38. Industry 4.0 architecture [Industry 4.0, 2018; RAMI, 2018]

The Industry 4.0 architecture aims at achieving interoperability between objects, machines and people, making the factories smart. However, the interoperability of the devices in a heterogeneous environment is still not supported well. The CPS used is capable to make the processes smart locally by creation and simulation of virtual copies of the real world and could monitor objects existing in the surrounding environment and take decisions. This decentralisation phenomenon allows the CPSs to work independently, being customised and integrated to the upper levels of the platforms at the same time.

Real-time capability of the platform supports processes in the production line allowing immediate decision-making and reallocation of tasks. Services are customer-oriented aiming to connect efficiently objects and devices through the Internet of Services. This smart feature is still not completely interoperable between different industries. Modularity and scaling in market support are key features of the smart production. The self-organised smart devices decrease the production time during the production process. This feature also supports fast customisation linking manufacturer, service provider and the customer. Security and education features as well as innovations are also taken into account. The selection of shared data that may allow coordination between end-users, service providers and producers is still not completed. The introduction of cloud computing and the use of big data analyses are at an initial stage. Data abstraction and data processing need to be automated using artificial intelligence technologies aiming to create a robot-assisted production. The problem of interoperability between smart devices equipped with cameras, sensors, and actuators that can identify the product and then deliver necessary changes is even harder while speaking about Machines-as-a-Service. Industry 4.0 covers a highly diverse landscape of industries, stakeholders, processes, technologies and standards. To achieve a common understanding of what standards, use-cases, etc. are necessary for Industry 4.0, a uniform architecture model (the Reference Architecture Model Industry 4.0 (RAMI 4.0)) was developed [RAMI, 2018]. It serves as a basis for the discussion of interrelationships and dependencies between processes, devices and technologies. RAMI 4.0 has been further defined by [DIN SPEC 91345, 2016] and IEC [IEC PAS 63088, 2017].

Industry 4.0 is a good starting point for standard development towards fog computing and system autonomy.

OpenFog

Fog computing represents a new trend in computing technologies making the platforms decentralised, spreading the data storage and processing in the periphery of the networks [OpenFog, 2018]. It is a horizontal architecture allowing implementations in multiple layers of network topology while preserving the cloud computing features. In many cases, fog computing works with a cloud [OpenFog Architecture, 2017]. OpenFog reference architecture supports security, is scalable, open, autonomous, reliable, allows service development, is hierarchical and programable. The architecture is structured keeping the roles of stakeholders in the fog (Figure 39).

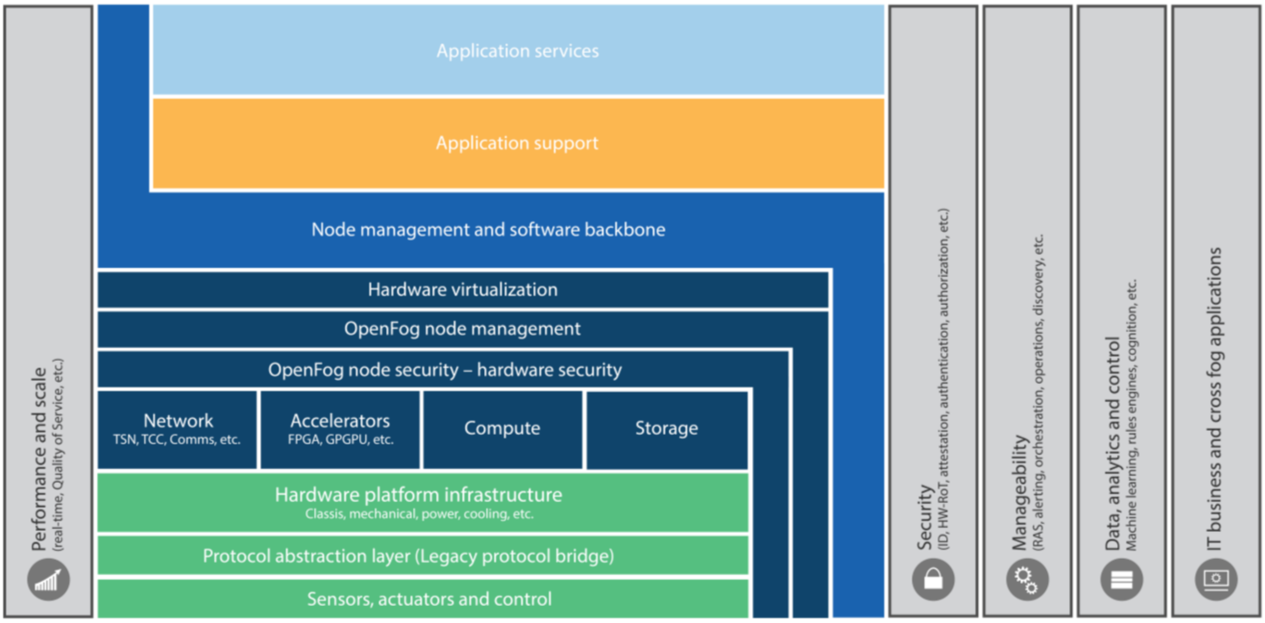


Figure 39. OpenFog reference architecture for fog computing [OpenFog Architecture, 2017]

zWave

zWave creates an interesting smart home solution through controllers and Wi-Fi network [zWave Hierarchy, 2018]. Data sharing at cloud level is not presented yet.

FIWARE

The FIWARE platform aims to supply the end-users with a plug and play high-level modular instrument for fast IoT service development, implementation, and deployment [FIWARE, 2018; FIWARE. Smart Industry, 2018]. The platform is cloudified and intensively tested in smart cities environment [FIWARE Services, 2018], as seen from Figure 40. However, the generic FIWARE services need additional customisation and software development.

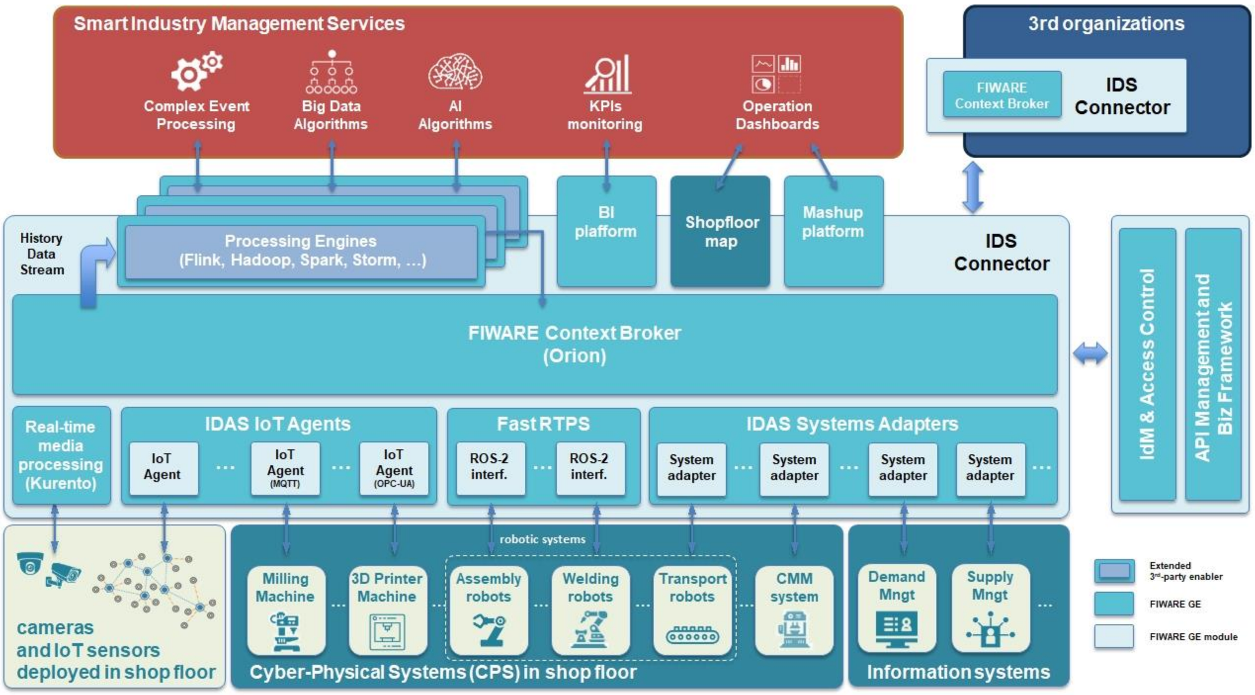


Figure 40. FIWARE smart industry management services architecture [FIWARE Services, 2018]

Details of the architecture related to the application, services and data delivery could be seen in [FIWARE Architecture, 2018]. Data sharing is defined at REST API interface called also Open API architecture and is based on known data formats like JSON through NGSI interface [FIWARE-NGSI, 2019]. NGSI is standardised by ETSI in [ETSI GS CIM 009, 2019]. A new project Fiwate4Water is expected to advance the data sharing and integration in the water sector next years [Fiware4Water, 2019].

