Emerging Topics and Technology Roadmap for Information and Communication Technologies for Water Management

August 2016

Executive Summary

The document is based on the deliverables of the ongoing and finished project grouped in ICT4Water cluster, ICT4Water Cluster report on Recommendations for Standards and Standardisation in the European SMART Water Market, Societal Challenges 5 (SC5) Expert Advisory Group Report and other documents listed in References section. Furthermore the output from the ICT4Water cluster in Jerez de La Frontera on June 17th, 2016 was taken into consideration.

The document presents the main gaps and challenges that need to be addressed in the future development of the ICT for water management sector. These can be summarised in six groups:

- Big data,
- Data Infrastructures,
- Links with smart cities,
- Water - food - energy nexus,
- Standardization,
- Lack of reliable field trials.

The document finishes with a proposed roadmap. The conclusion is that the creation of a borderless Digital Single Market for water services should be preceded by creation of digital public-private partnerships (PPP) as an Innovation Hub that aims to foster innovative technology and entrepreneurial talent for water services.

The activities should contribute to:

1. Development of specifications for interoperability and data sharing across services and infrastructures.
2. Development of system standards for smart cities and communities solutions.
3. Creation of ecosystems of "Platforms for Connected Smart Objects", integrating the future generations of smart devices (i.e. sensors) and network technologies and other evolving ICT advances.
4. Initiatives on data ownership, free flow of data and on a European Cloud.
5. The establishment of a pan-European standard on water management systems.
6. Development of Water Audits across EU.
7. Contribution to Water-Food-Energy Nexus and Smart Cities interactions.
8. Development of new framework methodology for measuring the environmental impact of ICT.
9. Provide a market analysis of a water industry in terms of current and foresight integration of ICT solutions and systems

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1. Approach and History

This document stems from the previous ICT4Water for Water Management Roadmap, delivered in 2015, and is also the result of the cluster meeting that have been held on June 17th, 2016.

The previous version of the *Emerging Topics and Technology Roadmap for Information and Communication Technologies for Water Management* document identified the main actors, challenges, issues and gaps in the usage of ICT for water management, as well as a list of emerging topics and technology challenges, which resulted in the final technology roadmap being proposed.

The current version is based on the deliverables of the ongoing and finished EU funded projects, grouped in ICT4Water cluster, ICT4Water cluster report on Recommendations for Standards and Standardisation in the European SMART Water Market, Societal Challenges 5 (SC5) Expert Advisory Group Report and other documents listed in References section. Furthermore the output from the ICT4Water cluster in Jerez de La Frontera on June 17th, 2016 was taken into consideration. The final document was compiled by Marcin Stachura.

1.1. ICT4Water cluster

ICT4Water is a cluster of ICT and water management projects, all co-funded by the European Commission. Their common goal is to increase efficiency in water management and enable greater cooperation among water regulators, operators and users by developing innovative products and services based on Information and Communication technologies (often referred to as SMART technologies). Many of the projects are focused on exploiting the opportunities for greater efficiency in the delivery and use of water by the utilities, industry and households; these opportunities have been created by the advent of SMART metering. All have the consideration of standards as part of their terms of reference.

The ICT4Water cluster is made up of ten FP7 projects (DAIAD, EFFINET, ICeWater, ISS-EWATUS, iWIDGET, SmartH2O, UrbanWater, WATERNOMICS, WatERP, WISDOM) and ten Horizon 2020 projects (BlueSCities, FREEWAT, KINDRA, WaterInnEU, WIDEST, CYTO-WATER, POWERSTEP, iMETland, SUBSOL, CENTAUR). The individual participants within these projects collectively represent all the potential players in a SMART water market place and range from global companies such as IBM and SAP, utilities large and small, SME's, developers and added value resellers onto government research organisations and universities listed in the top 100 of The Times Higher Education World University Rankings 2015-2016

2. Current trends

This first report, conducted by WIDEST project, regarding technology trends and commercial developments has analysed several institutions, including universities, research centres, associations and private companies. As this is the first iteration of this analysis, it has been focused on the members of the consortium of each ICT4Water cluster project. For each institution, a search regarding its research interests and fields of activity has been done, mainly consulting online resources, and especially their corresponding main websites. Hence, the information here presented may differ from the actual role the member has in its participating project, as it has been based in the public available information. The information collected has been exclusively obtained from public and open websites. When possible, the information has been focused on the concrete department or secondary company, instead of focusing in the generic one, or group, or University. Thanks to that, the results are closer related to the intentions of this report. When no information has been found, the partner has been linked to activities related to the project, making use of available project related information.

