Emerging topics and technology roadmap for Information and Communication Technologies for Water Management

June 1st, 2015

Executive Summary

This document stems from the previous ICT for Water Management Roadmap, delivered in 2014, and is also the result of three cluster meetings that have been held during 2014 and 2015 with running EU projects.

After an initial analysis of the stakeholders that need to be considered in the context of applying advanced ICT for water management (including water providers, customers and policy makers), the document describes the main gaps and challenges that need to be addressed in the future of the ICT for water management sector. These can be summarised in four groups:

- Understanding the cost-benefit ratio of applying advanced ICT solutions applied to water management.
- Building a comprehensive set of indicators at all levels (technological, societal, economic, environmental), which allow measuring progress in the application of ICT for water management.
- Identifying synergies across sectors, which go beyond the well-known water-energy nexus, and especially relating the water sector with the other sectors considered in Smart Cities.
- Implementing data sharing policies across projects and stakeholders, so as to increase interoperability, proposing and making use of standards

The document finishes with a proposed roadmap of how the activities associated to each of these challenges should be addressed in the future, organised according to the level of priority to be applied to each of these activities and the suggested timeframe for their application, together with a roadmap on how ICT for water management can be included in the more general context of smart cities and communities.

Table of contents

1. Approach and History

This document has been created taking as a starting point the previous ICT 4 Water Management roadmap, which resulted from a cluster meeting of 10 running projects in Brussels, February 2014. That 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.

Based on this initial document, a set of cluster meetings with the running projects in the area have been held, where discussions among project representatives have occurred on the topics that are considered to be the most relevant to continue improving the current status quo in the area. More specifically, the meetings that have been held with the objective of defining the contents to be included in this roadmap, are the following:

- Special Session on Smart Water and ICT, associated to the 16th International Conference on Water Distribution System Analysis (WDSA2014), held in Bari, Italy, on July 15th, 2014.
- Special Session of the Water IDEAS 2014 Conference, held in Bologna, Italy, on October 23rd, 2014.
- ICT for Water annual workshop and cluster meeting, held in Brussels in March 18th-19th, 2015.

The ten FP7 projects that have participated in the three sessions are: EFFINET, ICeWater, iWIDGET, WatERP, UrbanWater, DAIAD, ISS-EWATUS, SmartH2O, WATERNOMICS and WISDOM. Furthermore, the following H2020 projects have participated in the latest workshop and cluster meeting: WaterInnEU, KINDRA, FREEWAT, BlueSCities and WIDEST.

Dr. Oscar Corcho has acted as the rapporteur for these sessions and has been in charge of compiling the current document.

2. Identification of stakeholders, current gaps, and technology, social and organisational challenges and issues

In this section we provide an overview of the main stakeholders that need to be considered in the context of ICT for Water management, as well as the gaps and challenges that have been brought forward from the previous roadmap and refined during the meetings that have been held.

2.1 Stakeholders

A varied set of target groups and actors need to be considered in the context of the application of ICT for Water Management. These include:

- Water entities, including those that treat water and/or waste-water, water supply and distribution system (WDS) operators, etc.
- Governments and other types of policy-making or influential organisations, including:
  - Municipalities
  - Water authorities/regulators (e.g., River Basin Authorities, OFWAT in the UK)
  - Environmental authorities
  - Non-Governmental Organisations (NGOs)
- Customers
  - Individual customers
  - Groups of customers (e.g., blocks of flats, suburbs, hotels, etc.)
  - Industry end-users
  - Agriculture end-users

The most relevant change with respect to the previous roadmap has been the inclusion of NGOs and water authorities into the list of users. It is also important to highlight the importance of agriculture as one of the most important consumers of water. This group of stakeholders was already considered in the previous roadmap, but it has been acknowledged among the projects involved in the development of this roadmap that agriculture has received less attention recently. Finally, special types of citizens, such as children and young people at school, should be also considered, especially when addressing changes in user behaviour.