4.3. Gap Analysis in Standardisation for Smart Water Management. Priorities in Standardisation

The comparison between standards and architectures is based on well-defined parameters applied for the projects and specifications. The work performed during preparations of the Roadmaps for Water Management and Rolling plan of the European Commission is taken into consideration. As already have been mentioned, the smart water sector is still fragmented and needs active measures to be integrated in the next

3 to 7 years. The synergy with other sectors is not clearly defined and widely implemented yet.

The requirements of the end-users and stakeholders have been collected and simplified in Tables 26 to 33 where the acronyms of the standard organisations are used. More explanation per standard organisation can be found below the tables. The colours used are related to the priorities in the standardisation process. The table could be easily expanded to the existing technologies applied in different member states and worldwide as explained in [ITU Focus Group, 2016; Mekonnen and Hoekstra, 2011a; Mekonnen and Hoekstra, 2011b]. The guidelines for ICT standards adoption and implementation of the emerging digital technologies in the water sector should be clearly defined as stated in the EC rolling plan [Anzaldi Varas, 2018; Rolling Plan, 2018]. The number of selected use-cases, customised ontologies, and architectures should be a good starting point towards data sharing, cloudification, integration, interoperability, and synergy between sectors. The ontology proposed should define in enough details water information generation, collection, processing, and exchange. The solutions should be many but open to allow good set of selection for further implementations in the EC member states.

Multiple solutions should be possible throughout use-cases including defining of micro (atomic), macro (monolithic) services, northbound and southbound interfaces, data models for data sharing within the smart water sector and between sectors. Regulation in the water sector at European level is still fragmented. There is a need for clear licensing, local, national, and international regulations including EU level regulations. **New water metering devices and infrastructure parts need to be produced and deployed under well-defined standards that allow further interoperability and openness.**

The gaps identified are marked in the tables in:

- Blue – short term gaps needed to be solved within the next two years.
- Violet – medium term gaps needed to be solved within four years
- Green – long term gaps needed to be solved within six years

All platforms are open by design which is a good starting point for further integration and good interoperability level. The definition of the openness in different platforms varies. For example, ETSI and ITU-T use standard way known from well-defined communication standards, whereas oneM2M, BDVA, Industry 4.0, FIWARE and many others use the three layer definition known from computer science. In this sense, the conclusion is that the platforms based on these standards could exchange data and be integrated at different layers.

Most of the standards are cross-sectoral. They define possibilities to measure and manage not only smart water but also smart energy, smart cities, smart transport, smart health, etc. The general synergy potential between platforms is good. All standards allow possibility for further innovations and try to make the platforms secure. Scalability also seems to be possible with all standards applied. However, this issue needs further analysis considering also the effectiveness and the efficiency of the implementations in different scales.

While the standard support is part of almost any existing architecture, the integration of the legacy platforms is still a wish. ICT-related KPIs defined at ontology level are not well standardised. The sector is far from having a Pan-European water management platform.

Water in circular economy implementations in Europe are not at the level that could allow drastic reduction of wastewater from the industry and households. The sustainability of the chemical and bio technologies applied is still problematic. ICT support for water in circular economy is very limited and not standardised.

Data sharing among platforms and architectures is possible but not implemented. Cloudification is done at service level. The unification between clouds is still desirable and not done in practice. Definition of micro and macro services is under intensive development.

Local legislation in different member states is harmonised little by little. The complete picture that may allow the creation of Pan-European platform will not be a reality within the next six years. Cloud computing is implemented in the sector but fog and dew computing are not.

Table 26. Architectural, technological and functional aligning between the smart water management requirements and standards. Openness, interoperability, integration, scalability, synergy and security analyses

Requirement/ Standards	**Open**	**Cross sectoral**	**Interoperable**	**Integrable**	**Scalable**	**Secure**	**Focused on people**	**Open for innovations**
CEN/CENELEC	Yes	Yes	Possible	Possible	Possible	Possible	Not clear	Yes
ETSI SAREF SmartM2M	Yes	Yes	Yes	Yes	Possible	Yes	Possible	Yes
ETSI Smart Grid	Yes	Yes	Yes	Possible	Possible	Possible	Possible	Yes
OGC	Yes	Yes	Yes	At semantic level	Possible	Yes	Possible	Yes
INSPIRE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
ISO/IEC	Yes	Yes	Could be	At semantic layer	Could be	Yes	Possible	Yes
ITU-T	Yes	Yes	Yes	Yes	Yes	Yes	Might be	Possible
WITS	Yes	Partially	Possible	Possible	Yes	Possible	Possible	
AIOTI	Yes	Yes	Yes	Yes	Yes	Yes	May be	Yes
W3C	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
NIST	Yes	Yes	Possible	Possible	Yes	Yes	Partially	Yes
BDVA	Yes	Yes	Yes	Yes	Yes	Yes	Possible	Possible
oneM2M	Yes	Yes	By definetion	Yes	Possible	Yes	Yes	Yes
Industry 4.0	Yes	Could be	Partially	Could be	Could be	Yes	Could be	Yes
zWave	Yes	Possible	Possible	Possible	Possible	Possible	Yes	May be
OpenFog	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
FIWARE	Yes	Yes	Partially	Partially	May be	Yes	Yes	Yes

Table 27. Architectural, technological and functional aligning between the smart water management requirements and standards. Maturity, KPIs support, connectivity, standard support and potable water management

Requirement/ Standards	**Mature**	**Connecting Europe facility deployments**	**Endorsement of formal platforms**	**KPIs support**	**Standards support**	**Potable water management**
CEN/ CENELEC	Yes	Partially	May be	Yes	Yes	Initially
ETSI SAREF SmartM2M	Yes	Yes	Possible	Yes	Yes	Possible
ETSI Smart Grid	Yes	Possible	Possible	Yes	Yes	Possible
OGC	Yes	Possible	Possible	Yes	Yes	Possible
INSPIRE	Yes	Possible	Possible	Yes	Yes	Yes
ISO/IEC	Partially	Possible	Possible	Possible	Possible	Possible
ITU-T	Partially	Partially	Partially	Yes	Yes	Yes
WITS	Yes	May be	May be	Yes	Yes	Yes
AIOTI	Yes	Possible	Possible	Possible	Yes	Possible
W3C	Yes	Yes	Yes	Possible	Yes	Possible
NIST	Yes	Possible	Possible	Possible	Possible	Possible
BDVA	Partially	Possible	Possible	Possible	Possible	Possible
oneM2M	Ye s	Possible	Possible	Yes	Ye	Yes
Industry 4.0	Yes	Not clear	Could be	Yes	Yes	Could be
zWave	Partially	Might be	Possible	Possible	Nor clear	Possible
OpenFog	Could be	May be	May be	Could be	Yes	Possible
FIWARE	Partially	May be	Not clear	Could be	Yes	Possible