Figure 1. Technology trends word cloud[1]*.*

Following with the analysis, the above figure depicts the more frequent words used in the "personal" description of research interests and activity fields. It has to be taken in consideration that this field is open, and freely described by each institution. However, there are no surprises in the results, where **water and management have a key role**. Other important technology trends include the words quality, resources, environmental and

[1] WIDEST D1.6 Reports containing Analysis of commercial developments and technology trends 1st release

treatment. This is also an expected outcome, as many efforts are focused on assuring quality of water, improving water treatment, optimizing resources and environmental regarding issues.

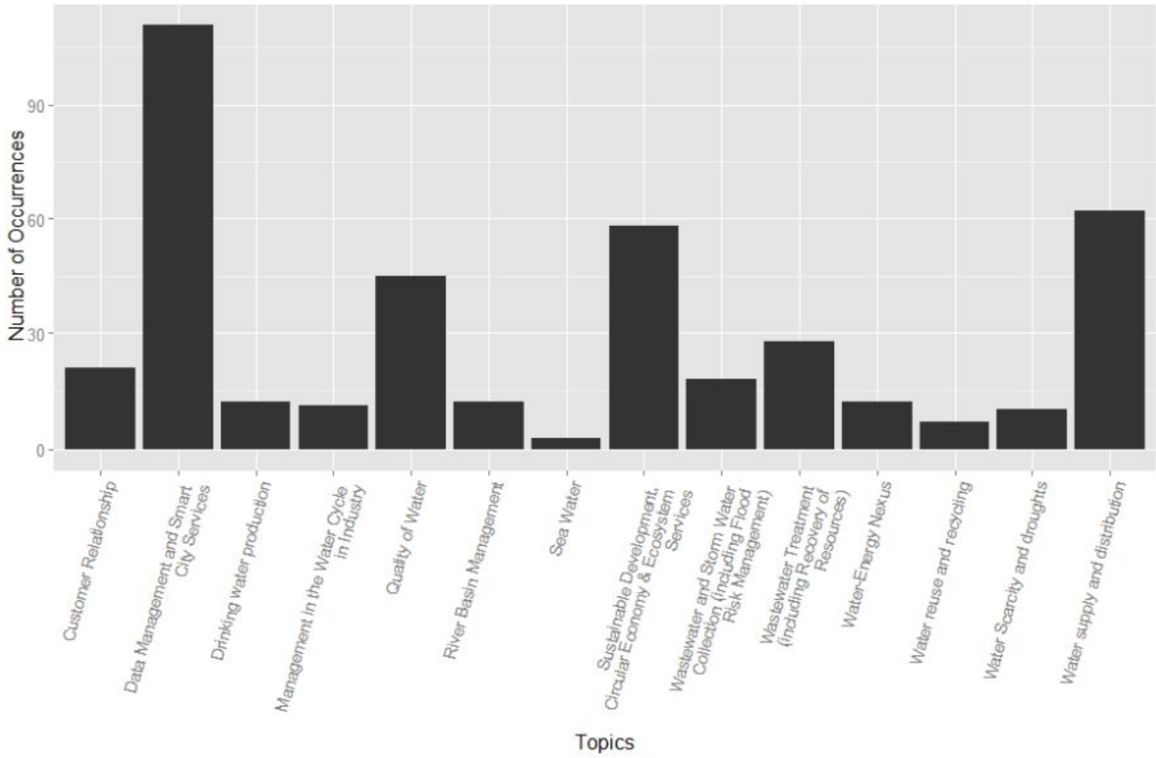

Figure 2. Topic frequencies in technology trends[2].

As can be seen in the above figure, the more important trends are related to "Data Management and Smart City services", "Water supply and distribution" and "Sustainable development, circular economy and ecosystem services". From these results, the importance of data management has been made evident. Current technologies regarding sensor data, semantic tagging and big data analytics reinforce this topic. What is more, in most cases it will serve to Smart City's necessities. Moreover, water supply and distribution is one of the major concerns in the sector, smart monitoring and leakage controls are basic in modern infrastructures. Finally, the "Sustainable development, circular economy and ecosystem services" topic is also on top topics. This can be explained by understanding the importance of how the necessity to accomplish with limitations and trying to make good use of each available resource. Ecosystem services are reinforced by the fact that several projects have consultancy institutions to improve project management and provide policy advice.