The need to **improve the coordination and synergies among these different stakeholders** has been highlighted as one of the main challenges and, at the same time, opportunities in the sector.

2.2 Current gaps

Based on the available information and experience from on-going projects, the set of gaps described in Table 1 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.

A general agreement among the project representatives in the meetings that have been held is related to the fact that so far the roadmaps have mostly focused on urban water and utilities, leaving apart other aspects like the usage of water in agriculture, the consideration of rural areas and regions that are wider than cities, and the nexus not only between water and energy, but also with other aspects in

Smart Cities (e.g., telecommunications) and in land, food, climate change, etc. As such there is a great potential for uptake and exploitation of ICT advancements in the whole water allocation and management and planning sector also at basin scale.

Table 1. Gaps identified in ICT for Water Management

Area	Description of main gaps
Efficient water use and reuse	Efficient water use and reuse is still one of the major challenges to be dealt with. Most of the projects that have been running so far have focused on this topic, from different perspectives: **leakage detection**, **sustainable reduction of elastic water consumption, increased user awareness**, **usage of grey water and cascade use of water**, etc. Work on this area should continue, including also the optimisation in the use of water in agriculture.
Reducing Total Cost of Ownership for Water ICT	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 towards accurately monitoring and understanding water use and demand. Specific emphasis should be placed on strengthening R&D to deliver: (a) cost-effective technical solutions addressing water consumption monitoring (e.g. sensing, analysis, engagement), (b) technical synergies and business models with energy consumption monitoring, Smart Cities, and smart home ecosystems, and (c) an improvement of Water ICT towards leveraging the circular characteristics of water.
Water-energy nexus	While this area has been considered key in the previous workprogrammes, work on it is still seminal and there is still a wide room for improvement. First of all, solutions should not just aim at reducing the energy spent for water distribution or water waste processing, but mostly at **reducing the total cost of the used energy** (that is, not only how *much* energy it is consumed, but also *when and why* it is consumed). Besides, the synergies to explore should be also **extended to other areas**: land, food, climate change, etc.
Data sharing and privacy management	Following trends in other areas of H2020, data produced by projects in this cluster should be **shared by default**, especially for research purposes. This would allow overcoming one of the main barriers that projects are finding in evaluating the benefits of their solutions. However, the **current legislation** in most European countries does not ensure that water consumption data (and the related energy data) can be shared, hence special effort should be put into improving legislation and providing common sets of terms and conditions to be used. Including **open data clauses** in contracts between local authorities and WDN operators may be also an important step forward. Furthermore, there is a need to proactively identify **potential privacy risks** and propose **privacy-preserving** solutions (at the technical and policy levels) to facilitate data sharing.
Standardisation	Connected to the need for data sharing, there is also a strong need to get projects to use and suggest standards, so that they can be used to increase interoperability, avoid vendor and customer/end-user lock-in and fight against the obsolescence of the systems that they use

	(e.g., a few years after deploying a new system they may not be able to access data anymore due to it). Standards need to be considered at several levels: **formats, vocabularies, procedures and software/API**. The most relevant **standardisation committee** where to make contributions should be also agreed (e.g., OGC, W3C, Joinup, etc.)
Decision Support Systems (DSS)	There is still much **heterogeneity** among DSS implementations, with various technologies and algorithms been used in the current status-quo, each one focusing on different WDN aspects. The implemented algorithms are not always **compared and comparable**, and the problem of standardisation is especially relevant here.
Consumer awareness	Consumer awareness has been low so far, with the general population at large still considering water as a perishable resource. More effort is required towards developing solutions to improve **consumer awareness**, induce sustainable changes in **consumption behaviour**, and improve **social perceptions** for water. **Long-term goals** (such as those related to addressing the youth) and consumer empowerment to harness network effects (e.g. social media) would also be advisable. In terms of pricing incentives for raising consumer awareness, legal and policy challenges have been identified for the implementation of adaptive pricing strategies. Vastly different water pricing schemes exist in EU, with water consumption still not metered for a large part of the population. The use of pricing incentives should be explored, but with absolute respect to the human right to water. Finally, water pricing is also a very strong factor for agricultural water-use. Water use for agriculture is often subsidised at national level, leading to excessive and non-efficient water use (and significant energy consumption though pumping), whereas any water pricing policies in this domain need also the support of national governments, through changing irrigation practices and methods (e.g. a drive towards drip irrigation as more efficient and off-peak irrigation) social awareness and incentives.