Table 28. Architectural, technological and functional aligning between the smart water management requirements and standards. Stormwater, flooding, sewage, wastewater reuse, IoT implementation and cloudification level

Requirement/ Standards	**Stormwater/ flood management**	**Sewage management**	**Wastewater management**	**Water reuse**	**Use of IoT and communication**	**Cloudification**
CEN/CENELEC	Yes	At the beginning	At the beginning	At the beginning	Yes	Not yet
ETSI SAREF SmartM2M	Possible	Possible	Possible	Possible	Yes	Yes
ETSI Smart Grid	Possible	Possible	Possible	Possible	Yes	Yes
OGC	Defined	Defined	Defined	Defined	Yes	Yes
INSPIRE	Yes	Yes	Yes	Yes	Yes	Yes
ISO/IEC		Possible	Possible	Possible	Yes	Yes
ITU-T	Yes	Yes	Yes	Yes	Yes	Possible
WITS	Yes	Yes	Yes	Yes	Yes	Possible
AIOTI	Possible	Possible	Possible	Possible	Yes	Yes
W3C	Possible	Possible	Possible	Possible	Possible	Yes
NIST	Possible	Possible	Possible	Possible	Yes	Yes
BDVA	Possible	Possible	Possible	Possible	Yes	Yes
oneM2M	Possible	Yes	Yes	Yes	Yes	Yes
Industry 4.0	Could be	Could be	Cloud be	Could be	Partially	Not clear
zWave	Possible	Possible	Possible	Possible	Yes	Yes
OpenFog	Possible	Possible	Possible	Possible	Yes	Yes
FIWARE	Possible	Possible	Possible	Possible	Yes	Yes

Table 29. Architectural, technological and functional aligning between the smart water management requirements and standards. Data sharing, service definition, big data and ontology analyses

Requirement/ Standards	**Data sharing**	**Cloud-based services**	**Water-as-a-Service, micro services**	**Macro services**	**Use of Water Big Data**	**Ontology defined**
CEN/CENELEC	Not clear	No	No	No	No	Partially
ETSI SAREF SmartM2M	Yes	Yes	Possible	Possible	Possible	Yes
ETSI Smart Grid	Yes	Yes	Possible	Possible	Possible	Yes
OGC	Yes	Yes	Possible	Possible	Possible	Yes
INSPIRE	Yes	Yes	Yes	Yes	Yes	Yes
ISO/IEC	Yes	Yes				
ITU-T	Possible	Yes	Yes	Yes	Yes	Not clear
WITS	Possible	Possible	Possible	Possible	Possible	Yes
AIOTI	Possible	Yes	Yes	Yes	Yes	Not clear
W3C	Yes	Possible	Possible	Possible	Possible	Not clear
NIST	Possible	Yes	Yes	Yes	Yes	May be
BDVA	Yes	Yes	Yes	Yes	Yes	Not clear
oneM2M	Possible	Possible	Possible	Possible	Possible	Yes
Industry 4.0	Could be	Possible	Possible	Possible	Planned	Not clear
zWave	Possible	Yes	Possible	Yes	Yes	Not clear
OpenFog	Yes	Yes	Yes	Yes	Yes	Could be
FIWARE	Partially	Yes	Yes	Yes	Yes	Not clear

Table 30. Business smart water management requirements aligning. End-users, stakeholders' cooperation, replicability, standard adaptation, Quality of Service analyses

Requirement/ Standards	**Players cooperation**	**Replicability**	**Aligning to the legislation and policy makers**	**Necessity of standard adoption**	**Quality of Service**
CEN/CENELEC	Not clear	May be	May be	May be	Yes
ETSI SAREF SmartM2M	Yes	May be	May be	May be	Yes
ETSI Smart Grid	Yes	Possible	May be	May be	Yes
OGC	Yes globally	Possible	Possible	May be	May be
INSPIRE	Yes	Yes	Possible	Possible	Possible
ISO/IEC	Yes	Yes	Possible	Possible	Possible
ITU-T	Partially	Might be	May be	Not clear	May be
WITS	Possible	Possible	Possible	Possible	Possible
AIOTI	Good	May be	May be	Possible	Possible
W3C	Possible	Possible	May be	May be	Possible
NIST	Possible	Possible	Possible	Possible	Yes
BDVA	May be	May be	May be	May be	Possible
oneM2M	yes	May be	May be	Not clear	May be
Industry 4.0	Yes	Possible	Possible	May be	Yes
zWave	Ye s	Yes	May be	May be	Yes
OpenFog	May be	Yes	May be	May be	Yes
FIWARE	Yes	May be	May be	May be	May be

Table 31. Business smart water management requirements aligning. Synergy, diversity, competitiveness, sustainability analyses

Requirement/ Standards	Access to other services	Diversity and social cohesion	Green economy support	Attractiveness and competitiveness	Sustainability
CEN/CENELEC	Yes	Yes	Not clear	Yes	Yes
ETSI SAREF SmartM2M	Yes	Yes	Good	Good	Yes
ETSI Smart Grid	Possible	Possible	Possible	Possible	Possible
OGC	Yes	Yes	Possible	Good	Yes
INSPIRE	Possible	Possible	Possible	Possible	Possible
ISO/IEC	Possible	Possible	Possible	Good	Yes
ITU-T	May be	May be	May be	Not clear	May be
WITS	Possible	Possible	Possible	Not clear	Possible
AIOTI	Possible	Possible	Possible	Good	Possible
W3C	Possible	Possible	Possible	Good	Possible
NIST	Possible	Possible	Possible	Good	Yes
BDVA	May be	Possible	Possible	Good	Possible
oneM2M	Not clear	Yes	Possible	May be	May be
Industry 4.0	Possible	Possible	Possible	Possible	Yes
zWave	Possible	Possible	Possible	Good	Possible
OpenFog	Yes	Yes	Possible	May be	Could be
FIWARE	Yes	Possible	Possible	Possible	Not clear

Table 32. Business smart water management requirements aligning. Loss, data awareness, water exploitation and efficiency analyses

Requirement/ Standards	Water losses and leakage analysis	Level of water data awareness analysis	Share of reclaimmed water analysis	Reduction in potable water consumption analysis	Self-sufficiency level analysis	Water exploitation index analysis
CEN/ CENELEC	Possible	Possible	Possible	Possible	Possible	Possible
ETSI SAREF SmartM2M	Possible	Possible	Possible	Possible	Possible	Possible
ETSI Smart Grid	Possible	Possible	Possible	Possible	Possible	Possible
OGC	Partially	Partially	Partially	Partially	Partially	Partially
INSPIRE	Possible	Possible	Possible	Possible	Possible	Possible
ISO/IEC	Partially	Partially	Partially	Partially	Partially	Partially
ITU-T	Yes	Yes	Yes	Yes	Yes	Yes
WITS	Yes	Yes	Yes	Yes	Yes	Yes
AIOTI	May be	Possible	Possible	Possible	Possible	Possible
W3C	Possible	Possible	Possible	Possible	Possible	Possible
NIST	Possible	Possible	Possible	Possible	Possible	Possible
BDVA	Possible	Possible	Possible	Possible	Possible	Possible
oneM2M	Possible	Possible	Possible	Possible	Possible	Possible
Industry 4.0	Possible	Possible	Possible	Possible	Possible	Possible
zWave	Possible	Possible	Possible	Possible	Possible	Possible
OpenFog	Possible	Possible	Possible	Possible	Possible	Possible
FIWARE	Possible	Possible	Possible	Possible	Possible	Possible

Synergy and sustainability of the proposed standards are not mature. There are possibilities of multisectoral integration that are not implemented yet.

KPIs related to the ICT support of the smart water sector are not well-defined. In this sense, the ontology proposed at the end of this document may create a common ground for all standards and architectures to be integrated and made interoperable.

The analysis demonstrates clearly the presence of more than 50 different use-cases that are applicable to ontology development and other standards specifications.