[2] WIDEST D1.6 Reports containing Analysis of commercial developments and technology trends 1st release

3. Identification of stakeholders, current gaps, and challenges

3.1. Stakeholders

ICT4Water cluster identified the stakeholders as a broad set of actors which includes all the organisations and people who are conceiving, researching, financing, designing, developing, manufacturing, selling, buying, reselling, regulating and using the ICT products and services. In practical terms they are:

- Academics,
- Government research laboratories,
- Entrepreneurs and venture capitalists,
- Software and hardware developers,
- Communications companies,
- Sensor manufacturers and installers,
- Value added resellers,
- The utilities, regulators and their agents, usually consultants, and
- Water users both industrial and domestic.

3.2. Current Gaps and Challenges

Based on the available information and experience from ongoing projects, the set of gaps have been identified. This list of gaps is based on the structure provided in the previous roadmap. It is expected that some of these gaps should be covered by future projects.

3.2.1. Big Data

The achievement of a functional digital market will be conditioned by ensuring **a free flow of data** and by appropriately tackling issues such as **data ownership**, **interoperability**, **usability** and **access to data** in situations such as business-to-business, business to consumer, machine generated and machine-to-machine data. We also need to work to make rules around data use and reuse.

Some examples that can be viewed in the flood management domain with maps, weather data, satellites images, hydrological and meteorological (GCM) models. There is a need to store the data for the future which means that there is a need for Big data.

Today, thanks to the low prices of hardware devices and the fast adoption of the Internet of Things (IoT) paradigm that implies sources of information in almost any asset in

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infrastructures, all organizations have the possibility to be connected to their customers and partners every minute of every day.

With that connectedness comes exploding volumes of data, of greater variety and at a greater velocity. These flows are so large that they define a new category: Big data. Water systems are being sensorized and **generate very large amounts of data with high variety of data formats** from different sources such as pressure sensors, flow sensors, meters, quality sensors, SCADA systems, all in real-time.

The large captured data offers tremendous potential for deep insights that support smarter decisions and increased revenue. Big Data Data Analytics also permits to **enhance water management**, e.g. to provide smarter advising on the operation of water network infrastructures by **applying machine learning techniques** over historically and real time data (see the example of WatERP project). In addition, Big Data technology helps to **overcome** the barrier settled by **climate change over data collected** during 20th century (data no longer valid due to climate changes over multiple regions). Thanks to Big Data, large amounts of information can be collected (renewed) in a short time again. It has to be noted, that more than 90% of the world's data available has been collected in recent years thanks to the use of Big Data techniques.

How can businesses benefit from these information flows? How can they harness Big data to generate new insights quickly and cost-effectively, while building off their existing information management approaches and strategies?

The difficulties include obtaining utility and householder consent and participation, **data protection issues**, the cost of instrumentation and communication for one off case studies, achieving the high frequency of monitoring and data collection required and the absence of standards, especially standard interfaces, which make it **difficult to link components**.

Labeled Water Consumption data

Inducing sustainable changes to water consumption from individual consumers strongly depends on the timeliness, accuracy, and locality of the provided interventions. Real-time feedback offered at the point of consumption, as well as diagnostic information after a specific consumption event has ended, require knowledge about **who, when, and where** consumed water, i.e. access to detailed data per water fixture. Smart water meters only provide a piece of the missing data, monitoring aggregated consumption at the household level and transmitting this information at periodic intervals. Given the real-world constraints of increasing the data monitoring and transmission granularity of smart water meters (i.e. **reduction in battery life and significantly increased operation costs**), the missing information on a household level can only be produced by disaggregating the total water consumption.

The challenge of devising effective disaggregation algorithms and thus more powerful interventions for water efficiency, lies within the difficulty of collecting labeled water consumption data at the fixture level. These would allow researchers to train, improve, and validate disaggregation approaches that fill-in the missing data on a household setting. Labelled water consumption data have been produced in the context of international R&I

projects, at a significant effort and cost. However, these studies and data are not transferable in an EU setting, as the characteristics of water consumption (e.g. habits, types of water fixtures, water monitoring equipment) are extremely location-sensitive. A concentrated effort should be performed to **develop a study protocol**, as well as produce a representative collection of EU-wide labelled **open water consumption data**, spanning a significant period in time (18-24 months), population, water fixtures and markets.