2.3 Technology, Social and Organisational Challenges

The main challenges involved in the use of ICT for Water Management can be organised according to four main groups, some of which are already identified by H2020 documents, and in which ongoing projects are currently working. All of them are driving towards the general goal of achieving a significant reduction of water and energy consumption, which cannot only be obtained by applying advances in technology, but also requires social and behavioural changes (mostly through increasing user awareness) and policy-based changes.

Technology challenges have been already widely covered in the previous roadmap, where much attention was put into aspects related to improving water metering, in terms of sensors (heterogeneity among existing sensors and communication technologies, aspects related to power supply) and those related to smart meters. It is worth to notice that in the rural and peri-urban segment there is an increasing need of technologies for monitoring and managing water related agroecosystem services (i.e. large scale phyto-treatment plants, o Managed Aquifer Recharge schemes, etc.). These needs span from low-cost, low-energy sensing technologies

and relative based devices to software tools for remotely controlling operational activities. In the field of water quality (i.e. management of wastewater treatment plant) the needs for new sensing technologies (biosensors, optical fibers) is also strongly related to the reduction of energy consumption.

Besides these challenges, four additional groups of challenges, which focus more on the other two areas, have been considered and described further in this section:

- **Cost-benefit analysis of ICT solutions applied to water management**: Advanced ICT solutions for water management should continue to be improved, implemented, deployed and evaluated. This includes the implementation, deployment and evaluation of improved decision support systems, which may make use of increasingly more types and amounts of data (e.g., including real time data, geographical data, etc., when useful), improved leakage detection technologies, etc. However, a strong focus needs to be put as well on analysis, i.e., on understanding better and improving the TCO/benefit ratio of applying such solutions through the entire water value chain, in order to make these efforts and developments sustainable and improve their uptake.
- **Synergies across sectors (water, energy and beyond)**: A better understanding of the water-energy nexus is required, then followed by a significant reduction of the total cost of energy related to water processing and distribution (cf. Table 1). However, not only energy can be related to water, but also other areas like land, food, climate change, transport, telecommunications, etc., some of which are already covered in the context of the Smart Cities initiatives.
- **Indicators**: Indicators related to water management exist, from different organisations (e.g., the International Water Association), with different focus and at different levels (e.g., technological, societal, economic, environmental). A better understanding is needed of the indicators that should be used for different types of problems to be addressed, the stakeholders that they are targeting, etc.
- **Data sharing, Interoperability and Standardisation**: An increase in the sharing of data across projects and stakeholders will allow faster advances in this area. Standards need to be considered at this stage, to facilitate data sharing and interoperability between systems. Finally, privacy needs to be respected, and appropriate technology and legal measures need to be put into practice for such a purpose. This is considered in the general framework for moving towards "open" ICT for Water management principles and practices.

The following subsections will now go through each of these challenges and identify the main actions to be taken for each of them, so that this list of actions can be used to build the roadmap that will be presented in section 3.