Table 33. Business smart water management requirements aligning. Political relevance, use-case applicability, multi-level governance analyses

Requirement/ Standards	Factors of success	Efficiency in use	Applicable use-cases to validate the standards and cross-sectorial interoperability	Political relevance	Multi-level governance
CEN/CENELEC	Yes	Yes	Yes	Yes	Yes
ETSI **SAREF** **SmartM2M**	Yes	Good	Good	Yes	Good
ETSI Smart Grid	Good	Good	Yes	Yes	Yes
OGC	Good	Depends on implementation	May be	Possible	Possible
INSPIRE	Good	Possible	Possible	Possible	Possible
ISO/IEC	Good	Depends on implementation	May be	Possible	Possible
ITU-T	Good	Not clear	Yes	Yes	Yes
WITS	Yes	Yes	Yes	Yes	Yes
AIOTI	Good	Good	May be	May be	May be
W3C	Good	Good	Yes	Yes	Yes
NIST	Good	Good	Yes	Yes	Yes
BDVA	Good	Excellent	Yes	Yes	Yes
oneM2M	Positive	May be	Yes	Yes	Yes
Industry 4.0	Good	Good	Yes	Good	Good
zWave	Good	Good	Yes	Yes	Yes
OpenFog	Good	May be good	Yes	Yes	Yes
FIWARE	Not clear	Not clear	May be	Possible	Possible

5. Feasibility and Priorities Identification for Smart Water Management

Feasibility and priorities identification of the standardisation process in smart water management is done in short (two years), medium (approximately four years), and long term (six years and beyond). The longer period will need significant update in the use-cases proposed and the clear analysis of preliminary standards' implementations.

The aim of the gaps and priorities analysis is to speed up and harmonise the process of standardisation increasing the opportunities of the customers and businesses to access standardised goods and services across Europe. The process could also stimulate the digitalisation of the networks and maximise the growth potential in the sector based on the requirements of the customers. Furthermore, the process of standardisation and its adoption needs to be guided in the different countries to allow harmonisation of the local legislation and regulation procedures. This is expected to maximise the growth potential of the European Digital Economy. The adoption process could not be successful without clear specification of global EU standards where the data sharing is the first step.

The main standard's gaps defined in the ICT4Water action plan are related to the [Anzaldi Varas, 2018]:

- Poor level of systems interoperability
- Limited data sharing that is not based on any standard data models
- Limited smartness of the water management
- Limited cyber-security procedures
- Lack of actors' awareness
- Lack of harmonised policy
- Lack of good business models leading to the Digital Single Market

Additional gaps identified within the scope of this study are also summarised as lack of:

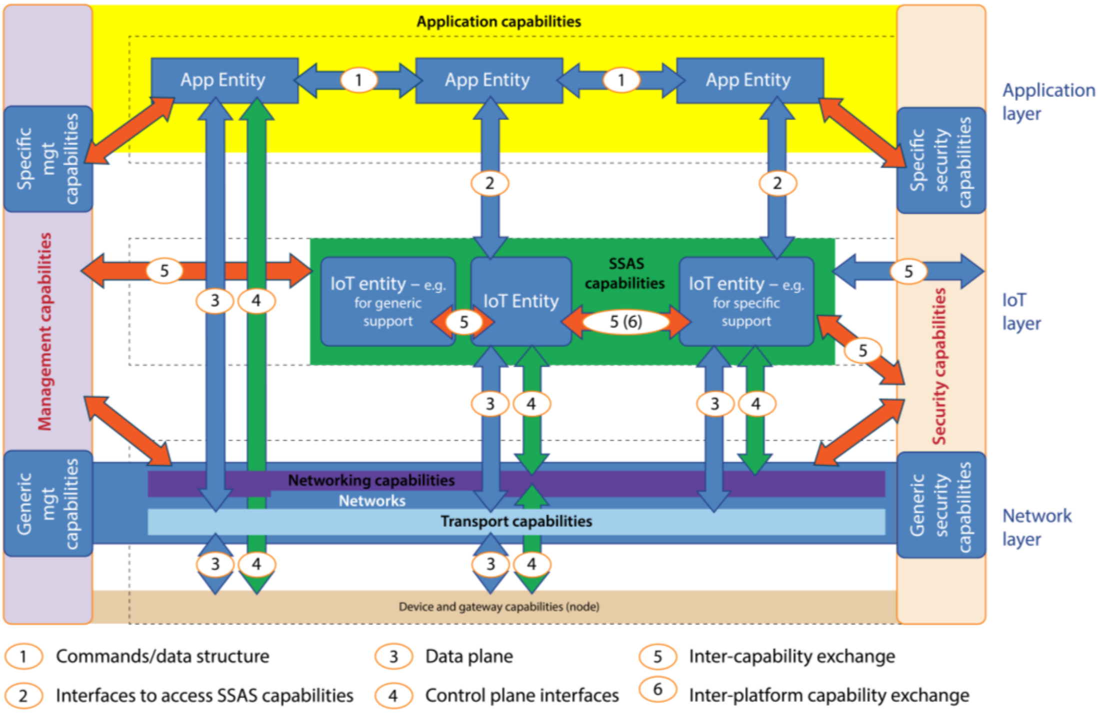
- clear interoperability of the smart water, smart utilities, waste, smart cities platforms, health, agriculture, transport etc., i.e. provision of cross-domain smart services and data sharing
- adaptability of platforms to innovative technological solutions as well as to the new user requirements
- standardised common meta-data structures allowing to produce, deploy and develop services in a standard way in the Digital Single Market
- well-defined data sharing in the water sector and between different sectors
- clear specification of data sharing at different levels of the architectures allowing also data sharing through the standard interfaces that are not clearly southbound and northbound
- clear statement and definitions on how the existing platforms cloud be integrated and made therefore interoperable
- appropriate measures concerning actors' awareness, policy and business models

There are many trials in cooperation between standardisation organisations in the IoT domain in general and partially in smart water management, such as:

- AIOTI and ETSI
- OneM2M and AIOTI
- OneM2M and ETSI
- ITU and AIOTI
- ITU and OneM2M
- IEC and ETSI
- OGC and ETSI
- NIST and AIOTI

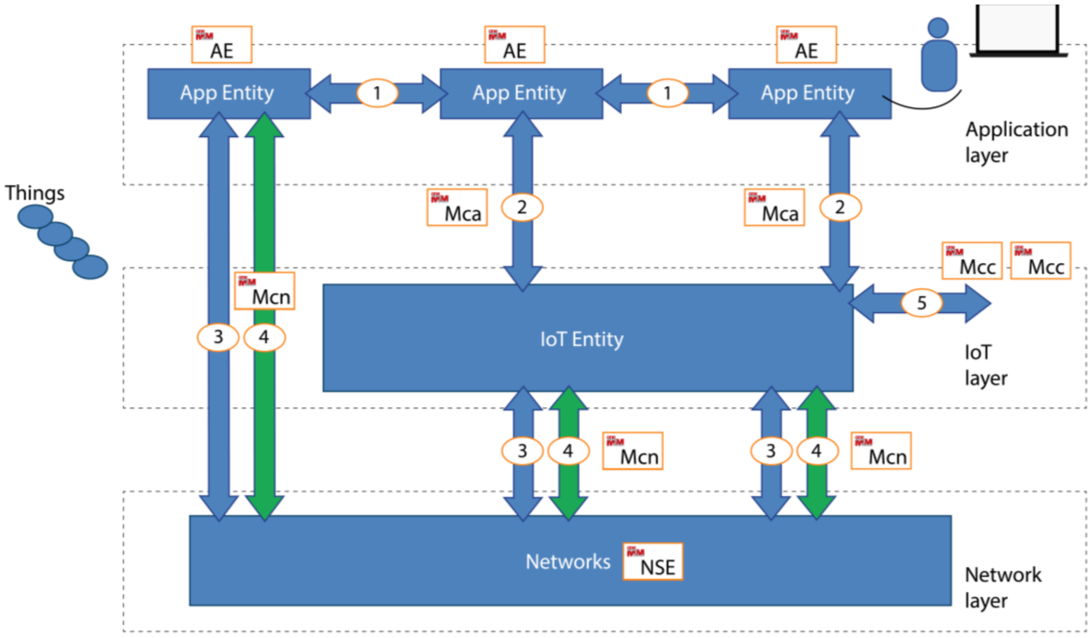
The main actors in this cooperative approach are AIOTI, ETSI, oneM2M, OGC, ITU. In Figure 41, AIOTI HLA functional model is mapped to ITU-T IoT reference model mostly at northbound and southbound interfaces. Control and data planes are separated. Security and management capabilities are defined at generic and specific level. The architecture is still generic but could be considered as a good first step towards the task of integration and interoperability.