3.2.3. Data Infrastructures

Many European businesses, including water stakeholders, research communities and public bodies are yet to tap into the full potential of data and of its potentially transformative effect on traditional sectors and on the way research is conducted. Data coming from publicly funded research is **not always open**; likewise data generated and / or collected by water sector is **often not shared**, and not always for commercial reasons. Some **data is shared after a large request protocol**, and consequently this is not useful for near real time modelling. Reasons include the lack of a clear structure of incentives and rewards for data sharing (mainly in academia), of a clear legal basis, including privacy concerns (mainly in the public sector) and the shortage of data-related skills and lack of recognition of their value (in all sectors). The reticence of costumers to adopt technological advances (e.g http://stopsmartmeters.org/) is also an issue.

The EU data protection framework prevents restrictions to the free movement of personal data on the grounds of privacy and personal data protection. **Lack of interoperability** prevents addressing grand societal challenges that require efficient data sharing and a multidisciplinary or multi-actor approach. Many data sets remain unavailable to scientists, public administrations and policy makers. Sharing research data is also hampered by the size of datasets, its varied formats, the complexity of the software needed to analyse it. **Data infrastructures are split** by scientific and economic domains, by countries and by governance models. Access policies for networking, data storage and computing differ. Disconnected and slow data and computing infrastructures hinder scientific discovery, create silos and slow down the circulation of knowledge. Furthermore, from citizen point of view, it is not clear how data sharing can enhance or benefit their day to day life.

3.2.5. Link with the Smart Cities

Cities host more than 70% of Europe's population, consume 75% of global energy and emit 80% of greenhouse gases generated by human activity. They are also the home of problems related to health, social cohesion, and immigration. At the same time, cities are the places where capital investments, high productivity and high-skilled persons and jobs are located and are therefore key players in providing solutions to these challenges. The critical role of cities in addressing these global challenges as well as the essential role of Research & Innovation in developing new solutions have recently been acknowledged in all international policy fora (e.g. Paris Agreement, Habitat III Global Urban Agenda, UN SDGs) as well as the EU Urban Agenda. At the same time, cities have globally declared their readiness to engage actively in designing and rolling out actionable strategies and transition trajectories towards sustainable, low-carbon, climate-proof and resource efficient futures, in line with the EU priority 'Energy Union and Climate'.

In urban areas a large amount of **energy consumption is associated with delivering municipal drinking water**. Moreover, sources of energy from mines, use of hydropower, and the common practice of producing power with boilers and cooling systems all require water. Likewise, the **extraction, transmission, treatment and distribution of water are all highly energy dependent**.

A Smart Water Network **is not simply an individual system that optimizes a network's efficiencies** but rather a means of **linking together multiple systems** within a network to share data across platforms. This way of thinking in the Water Distribution Network as a set of systems that can work independently but that provide a high degree of connectivity (and interoperability) has changed the paradigm, leading to the concept of Systems of Systems and becoming a suitable tool to foster the Smart City concept, as Smart Energy Grids are doing. WatERP Project is a good example of interoperability among systems. In WatERP different modules such as meteorological forecast, demand forecast and pump management tools are managed in an holistic manner and integrated through interoperability framework to **increase over a 10% the efficiency in Water Distribution Networks**.

Cities are resource-intensive environments. The **limited availability of water, energy and other resources**, and the high costs of city infrastructures demand a critical analysis of the relationships between water and waste with energy, transport and ICT in their regulatory and operational contexts. The **total cost of ownership for Water ICT** systems throughout the water value chain remains a significant challenge, being an entry barrier for water utilities with regards to accurately monitoring and understanding water use and demand.

The following topics were identified to be required to be improved (especially in regulatory aspects): **management systems for water – energy optimization, smart alarm for management of floods, citizen awareness on water**.

To tackle the challenges of water in the city it is necessary to take numerous aspects, interests and actors into account. These can be brought together under the heading of water governance. Good governance is the real challenge. Governance is the range of political, institutional and administrative rules, practices and processes (formal and informal) through which decisions are taken and implemented, stakeholders can articulate their interests and have their concerns considered, and decision-makers are held accountable for management. There is a **need to provide technologic tools for the intercommunication of information among systems within Smart City**.