2.3.1 Cost/benefit analysis of ICT solutions applied to water management

So far there have not been clear and deep studies, applicable to a sufficiently wide range of settings, of the ratio between cost and benefit of the ICT solutions that are being developed and deployed in many of the ongoing projects (in terms of DSS, leakage detection, data collection, water efficiency, cost savings, etc.). There are several reasons for this to happen:

- **Most projects do not have sufficient historical data to measure the impact of the application of the developed ICT solutions**. Therefore, a lot of effort is being spent by ongoing projects (and probably this will also happen with future projects) in trying to understand such an impact by generating synthetic user data and/or water consumption data that can be used for the evaluations (e.g., the WaterVille tool from the iWIDGET project). Many utilities participating in projects have already many of these data sources available internally, and use them to build their own socio-economic studies and customer segmentations. However, they do not always disclose such data to projects, and as a result of this a lot of effort is spent by projects in the task of synthetic data generation without having clear benefits of improvement with respect to the current state-of-the-art in industry.
- Even in those cases where historical data are available, sometimes the data need to be supplemented with **simulated data** or **field surveys** because the historical data available may not exhibit all the characteristics needed for the evaluation of the ICT platforms (e.g., for testing the behaviour against concrete events or scalability). The WaterVille tool, mentioned in the previous paragraph, is a step towards this direction and can be used for generating simulated data.
- There is a general lack of **common frameworks and KPIs that allow objective assessment of improvements**.
- There is a need to deal in a balanced way with **real-time and non-real-time data**. Real-time data, even if desirable, are not always available because of different factors (device characteristics, manual measurement processes, data privacy, non-disclosure of data by utilities, etc.).

A common problem in the water sector is that it is not always easy to determine the "**true cost of water**", something that should be done considering the context of a circular economy, as well as the fact that the water industry has been experiencing very important changes in the recent years, moving away from a mostly-CAPEX-based industry, to a TOTEX- based industry, where CAPEX (capital costs) and OPEX (operational costs) are being combined in a single framework (TOTEX-total costs).

Furthermore, there is a need to identify sustainable **business models** for the application of ICT on water management. Such business models should not only address water utilities, but also alternative domains (e.g., assisted living, applications in the process industry), as well as the cleanweb market. Also any business plans should take into consideration the differences between state-owned and private water utilities, as both types do exist (sometimes even co-exist) in EU countries. For instance, such a business model should consider that in the future every single house may have single common hub for smart meters to be connected handling secure data transmission. Besides, smart meters cannot always be upgraded (e.g., once that they run out of battery they need to be thrown away, as they are sealed – life expectancy of 5 years).

2.3.2 Indicators

Plenty of indicators exist in the water sector[1], most of them coming from the International Water Association (e.g., for clean water[2], waste water[3]). Some indicators are more technology focused, while others may be seen as more focused on the policy level.

It is generally agreed across sectors that in order to be useful, indicators need to be simple and easy to understand, with very concrete definitions, they need to include clear targeting/goals, and appropriate validation mechanisms.

As a result of this variety, there are plenty of different indicators that can be used for the same area (e.g., for water losses). Consequntly, stakeholders do not always have a clear view about which indicator is the best to be used. Selecting a wrong indicator may lead to incorrect interpretations; furthermore, different indicators take into account different perspectives and none of them will satisfy every perspective/stakeholder. Hence there is a need to **guide and educate stakeholders on the selection and use of indicators, as well as methodologies for their objective and repeatable evaluation**.

In any case, the definition of indicators should not be an end product on its own. This would be continued through the generation of **methodologies and benchmarks**, then a general **certification process**, and when relevant, the creation of **objective bodies** to do the analysis and assign certifications. Some of these selections of indicators may be published in the context of **EC guidelines** (e.g., Good Practices on Leakage Management), for better uptake.

2.3.3 Synergies across sectors (water, energy and beyond)

All types of challenges (technological, societal and organisational/political) arise when considering the relationship between the water sector and other sectors like energy. In the previous section we already pointed out that the learning obtained from the use of existing tools in the energy sector may be transferable to the water sector, to help determine the business impact of applying ICT advances in water management.