Very clear correspondence between oneM2M and AIOTI architectures is presented in Figure 42. OneM2M are also advanced in ontology work mapped to the architecture.



Note: not equivalent to physical device/ gateway

Figure 41. AIOTI WG03's HLA functional model mapping to ITU-T IoT reference model [AIOTI HLA, 2018]



CSE: Common Service Entity – **NSE**: Network Services Entity – **AE**: Application Entity
Mcn: reference point between a CSE and the NSE that enables a CSE to use the network services such as location and QoS
Mcc: reference point between a CSE and a CSE. It allows registration, security, data exchange, subscription, notification, etc.
Mca: API to AE exposing functions to the CSE
oneM2M CSE functions include: device management, registration, discovery, group management, data management and repository, etc.

Figure 42. Aligning oneM2M and AIOTI HLA [AIOTI HLA, 2018]

Industrial Internet reference architecture is presented in [IIC Architecture, 2017] and [IIRA, 2018]. Aligning to the AIOTI architecture could also be seen in [AIOTI HLA, 2018] (Figures 43 and 44). The platform is divided into tiers showing clearly the southbound, northbound interfaces and data management. Mapping is done at southbound and northbound interfaces where data structures need to be clearly defined.

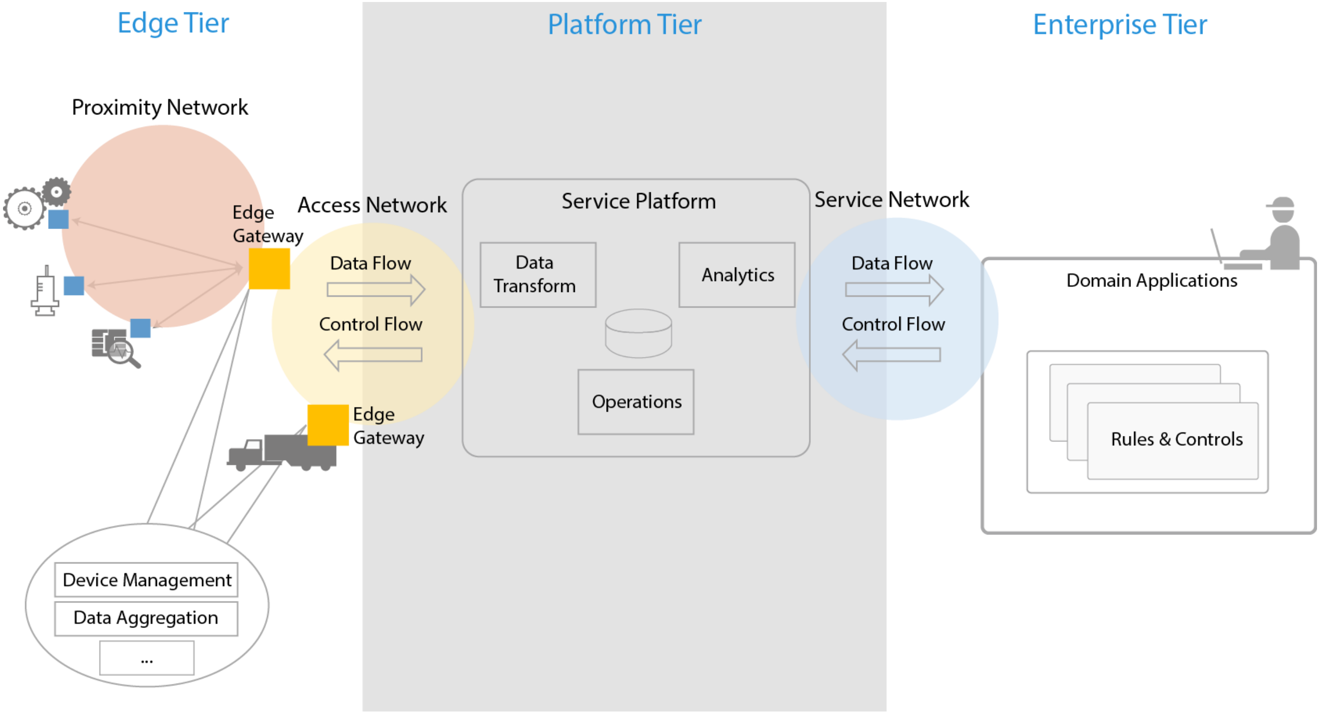


Figure 43. Industrial Internet Consortium three tier architecture [IIC Architecture, 2017; AIOTI HLA, 2018]

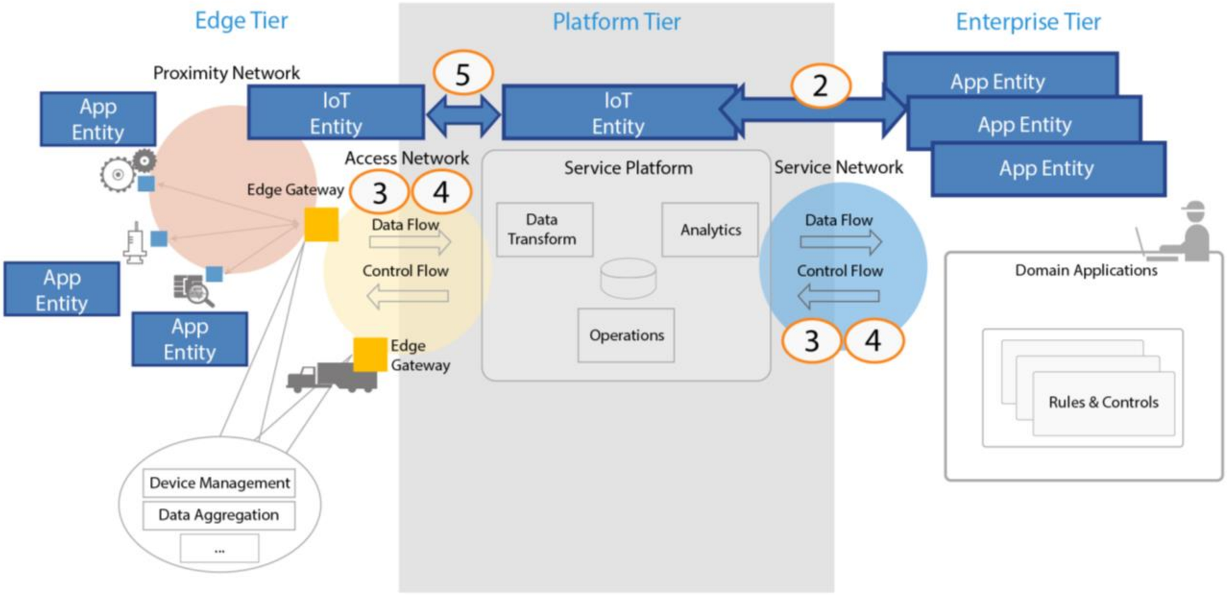


Figure 44. Aligning HLA and IIC three tier architecture [IIC Architecture, 2017; AIOTI HLA, 2018]

Reference architecture model for the Industry 4.0 is presented in Figure 38 [RAMI, 2018; NETIoT, 2018]. The mapping to the AIOTI HLA is also shown in the Figure 32 [AIOTI HLA, 2018]. It is not prepared in details. Data models are not presented. Southbound and northbound interfaces are not clearly shown in RAMI. However, RAMI architecture is well structured and covers different aspects of the domain as the one for smart grid [ETSI TR 103 290 V1.1.1, 2015] (Figure 45).