The wide variation in the way cities deal with their water, wastewater, solid waste and climate adaptation offers key insights for **improving their resilience and sustainability.** These challenges are too often not taken up, because people are waiting for new technological breakthroughs and fail to make use of existing knowledge and technologies. Therefore, there are probably two necessary steps to make our cities more sustainable and resilient:

1. Cities can learn from each other, provided they make that knowledge available and actively share it (city-to-city learning). Through cooperation and by applying best practices it is possible to make great progress in improving their sustainability and resilience.
2. Given the megatrends and challenges in cities, existing technologies may not always suffice. Therefore there will always still be a role for new technologies which could gradually be introduced and for which the options should be left open.

3.2.4. The water-food-energy nexus

In the context of growing scarcity of natural resources and raw materials, increasing interconnectedness across various economic sectors and pressing needs for climate change mitigation and adaptation measures, a comprehensive understanding of the linkages and **interdependencies across the water, food and energy sectors** together with the environmental, economic, social and political drivers needs to be developed. This will also conciliate resource efficiency and sustainable production and consumption with the imperatives of a resilient EU energy and forward-looking climate change policy. A nexus approach and a **solutions-oriented Research and Innovation** strategy that addresses resource interdependencies and crosses policies, disciplinary, institutional and cultural boundaries will allow for the development of novel and mutually beneficial solutions, sound management of trade-offs and synergies between sectors.

In the context of investigating the nexus between food production and water management, in a survey performed in the FREEWAT project (*Deliverable 6.1 - Evaluation of needs and priorities with software capability for water management issues*), the **development of ICT simulation** tools for **assessing the impact of agricultural activities on surface- and ground-water** (such as effects of irrigation and fertilizer management on surface and groundwater quality) was perceived as a priority among different stakeholders (research, water authorities, companies). While in the urban context, several solutions are already available on the market, I**CT for water solutions in the rural domain are still limited**, thus presenting an opportunity for a potential new large ICT market not only for software solutions, but also for sensors.

By promoting the development and application of **digital systems** and future emerging technologies, which is a perquisite to allow the nexus approach to be fully implemented, this action contributes directly to the 'Digital Single Market'. It also contributes to the 'Energy Union and climate' priority, by providing insight to address the **necessary trade-offs between food, water, energy and industrial policies**. The global dimension of this nexus makes this area a strong contributor to the 'Stronger Global Actor' and 'Open to the World' priorities, while also contributing to the implementation of the SDGs.

3.2.2. Standardization

One of the reason for the slowness of the market is the **absence of standards** in the water domain. One of the lessons learned, from EU funded WatERP project, is that by using current OGC standards it is possible to provide interoperability among different systems, but it requires the **participation of all stakeholders**.

As yet the emerging products and services are the result of **uncoordinated individual initiatives**. They do not join up and neither do their developers use a common terminology. Assembling a system from the available components has not yet reached the level of ease and reliability required by service providers and value added resellers for them to start setting up such services for end users.

The absence of standards is a major factor inhibiting the participation of public bodies. For them, following standards means they can demonstrate that they have endeavoured to follow best practice. This again highlights the importance of initiating action in this area now. The need for global data sets driven by climate change, the fact that many water issues are transboundary and the need to understand the earth as a system of interacting processes can only lead to stronger pressures for standards that will **make water datasets, tools and models implementations interoperable**.

There is a need for plant and networks **description guidelines** – to allow partitioning of the data based on their usage and their cost. Regarding ontologies, especially in the Asset Management area, one question is about the existence of a common language for people who have different views from very different business processes. Another question is about the capability to “navigate” inside this semantic model to see what the relationships are, what are the assets which are upstream or downstream in the network.

In spite of the above, the conclusions from the ICT4Water cluster’s meetings, which are supported both by the industry and the research partners, suggest that the new technologies and the products and services arising from them have reached the point where they can contribute to achieving the EC’s energy policy goals and that a market for their delivery could form. From experience within ICT4Water cluster projects and outside, it is clear that standards which **enable interoperability between products** (e.g. the definition of key terms and specification of connecting interfaces) will be of value to all the market players and will create further opportunities for innovation. **Lack of standardisation in the SMART Water Market is seen as one of the biggest obstacles** in realising the full potential that the adoption of this technology has in making SMART Water Networks standard practice.