In the specific context of the water-energy nexus, the following challenges are identified:

- Consumption data from water and energy may be **processed jointly** in order to facilitate detecting consumption models, and perhaps correlations in the usage of both types of resources. It is also essential to point out that they need to be shared, i.e. water utilities and energy providers need to share data and make them available to stakeholders and researchers. This is not currently the case, because different providers keep their data strictly confidential within the

[1] http://www.iwawaterwiki.org/xwiki/bin/view/Articles/RecentPapersonPerformanceIndicators

[2] Alegre, H. (Ed.). (2006). Performance indicators for water supply services. IWA publishing.

[3] Cardoso, A., Ashley, R., Duarte, P., Molinari, A., & Schulz, A. (2003). Performance indicators for wastewater services (Vol. 1). London: IWA Publishing.

company. Possible legislatives measures will be needed in order to achieve progress in sharing and jointly processing data from water and energy.

- Most water utilities are not certain if it is legally/regulatory possible, or how they can benefit from applying dynamic **adaptive pricing** (i.e. dynamically adapt water pricing to consumer demand). Since adaptive pricing has been already explored in the area of energy, the water sector could study the lessons learned in the energy sector, with respect to the right to water. Furthermore, would it be more effective if households were offered jointly combined energy and water adaptive pricing tariffs? The latter will obviously need the cooperation of water and energy providers, which in itself is a currently a problem, as mentioned in the previous paragraph.
- Related as well with adaptive water pricing, there is a need to understand whether the overall objective should be to reduce the amount of energy required to process and distribute water and waste water, or whether the focus should also be put into **reducing the cost of the energy used** overall (in cases adaptive energy pricing is affecting the price of water).
- **Standards in the energy sector and telecommunications** are generally more advanced than those in the water sector. Again, these lessons learned may be very useful when these are considered for application in the water sector.

There are many other connections that will arise in the future in terms of the relationship of water with other areas, beyond energy, such as those covered by smart cities or others like the impact of water in land, food, climate change, etc. Some **roadmaps into this direction** are already being created.

2.3.4 Data sharing, Interoperability and Standardization

As already identified in section 2.3.1, there are no clear policies and strategies yet for data sharing in the water sector. This makes progress in the ongoing projects slower and hinders the evaluation of developments and deployments with real data.

There is a clear agreement on the need to address the problem of lack of data sharing. This could be done either by having policies coming from the European Commission in this respect; creating, in a shorter term, appropriate incentives for those water (and energy) utilities that decide to provide data; generating a simple set of terms and conditions that can be reused by utilities; or proposing a charter on Data-Intensive Research for EU utilities and an open, voluntary process for opting in, where utilities in it can access to special types of funding.

In terms of standardisation, there is also consensus on the usefulness of standards for this sector. The following needs for interoperability and standardization have been identified:

- At the **software and API level**. The usage of open source platforms or components, and common programming interfaces (APIs) in project developments should be encouraged, as one of the ways to achieve de facto interoperability at the software level.
- At the **data level**, using common data structures, data models, vocabularies and/or ontologies. This does not mean that the standard needs to be used internally by the systems, but it is enough for the exchange of data across

systems. The provenance of data (e.g., following standard vocabularies already used in other areas) should be encouraged.

- At the **metadata level**. An agreement on metadata profiles to be used for different types of water data resources should be pursued, following examples like those done for other domains (e.g., DCAT-AP for Open Government Data , INSPIRE metadata profiles, GEOSS, BIM, etc.). A centralised metadata catalogue may be created for all projects working in the water area.

Several barriers have been identified in order to achieve the goals of data sharing, standardisation and interoperability:

- **Legal and competitive issues**. If a water utility or WDS operator provides data about its operations, then competitors may know some of the details of how operations are done, which may resulting in losing their competitive advantage and/or exposure of business-critical information.
- There is still a strong resistance to data sharing in general by many stakeholders (e.g., water utilities), because of being unsure about whether they may be **violating privacy acts**.
- It is agreed that in spite of the benefits of standards, their definition, development and certification procedure involves high costs in effort and in financial terms. Their implementation may also be costly when they are very ambitious and, therefore, complex. Furthermore, it is not always clear which standards will be necessary in the future and this will need to be clarified and investigated first.