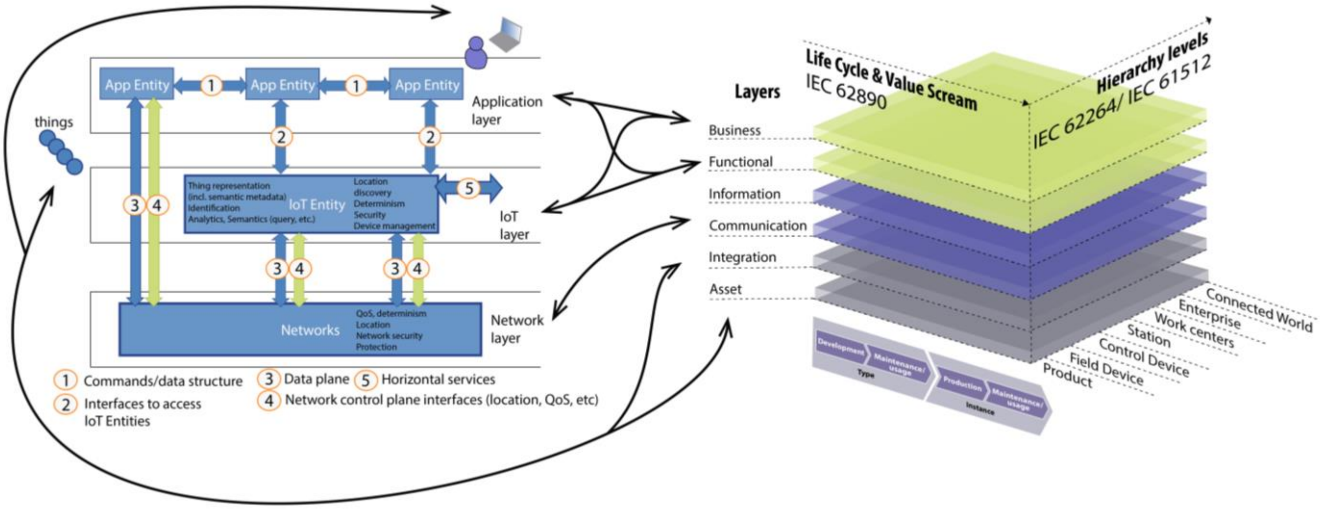


Figure 45. Aligning RAMI 4.4 and AIOTI HLA functional models [ETSI TR 103 290 V1.1.1, 2015]

It could also be easily adopted to the smart water by ETSI based on ontology definition providing a basic ground for the data modelling, sharing, harmonisation.

ETSI adopts many oneM2M standards including ontology specifications as seen in Figure 46 [ETSI TS 103 264 V1.1.1, 2013]. This process allows easy integration between different devices and smart meters information, easy data sharing keeping in mind the features of the devices and data dependencies. The aim is to reach interoperability and integration at southbound interfaces and dew computing level. Ontology aligning creates a circumstance for micro and macro services definition.

Ontologies and UML class charts are a matter of intensive technological aligning too. When this process will be automated completely the resulting formal specifications will be a ground base for further data sharing and interoperability between platforms.

The SAREF ontology has been initially created for home appliances and is now extended to different domains [ETSI TS 103 264, 2013]. The example presented in Figure 47 is related to a sensor and its data representation [SAREF Ontology, 2017].ETSI issued many extensions of SAREF that are related to smart cities, smart industry and smart agriculture [ETSI TS 103 410-4, 2019; ETSI TS 103 410-5, 2019; ETSI TS 103 410-6, 2019]. The details that are related to the water sector including meters are only mentioned in the standards. There are many other sectors that need to be also supported like environment, health, home automation etc. SAREF extension on water management is under intensive work at the moment of issuing this analysis.

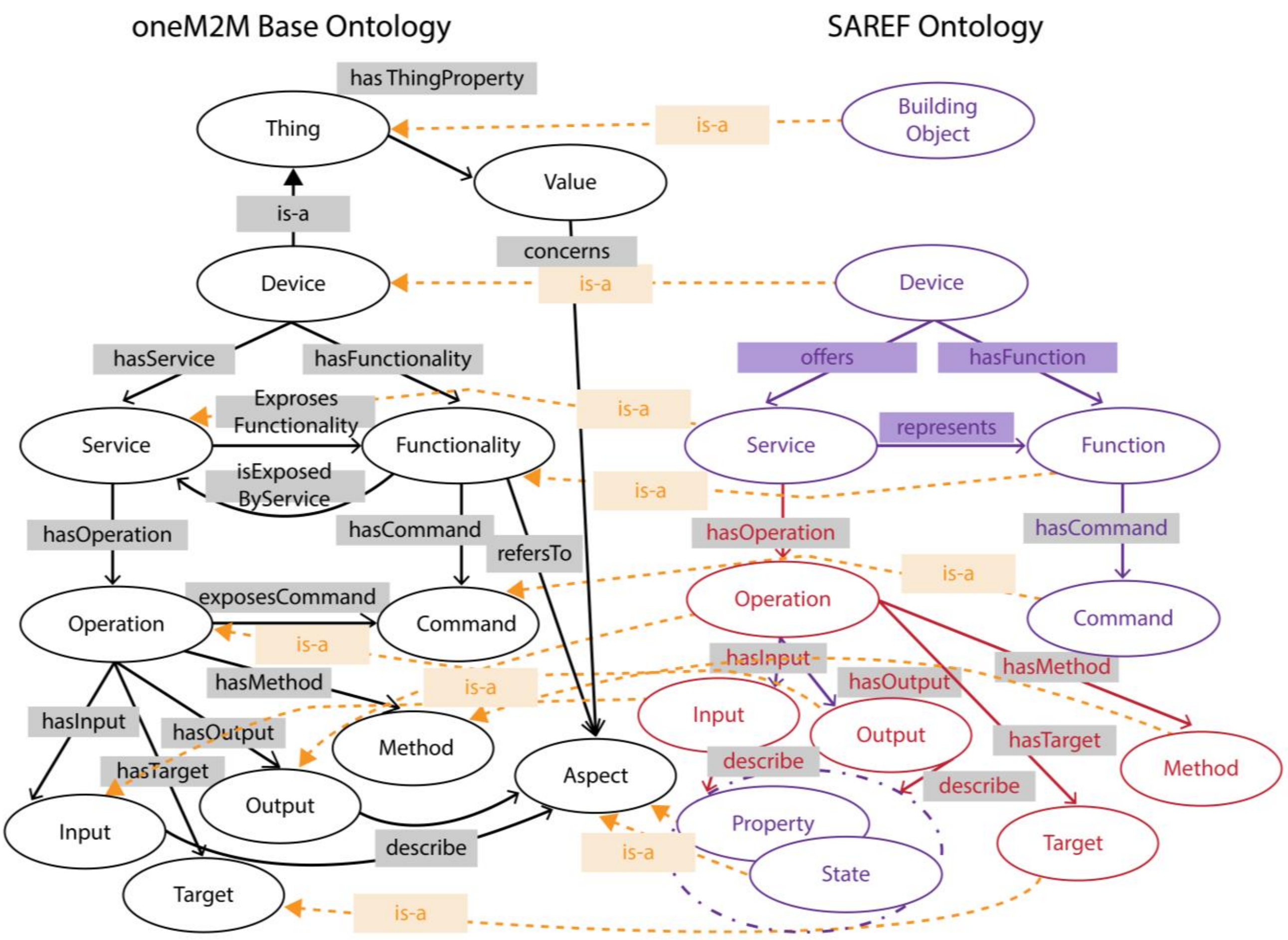


Figure 46. Aligning of ETSI SAREF and oneM2M base ontology [ETSI TS 103 264, 2013]