EU-wide Domestic Water Audits

Water demand management from water utilities strongly depends on the availability of detailed water consumption data, which allow accurate forecasting and thus effective management of water resources to ensure demand is met within specified cost, quality, and security constraints. With only one in two water consumers metered in Europe, and at best with an aggregated knowledge of total water demand (ranging from 3 months to 1 day), water demand management is based on crude assumptions about consumers and their typical water uses. On an international setting, this **missing knowledge is partly provided from Water Audits**, i.e. in-situ studies of consumers, water fixtures, and typical water uses. Such studies provide data needed from water utilities, as well as goods manufacturers (e.g. faucets, washing machines) for anticipating demand and the parameters that influence it, the provision of water calculators, the targeting of retrofit and rebate programs for water efficiency, the tuning and calibration of water-related products for different markets, etc. Unfortunately, the **results of international water audits cannot be transferred in EU**, and not even between different countries in EU. This is a result of the highly localized and evolving water use profiles across different populations.

3.2.5. Lack of reliable field trials

Compared with other city **infrastructures the water industries are much more conservative**. This is because water is of core importance to a civil society and distribution down-times are not tolerated lightly. It is for this reason that water industries are not as fast as, say, some of the energy suppliers, in the uptake of leading edge technology.

In parallel sensing and control technologies are becoming more mature and are being used in anger in other fields from transport to precision agriculture. Yet with this maturity there is a **reluctance of water companies to take on board this technology as it is not tested in their domain.** That is, sensing and control technologies that use modern telemetry and computer networks **has not been tested on real water networks** and on pipes both over and underground with all the challenges those environments bring. Such technologies, which have great potential to provide step-changes in the sustainability of water resources, are relatively new and one cannot imagine stopping water distribution just so that experimenters can test equipment.

So therein lies the catch situation. Water companies are **reluctant to use modern technology** because it has not been tested on real water networks, and at the same time **researchers cannot test their technologies** on real water networks **because water companies cannot risk untested technology** being placed on the live water network.So the question is how we progress this situation? One way to do this is **to provide funding for large live water test-bed construction.** They need to mimic exactly the behaviour of a live water network so as to test and **provide trust to the water companies** that the new technologies with not disrupt the operation of their assets. Currently many water companies (such as Welsh Water in the WISDOM project) have reasonably sized test water rigs. However, there are a number of aspects they cannot test. These aspects require that the sheer size of the network is that of numbers of kilometres to mimic the vastness and scale of a real system. One cannot test data communication on a test rig for example (many are indoors too). A **multi-kilometre test facility** will enable new communications technologies to be tested in realistic (urban and rural) environments and this in turn will ultimately provide the scale and dimensional guarantees required by water companies to invest in water technology research earlier.

Finally, a funding programme that supports the build of such facilities should take the **different terrains of Europe** into account; from lush green countryside to dry desert like soil to dense cities etc. This is because such systems will behave differently in different terrains.

3.3. Challanges

ICT4Water Cluster indicated that the new SMART technologies can lead to more efficient delivery and use of water and hence a reduction in the demand for energy. Then in the context of standards and creating a marketplace the challenges are:

- Overcoming the absence of impracticability of running field trials by creating a standardised model of water delivery and use comparable in concept to national economic models;
- Adopting/developing water vocabularies and ontologies so that there is semantic clarity;
- Developing a common architecture for SMART water;

- Identifying/adopting/developing critical interface standards so that:
  - users can confidently and easily assemble systems from interconnecting,
  - components sourced from multiple suppliers,
  - barriers to new entrants joining the marketplace are reduced,
  - competition is increased,
  - new opportunities for innovation are created,
  - synergies and coordination among stakeholders can be improved,
  - easy connection and exchanging data and metadata between other sectors involved: geographical data, meteorological data, earth-observation data, citizen science data, etc… can be provided;
- Identifying where quality (accuracy, reliability, resilience, etc.) standards are required, especially in relation to attaining the EC’s objectives but also in relation to the formation of the market;
- Harmonising energy and water monitoring practices sufficiently that it becomes practical to demonstrate to users through the metering or billing system how their water use is impacting their energy use, thereby giving water users the incentive to be efficient;
- Setting up a governance structure, one of whose terms of reference would be the introduction of standards.
- At last, technology changes should end in better applications for customers and citizens in order to benefit their day to day life and contribute to raise the awareness over water constraints

4. Proposed roadmap

To optimise the use of resources and to create synergies between activities, special attention has to be given to designing projects and topics which address more than one activity, contributing to the good coverage of the specific programme. In order to bring a SMART water market into existence as soon as possible, the ICT4Water cluster recommends to take the following steps:

1. Either establish a working group or request an existing group with the funds for meeting to identify an initial set of standards for adoption, adaption or development that will facilitate the formation of a market.
   These standards should cover issues specific to the water domain. For each standard the group should identify where appropriate:
   a. An organisation willing to champion the introduction of the standard;
   b. The accreditation organisation which either has or will take ownership of the standard (e.g. ISO, IEEE, CEN, W3C, OGC, etc.);
   c. Funding for the standardisation process. The working group should then hand over to the champion who will set the process in motion and see it through to completion.
2. Seek advice on the options for market governance, select an option acceptable to the market participants and implement it with the proviso that the arrangement should be self financing within 3-5 years.
3. Establish a project to develop a standardised data simulation model which can simulate the delivery and use of water at scales ranging from an individual sensor through households and industries to regions to facilitate the evaluation of:
   a. SMART water technologies which contribute to the EC's aims,
   b. any proposed water and energy policy,
   c. new SMART water products and services and so overcome the present difficulties in mounting credible field trials (e.g. with data acquisition and capacity testing).

A suitable vehicle for the working group might be a Coordination and Support Action (CSA), an existing project such as WIDEST or a new group or funding scheme **specifically established for the purpose**.

Taking into consideration ICT4Water inquiry, the creation of a **borderless Digital Single Market** for water services should be preceded by creation of digital public-private partnerships (PPP) as an Innovation Hub that aims to foster innovative technology and entrepreneurial talent for water services. The Hub should be supported with a **significant funding** so as to foster the **transition of ICT technologies in water sector from pilot scale to wide market uptake**.

The activities should contribute to:

1. Development of specifications for interoperability and data sharing across services and infrastructures, building on existing initiatives such as the Research Data Alliance and the Belmont Forum and legal provisions such as INSPIRE. Over time, any emerging standardization needs will be addressed through the DSM Priorities for ICT Standardisation. This should be implemented as the formation of a cross-cluster strategy for targeting specific standards bodies and groups. List of Ontologies (Measures, Assets Description, Interventions, Customers …) and Abstract Data Models available by all ICT Vendors, with an extension to software solutions that apply. The ontologies might be based on already developed semantic tools, like WatERP, or WISDOM ontologies to overcome the existing gap regarding syntactic and semantic interoperability. Relationship between what and where is a key issue. It is crucial to:
    a. enforce companies for the use of ontologies over natural resources,
    b. provide open models and open data through interoperable platforms,
    c. incorporate ontologies in products and also in internal procedures and processes,
    d. provide an open repository where all ontologies are available and described with examples of use.
2. Creation of ecosystems of "Platforms for Connected Smart Objects", integrating the future generations of smart devices (i.e. sensors) and network technologies and other evolving ICT advances. These environments support citizen and businesses for a multiplicity of novel applications. They embed effective and efficient security and privacy mechanisms into devices, architectures, service and network platforms, including characteristics such as openness, dynamic expandability, interoperability, dependability, cognitive capabilities and distributed decision making, cost and energy-efficiency, ergonomic and user-friendliness.
3. Initiatives on data ownership, free flow of data (e.g. between cloud providers) and on a European Cloud.
4. The establishment of a pan-European standard on water management systems involving:
    a. information management systems based on open and commonly accepted standards,
    b. monitoring systems for water networks using state-of-the-art algorithms to minimize water
    c. losses because of leaks,
    d. control systems that minimize the energy needed for pumping while providing a desired quality-of-service in terms of satisfaction of water demand

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   e. a contamination detection system based on SMART measuring devices and algorithms that filter out false positives and reveal possible contamination events using available measurements

5. Development of system standards for smart cities and communities solutions. The process for developing smart cities and communities standards should ensure interoperability of solutions, i.e. adaptability of solutions to new user requirements and technological change as well as avoidance of entry barriers or vendor lock-in through promoting common meta-data structures and interoperable (open) interfaces instead of proprietary ones; open and consistent data, i.e. making relevant data as widely available as possible – including to third parties for the purpose of applications development – whilst using common, transparent measurement and data collection standards to ensure meaningfulness and comparability of performance/outcome measurements. Special attention have to be put into better real-time operations decision-support, improved customer relationships and communications, stormwater management, citizen involvement in infrastructure management, improvement of preparedness, response to flooding and management of conjunctive use of surface- and ground-water for water supply. The following, specific, actions are recommended:
   a. to work in the standardization of a high level ontology for Water Management,
   b. increase the awareness at regulatory level by acquiring opinions from experts in water domain and ICT,
   c. provide a long term regulatory strategy and advice relevant stakeholders about the adoption of smart technologies,
   d. provide semantic tools to assure interoperability among systems,
   e. provide backup communication networks for Smart City subsystems connection.
6. The challenge of increasing water efficiency in EU and minimizing water-stress risks, demands accurate, detailed, and periodic Water Audits across EU, emphasizing current and future water-stressed regions. The following actions are recommended:
   a. a jointly agreed protocol and process for designing, implementing, analyzing, and sharing Water Audits should be established on an EU level,
   b. the protocol should be tested and validated for heterogeneous populations groups in EU, geographical areas, as well as water utilities,
   c. a concentrated effort is also required to establish a clear pathway on how this data are applied in water demand management, as well as the relevant industrial sectors.