3. A proposed roadmap for ICT for Water Management

Figure 1 shows graphically some of the components required to address the data sharing, interoperability and standardisation challenges described in section 2. The figure shows that different types of data sources from different sectors (not only about water consumption, but also from other types of meters) should be considered and possibly aggregated in a data API, so as to facilitate its usage for applications and in DSS. All of these data should be managed and exposed according to existing standards for the representation of city and water-related data, which are normally proposed by a wide variety of standardisation organisations. In all of these cases, personal data will need to be managed, hence appropriate privacy preservation mechanisms should be applied at all stages of the data management chain and appropriate sets of terms and conditions should be created and published to ensure that data use and reuse is done adequately.

Table 2 makes a proposal of the set of activities that need to be addressed in the future according to the four challenges, and organised according to the level of priority to be assigned to each of them.

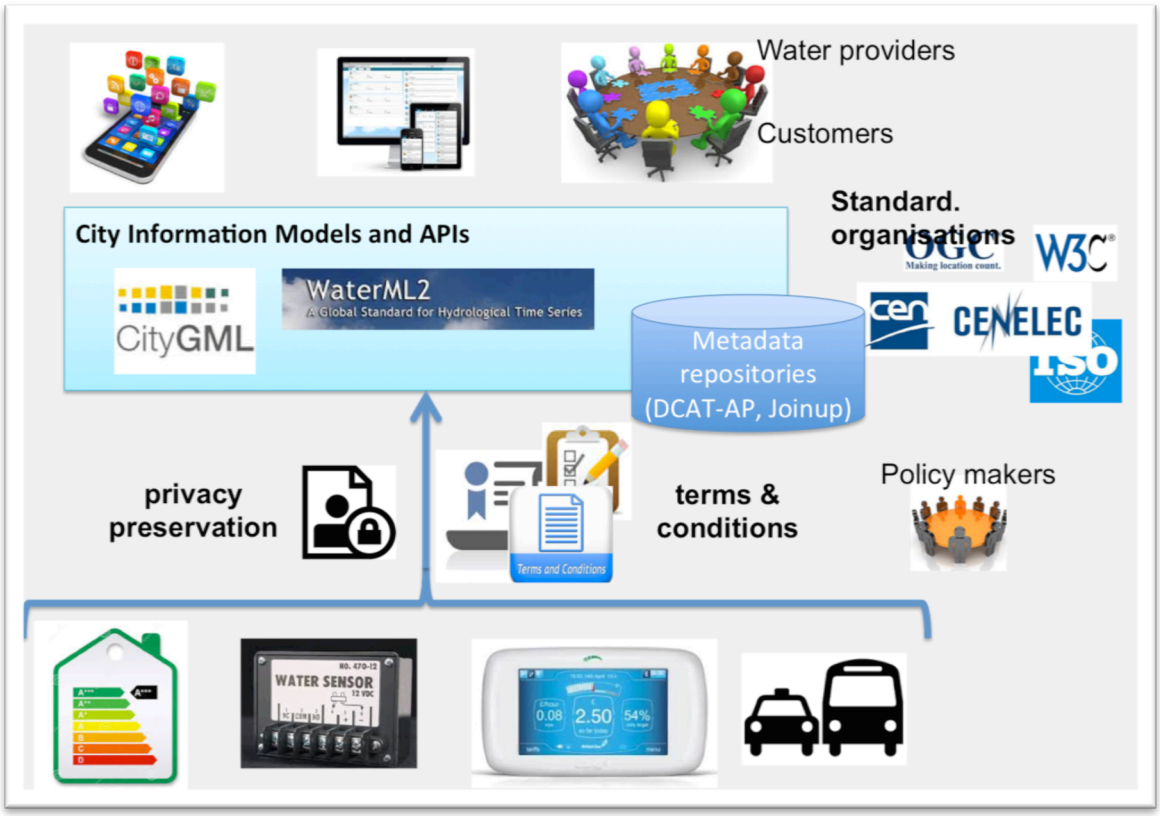

Figure 1. Main components for addressing data sharing, interoperability and standardisation challenges