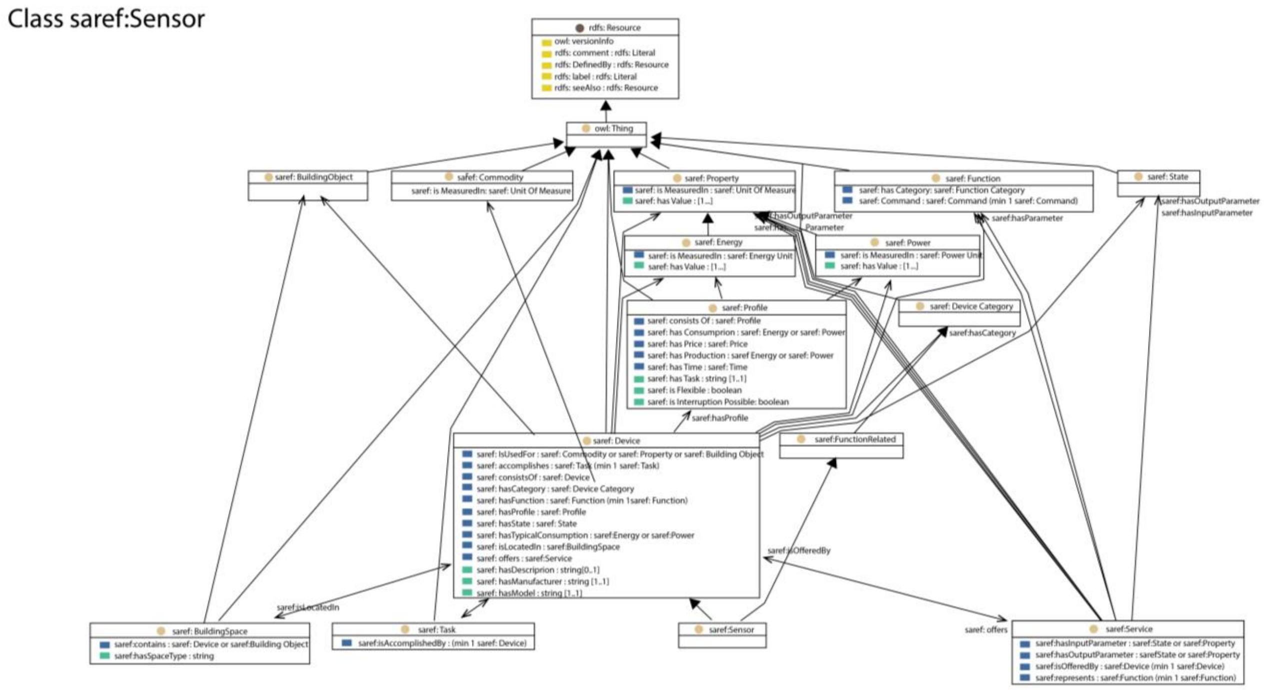


Figure 47. SAREF ontology. Example of a sensor [SAREF Ontology, 2017]

6. Proposals for Digital Single Market for Smart Water Services Action and Rolling Plans

The analyses presented result in proposals for the action and rolling plans for ICT for water management aiming to support the Digital Single Market in the entire Europe and beyond. The creation of a common generic smart water platform similarly to the smart grid solution is becoming important at European level. The use-cases presented in this document are a good starting point. The main recommendations towards the water sector's ICT part in the Rolling plan could be summarised as:

- The defined architectures for smart water management have to be interoperable with the architectures for smart cities, industry, agriculture, home and health with well-defined southbound and northbound interfaces.
- The requirements of the end-users and stakeholders need to be identified and specified.
- The end-users and stakeholders have to be profiled, i.e. classified with abstracted data and functionality.
- **Data sharing between platforms should be based on ontologies and further standardised to allow easy integration and interoperability.**
- Micro or atomic services need to be identified and specified continuously based on the end-user requirements and market development.
- Macro services should be identified and developed based on the market needs.
- Anything-as-a-Service and Water-as-a-Service need careful analysis and aligning in the future cyber-physical synergetic systems.
- Platform cloudification could be defined at different scale, i.e. smart dust, dew, fog, cloud computing stage depending on the region and community of implementation.
- Smart water management platforms should be open and go beyond IoT, 5G, big data, artificial intelligence, machine learning.
- Procurement and design principles of the smart water platforms need to be reusable and clearly based on the standard solutions.
- The identified standards' gaps aim to allow a smooth convergence from existing to the new technologies and platforms.
- New methodology is expected to map and consolidate existing and future smart water platforms and standards in the right direction.

7. Gaps and priorities

Gaps and priorities in standardisation are classified in three groups, i.e. short, medium, and long terms or 2, 4 and 6 years accordingly.

Short Term Standardisation Gaps

(2 years)

1. Extension of SAREF for smart water management based on experience in smart water and smart cities.
2. Speeding up of mapping between ontologies coming from different standardisation players.
3. Looking at possibilities to define data sharing at southbound and northbound interfaces at ontology level.
4. Definition of the synergetic approach towards platform integration and interoperability. Analysis of the integration level towards existing platforms.
5. Definition of use-cases for standard development and verification based on the running projects as existing pilot implementations.
6. Analysis of the efficiency and effectiveness of the proposed standards in different scales. Analysis of the possible replicability of the solutions. Selection of more than ten use-cases per specific smart water implementation as part of the standards.
7. Identification of the risks and increasing of the citizens awareness through appropriate licencing locally, regionally and globally.
8. Analysis and harmonisation of the licensing process of the water suppliers at European level.
9. Identification of all smart water management players, classification of the needs and contractual requirements that could support the procurement process.
10. Initial definition of data collection, harmonisation and processing related to the end-users and stakeholders. Mapping between SAREF and BDVA ontologies.
11. Selection of a list of standards to be applied in all new smart water projects in EU Member states.

Medium Term Standardisation Gaps

(4 years)

12. Adoption and reuse of all standards applicable to smart cities and environment to the smart water management. This process needs to cover the findings and work done worldwide.
13. Mapping of ICT-based smart metering standards and ICT-based hydrogenic metering standards together with smart agriculture and smart wastewater standards. Attention to the industrial standards to be paid as well.
14. Definition of sensor-to-cloud-to-service solution. Attention to the communication and information parts needed. Smart grid architecture customisation for the water and wastewater management is one possibility.
15. Definition of possible protocols, southbound, northbound interfaces, micro and monolithic services.

16. Mapping of micro and monolithic services to KPIs and SLA.
17. GDPR relevance of the existing solutions and definition of a strategy for better support.
18. Clear view of legacy platforms integration

Long Term Standardisation Gaps

(6 years)

19. Cloud level integration through northbound interfaces and ontology-based data exchange through APIs.
20. Cloudification of platforms at fog, dew and smart dust computing levels.
21. Mature definition of data collection, harmonisation and processing related to the end-users and stakeholders. Aligning between SAREF and BDVA ontologies.
22. Definition of a synergetic approach at local, regional and global level.
23. Hydrogenic platform globalisation through satellites and using local sensor technologies.
24. Definition of cross-domain services at local, regional and global level.
25. Aligning smart water standards with ICT-based standards while looking for Digital Single Market in all EU Member states.
26. Identification of all smart water standards necessary to support the water in circular economy in small, medium and big scale.

8. Conclusions

Smart water management is a challenging task for all players within the next decade. The critical mass of smart devices in the infrastructure allowing identification of existing and future services in the cloud, implementation of IoT and big data analysis could not be reached without investments at all technological levels. The definition of the Water-as-a-Service micro and macro services at cloud level could not be achieved without standardised data flows and data sharing capabilities. The level of water service awareness for different actors and the transparency level of the water related information is far from the end-user requirements. Furthermore, the classification and profiling of the end-users and stakeholders is not standardised and could not be used in smart water service validation. The distinction between Anything-as-a-Service and Water-as-a-Service is not clearly defined.