7. FAO has identified three working areas to identify, assess and manage Water-Food-Energy Nexus interactions, considering the impacts that any change – a policy decision, a large-scale investment or a change in agricultural practice – may have beyond the intended objectives and scale. The working areas are:
    a. evidence,
    b. scenario development, and
    c. response options.
8. Development of new framework methodology for measuring the environmental impact of ICT (including a cost/benefit analysis for companies) .
9. Provide a market analysis of a water industry in terms of current and foresight integration of ICT solutions and systems.

Table 1 makes a proposal of the set of activities that need to be addressed according to the above specified actions, identifying challenges in relation to activities. The activities are organized in terms of priorities (short, medium and long term).

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Table 1. Activities that need to be addressed, organized according to the level of priority

No	Activity	Challenges addressed	Short Term	Medium Term	Long Term
1	Development of specifications for interoperability and data sharing across services and infrastructures.	Adopting/developing water vocabularies and ontologies so that there is semantic clarity Developing a common architecture for SMART water			
2	Development of system standards for smart cities and communities solutions.	Overcoming the absence of impracticability of running field trials by creating a standardised model of water delivery and use comparable in concept to national economic models; Identifying/adopting/developing critical interface standards Identifying where quality (accuracy, reliability, resilience, etc.) standards are required, especially in relation to attaining the EC's objectives but also in relation to the formation of the market			
3	Creation of ecosystems of "Platforms for Connected Smart Objects".	Harmonising energy and water monitoring practices sufficiently that it becomes practical to demonstrate to users through the metering or billing system how their water use is impacting their energy use, thereby giving water users the incentive to be efficient			
4	Initiatives on data ownership, free flow of data	Users can confidently and easily assemble systems from interconnecting			
5	The establishment of a pan-European standard on water management systems.	Setting up a governance structure, one of whose terms of reference would be the introduction of standards			
6	Development of Water Audits across EU.	Increase water efficiency in EU and minimizing water-stress risks, demands accurate, detailed, and periodic Water Audits across EU, emphasizing current and future water-stressed regions			
7	Water-Food-Energy Nexus interactions.	Harmonising energy and water monitoring practices sufficiently that it becomes practical to demonstrate to users through the metering or billing system how their water use is impacting their energy use, thereby giving water users the incentive to be efficient			
8	Development of new framework methodology for measuring the environmental impact of ICT.	Technology changes should end in better applications for customers and citizens in order to benefit their day to day life and contribute to raise the awareness over water constraints			
9	Provide a market analysis of a water industry in terms of current and foresight integration of ICT solutions and systems.				

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5. References

European Cloud Initiative - Building a competitive data and knowledge economy in Europe

WIDEST D1.6 Reports containing Analysis of commercial developments and technology trends 1st release

ICT4Water Cluster report on Recommendations for Standards and Standardisation in the European SMART Water Market

The Water-Energy-Food Nexus: A new approach in support of food security and sustainable agriculture

KINDRA D2.3. Compendium of best practices for water, waste water, solid waste and climate adaptation

2016 Rolling Plan on ICT Standardisation

WaterInnEU D5.1: Compendium of available standards

WatERP D1.2 Generic Functional model for water supply and usage data

WatERP D1.3 Generic Ontology for water supply distribution chain

WatERP D7.1.1 Holistic Auditing

WIDEST D1.2 Report on Smart Water Community Group monitoring

WIDEST D4.2 Stakeholder participation report 1st version

WISDOM D2.2 Water semantic Models (Final Version)

FREEWAT D6.1 Evaluation of needs and priorities with software capability for water management issues