Table 2. A Roadmap to address the main challenges identified for the ICT for water management sector

	Short-term	Medium-term	Long-term
Cost/benefit analysis	Data simulation and field surveys to be used widely	Methodology for calculating the true cost of water Business models definition Real-time vs non-real-time data	Synergies with energy for cost-effective water consumption/demand management
Indicators	Selection of existing indicators	Development of new indicators Evaluation methodology Guidance and education to stakeholders EC guidelines	Certification processes and bodies
Synergies across sectors	Studies on total cost of energy associated to water	Studies on the transferability of adaptive pricing for water Exploring the applicability of energy tools for water Explore technical and business synergies with energy, smart home, and cleanweb industries Links with other sectors, apart from energy	Joint analysis of water and energy data consumption/demand Implementation of smart water as a component of the smart city.
Data Sharing, Interoperability and Standardisation	Metadata profiles Evaluation of existing data models/structures Terms and conditions for data sharing Study of privacy risks	Regional/National/EU Metadata catalogues Selection/development of new data models/structures Privacy-preservation techniques and guidelines	Regional/National/EU watedata catalogues Common Open APIs Adaptation of energy tools/standards to water.

3.1 Integration of ICT for Water Management into the Smart City and Community context

In this section we provide a final analysis of how the ICT for Water Management roadmap can be integrated into the more general context and roadmap of smart cities and communities.

The Strategic Implementation Plan of the European Innovation Partnership on Smart Cities and Communities identifies 11 priority areas

- Sustainable Urban Mobility
- Sustainable Districts and Built Environment
- Integrated Infrastructures and processes across Energy, ICT and Transport
- Citizen focus
- Policy and Regulation
- Integrated Planning & management
- Knowledge Sharing
- Baselines, Performance Indicators and Metrics
- Open data governance
- Standards
- Business Models, Procurement and Funding

Obviously, the role of ICT and Water does not necessarily fit with all of these priority areas, particularly the one focused on urban mobility. However, the ICT for Water constituency can have an impact on the rest of areas, even if in their current descriptions and scope such a relationship has not been established yet. Some initial ideas about these relationships are provided below:

- Section 2.3.3 has already explored some of the main challenges that can be associated to the synergies across sectors in the domain of smart cities and communities. The topics discussed on the joint processing of data and the development of joint consumption models, on dynamic adaptive pricing, and on reducing the cost of the energy used will all be able to provide relevant input to the priority areas of sustainability, integrated infrastructures across sectors, and integrated planning and management, since these areas may all benefit from the inclusion of water-related challenges.
- The focus on citizens has also been addressed in this roadmap are also covered in the context of smart cities and communities. Working on their motivation and achieving changes in their behaviour both in the short and in the long-term are aspects where the water domain can also included an interesting angle, especially since water is normally perceived to be less costly but more scarce (especially in those places where water scarcity is a recurrent issue) than others.
- The issues related to policies and regulations have been also pointed out in this roadmap, especially in relationship with open data policies and with the management of privacy. This is a shared concern between the current topics dealt with in Smart cities and communities and ICT for Water management.
- Finally, all the priority areas of knowledge sharing, performance indicators (which have been addressed deeply in this roadmap), standards and business models and public procurement can be safely considered to be shared across all these relevant sectors.

References and Related Initiatives

INSPIRE Directive: http://inspire.ec.europa.eu/

WISE – The Water Information System for Europe: http://water.europa.eu/

EIP on Water: http://www.eip-water.eu/

EIP on Smart Cities and Communities: http://ec.europa.eu/eip/smartcities/

"ICT for Water" Roadmap (2014): https://ec.europa.eu/digital-agenda/en/news/ict-water-resources-management-experts-consultation-4022014