The architecture that is interoperable to the smart cities, smart agriculture, smart environment, smart industry, smart home, smart health, smart marine and smart domain in general with well-defined southbound and northbound interfaces is still not well specified. Cloudification at different scales, i.e. smart dust, dew, fog, cloud computing including clouds integration is not considered seriously. Finally, the integration with existing legacy solutions and solutions beyond IoT, 5G and big data analytics are not described well.

Data sharing and data modelling based on clear ontology at European level could speed up the innovations and technological solutions towards all presented gaps. This could be solved by SAREF extension for smart water services and smart metering devices by ETSI and CEN/CENELEC respectively [Danielle at al., 2018]. Selected 50 use-cases are a good approach towards the standardisation process where definition of the generic features of the platforms might be demonstrated through examples. The policy of the European Commission towards smart water ontology and business processes standardisation in the framework of Digital Single Market may lead to market harmonisation and fairness.

9. List of Abbreviations and Terms

3GPP - 3rd Generation Partnership Project

AaaS - Anything-as-a-Service, IoT related micro and/ or macro services at cloud, fog, dew, and smart dust computing

ABM - Agent Based Modelling

AIOTI - Alliance for the Internet of Things Innovation

Anything-as-a-Service (AaaS) – IoT related micro and/ or macro services at cloud, fog, dew, and smart dust computing

AOP - Advanced oxidation processes

API – Application Programmable Interface

ARM - Architecture Reference Model

Atomic (micro) services – Services that support the process of data collection from different proprietary and standardised platforms through different APIs and are based on different interfaces and protocols. They also may support specific functionality provided by the cloud.

BDVA - Big Data Value Association

BES - Bioelectrochemical Systems

BF - Bank Filtration

BI ETL – Business Intelligence, Extract, Transform and Load

BSI - Big-Scale Implementation

CDP - City Digital Profile

CEN/CENELEC – European Committee for Standardisation/ European Committee for Electrotechnical Standardisation

CENTAUR - Cost Effective Neural Technique for Alleviation of Urban Flood Risk

CIM - Context Information Management

Circular principle – The term for use and reuse of water without or with limited wastewater in the closed environment. For example, during the long trips in the space the water should not be lost.

Circular economy – This is the economy having complete water cycle limiting the wastewater.

CityGML – City Geography Markup Language

CPS - Cyber-Physical (also styled cyber-physical) System

CW - Constructed Wetlands

DAF - Dissolved Air Flotation

DER - Distributed Energy Resources

Dew computing - distributed cloud at local level

DG CONNECT - Directorate-General for Communications Networks, Content and Technology

DNA - Deoxyribonucleic acid

DNP - Distributed Network Protocol

DSF – Demand Side Flexibility

DSM – Digital Single Market

DSP - Digital Social Platform

DSS – Decision Support System

EC – European Commission

EIGR - European Inventory of Groundwater Research

EIP – European Innovation Partnership

EIP SCC – European Innovation Partnership on Smart Cities and Communities

ENVI – Environment Council

ERP - Enterprise Resource Planning

ESA - European Space Agency

ESOs - European Standardisation Organisations

ETSI – European Telecommunication Standardisation Institute

EU – European Union

EUREAU - European federation of national associations of drinking water suppliers and wastewater services

FIWARE - Open Source Platform for Smart Digital Future

Fog computing - distributed cloud in different regions

GCS - Global Control System

GDPR - General Data Protection Regulation

GIS – Geographic Information System

GNG - Greenhouse gas

GWD - Groundwater Directive

HRC-SYS - Hydrogeological Research Classification System

ICT – Information and Communication Technologies

ICT4Water – ICT for Water

IEC - International Electrotechnical Commission

IGO - International Governmental Organisations

IIC - Industrial Internet Consortium

INSPIRE - Infrastructure for spatial information in Europe

IoT - Internet of Things

ISG CDP - Industry Specification Group "City Digital Profile"

ISO - the International Organisation for Standardisation

ISP - Internet Service Provider

ITU – D - International Telecommunication Union – Development sector

ITU – T - International Telecommunication Union – Telecommunication sector

JSON – Java Script Object Notation

KEE - Knowledge Elicitation Engine

KPIs - Key Performance Indicators

M2M – Machine-to-Machine

MaaS – Marketplace-as-a-Service, transparent use of the market instruments regardless of the time and place

MaaS - Machines-as-a-Service, transparent use of devices through the platform regardless of the time and place

Macro (monolithic) services – Services that support stakeholders and end-users at application layer and are possibly composed by micro services.

MAR - Managed Aquifer Recharge

MEMS - Micro-Electro-Mechanical Systems

Micro (Atomic) services – Services that support the process of data collection from different proprietary and standardised platforms through different APIs and are based on different interfaces and protocols. They also may support specific functionality provided by the cloud.

MODIS - Moderate Resolution Imaging Spectroradiometer

Monolithic (macro) services – Services that support stakeholders and end-users at application layer and are possibly composed by micro services.

MSI - Medium-Scale Implementation

NBS - Nature Based Solutions

Nexus – Interconnection between the water, land, food, energy, and climate solutions taking into account also the complexity and feedback

NGO - Non-Governmental Organisations

NGSI - Next Generation Service Interfaces

NIS – Network Information System

NIST - National Institute of Standards and Technology

Northbound interface – high level interface of the IoT and cloud platform

NSBs - National Standardisation Bodies

OASC - Open & Agile Smart Cities

OAT – Observation and Analysis Tool

OGC - Open Geospatial Consortium

OLE - Object Linking and Embedding

OMP - Open Management Platform

OPC - OLE for Process Control

PCP - Pre-Commercial Procurement

pH - scale used to specify how acidic or basic a water is

POWER - Political and sOcial awareness on Water EnviRonmental challenges

PSA - Protocol Standards Association

RAMI – Reference Architecture Model Industrie

Redox - reduction–oxidation reaction

RESTFUL API – Representational State Transfer API

RRI - Responsible Research and Innovation

RSS - Really Simple Syndication

RTC - Real-Time Control

RTWQM - RealTime Water Quality Monitoring

RZ - Reference Zones

SAREF - Smart Appliances REFerence

SCADA – Supervisory Control and Data Acquisition

SDOs - Standards Development Organisations

SLA – Service Level Agreement

Smart dust computing - distributed cloud at controller level

SME – Small and medium-sized enterprise

SNRA - Sensor Network Reference Architecture

Southbound interface – edge level interface in IoT platform

SPACE-O - Space Assisted Water Quality Forecasting Platform for Optimised Decision Making in Water Supply Services

SSI - Small-Scale Implementation

SWM – Smart Water Management

SWS - Subsurface Water Solutions

TC – Technical Committee

UML – Unified Modelling Language

USA – United States of America

W3C - World Wide Web Consortium

WaaR – Water-as-a-Resource. Water identification as a resource at different water distribution level.

WaaS – Water-as-a-Service. Micro and/ or macro services at cloud, fog, dew, and smart dust computing levels as well as the level of water awareness for different actors and the transparency level of the water related information.

WAIS - Water Information System

WFD - Water Framework Directive

WG – Working Group

Wi-Fi - radio technologies for wireless local area networking

WITS - Water Industry Telemetry Standards

WR - Water Reuse Effectiveness

WSS - Water Supply Systems

WUE - Water Usage Effectiveness

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European Commission
European Catalogue of ICT Water Standards and Specifications
Luxembourg, Publications Office of the European Union
2020 – 128 pages

This study was carried out for the European Commission by Rossitza Goleva, New Bulgarian University, Bulgaria

with acknowledgement to Svetoslav MIHAYLOV (DG CONNECT) for his contribution and support

ISBN: 978-92-76-17850-7

Catalogue No: KK-03-20-234-EN-N

doi: 10.2759/39178