Water Europe
Technology & Innovation

THE VALUE OF WATER

Multiple Waters, for multiple purposes and users

Strategic Innovation and Research Agenda

(SIRA)

Water Europe

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Introduction

The Water Europe Strategic Research Agenda (SIRA) has been developed by Water Europe with the input of its members, the Water Europe Working Groups, and its key stakeholders. A public consultation has also been part of the drafting process. A special thank you goes out to the members of the SIRA Task Forces that were set up to develop the 6 Key Components that are the logical building blocks of the Water Europe SIRA.

The Water Europe SIRA is a living document that has initially been developed in the first half of 2016 to promote a balanced mix of research and innovation measures that contribute to overcoming the main bottlenecks towards the realization of the Water Europe Vision as described in "Water Europe Vision: towards a future-proof model for a European water-smart society".

Contents

Summary of the Water Europe Vision

"Access to ..[water] .. is a basic human right and water is crucial for human health and well-being, as well as economic performance and business growth. It is also a finite and shared resource, therefore action by an individual, a business or a community can have a substantial impact on access to it by others".
Deloitte Water Tight 2015

The Water Europe vision for a water-smart society

The Water Europe vision aims to show the routes towards a better exploitation and stewardship of our water sources by society and businesses while developing resilient and sustainable solutions for our key global water challenges. It describes how these challenges can be turned into opportunities for Europe, to develop new technologies, solutions, business and governance models for the **water-smart society** of the future. The vision imagines a future, where water scarcity and pollution of ground- and surface water in Europe are avoided, water, energy and resource loops are closed to a large extent to realise a circular economy, the water system is resilient against climate change events and European water-related business thrives as a result of forward-looking research and innovation.

As such it frames the context for developing a renewed Strategic Innovation and Research Agenda (SIRA) that defines the most important research, development and innovation actions to be promoted by Water Europe and its collaboration partners for the upcoming decades.

Contributing to solve societal challenges and European competitiveness

The Water Europe Vision is focussing on European water challenges, trends and required developments, but it also indicates how this is connected to Europe's role in solving global water challenges, including the United Nations Sustainable Development Goals (SDGs), while confirming and strengthening Europe's position in the global water-related economy valued at 63 Trillion Euro.

In order to make the water-smart society emerge, Water Europe proposes to focus research, development and innovation investments in Europe on four key impact parameters:

1. **Reducing the impact** of Europe's society on our natural water resources by 50%;
2. **Realising the true value of water** for our society, the economy, and the environment;
3. **Boosting the European water market** as well as global competitiveness of the European water industries;
4. Securing long term **resilience, stability, sustainability, and security** of the society with regard to water.

To realise these objectives, Europe will need to develop innovative water-technologies, digital solutions, economic, business and governance models that contribute to solving water challenges in Europe and for the world at large. Moreover, it will need to enhance cross sectorial challenges in implementing the EU Water policy (in particular WFD) at various levels and supporting regional development.

A paradigm shift towards a sustainable and circular water-smart society

Water Europe promotes **a future proof European model for the water-smart society** that entails a **paradigm shift** in the way our future society will be organised and managed with regard to water. It requires bold and courageous decisions, investments, changes and new types of collaborations for stakeholders at all levels of society, involving citizens, public authorities at all levels, industries, farmers as well as representatives of our natural environment.

It will leverage on both dramatically higher levels of manageability enabled by the emerging cyber-physical society, **"digital water"** technologies and boosting the availability of **"multiple waters**" to complement fresh water sources, as well as much deeper levels of awareness, integration and collaboration between organisations and citizens.

These important changes will offer a boost for Europe's industry as it requires significant investments in redesigned infrastructure and innovative technologies. It also provides complex challenges that require a longer term programme to foster a stable migration towards the new water-smart society while ensuring high levels of health protection and affordability of water services.

A future proof model for a water-smart society

The **Water Europe future-proof model for a water-smart society** entails four key components to carry out research and development, but more importantly, to bring RTD results to market and realise systemic innovation in our water-system by:

1. The Value of Water: developing a water-smart economy using advanced solutions and a systems approach to eco-innovation, a state-of-the-future water infrastructure, a circular water-economy, as well as new economic models based on the **"true" value of water**, in order to increase rational use and re-use. It also entails valorising the value in water, meaning extracting and exploiting relevant resources, such as nutrients, minerals, metals but also energy that is embedded in used water streams. Innovations shall enable cost effective solutions that open-up new multi-Billion Euro markets for European industries towards the valorisation of secondary raw materials and energy;

2. New digital and water technologies: deploying advanced digital solutions for water in a capillary network of sensors in water distribution systems, capturing and using this new information to manage them in real time. Developing advanced water-treatment solutions to achieve good status of European water bodies, enable synergies between centralised and decentralised treatments, as well as economically viable extraction and valorisation of valuable substances and energy in water. Use advanced materials in the water infrastructure and improve solutions to reduce water use in agriculture. Our emerging technologies will enable Europe to reach previously unimaginable levels of control, manageability, and exploitability of our society with regard to water;

3. A hybrid grey and green water infrastructure: rethink and redesign the water distribution and water service systems into a high-tech human-built water infrastructure integrated with a nature based ecosystem, taking into account the impact on health risks and cost-effectiveness. It combines centralised and decentralised water treatments, leading to reduced water-loss, increased water reuse, optimising the exploitation of alternative water sources in a circular economy, and strengthening resilience against climate change events, especially droughts and floods;

4. Enabling inclusive multi-stakeholder governance: new governance models that manage availability of water for all users and sectors (industry, agriculture, cities, waterborne transport) and multiple purposes, based on the understanding of "true" value of water, and using fit-for-purpose, adaptive and evolving economic and governance mechanisms, supported by advanced near-real time decision support systems and information exchange at all levels (rural, industrial, urban, regional, national, European, and even global). These new governance frameworks will be based on a multidisciplinary nexus approach (water-energy-food-land use-climate).

The 4 Key components shall be complemented by a series of **horizontal measures** (i.e. from creating enabling conditions for water market, to international cooperation), and they shall be implemented in large-scale, multi-stakeholder setups, moving away from 'silo'-thinking via **living labs** and large scale demo.

In implementing its Vision, Water Europe will look at strengthening and consolidating synergies with all the main actors dealing with water in Europe, in particular the Water JPI and the EIP Water.

The transition to the water-smart society

Water Europe envisions that the European water sector will be significantly transformed with respect to the current state of play.

New concepts, such as **"Multiple Waters"**, **"Digital Water"** and **"Hybrid grey and green infrastructures"**, will be driving the transition, decision makers and new water-smart economics. All will be enabled by new technologies fostered within an open innovation environment and a completely **redesigned water infrastructure**. The impact of climate change events will be under control. **New governance structures, economic mechanisms** and novel more profound water stewardship programmes, will manage the water market towards smart allocation of water.

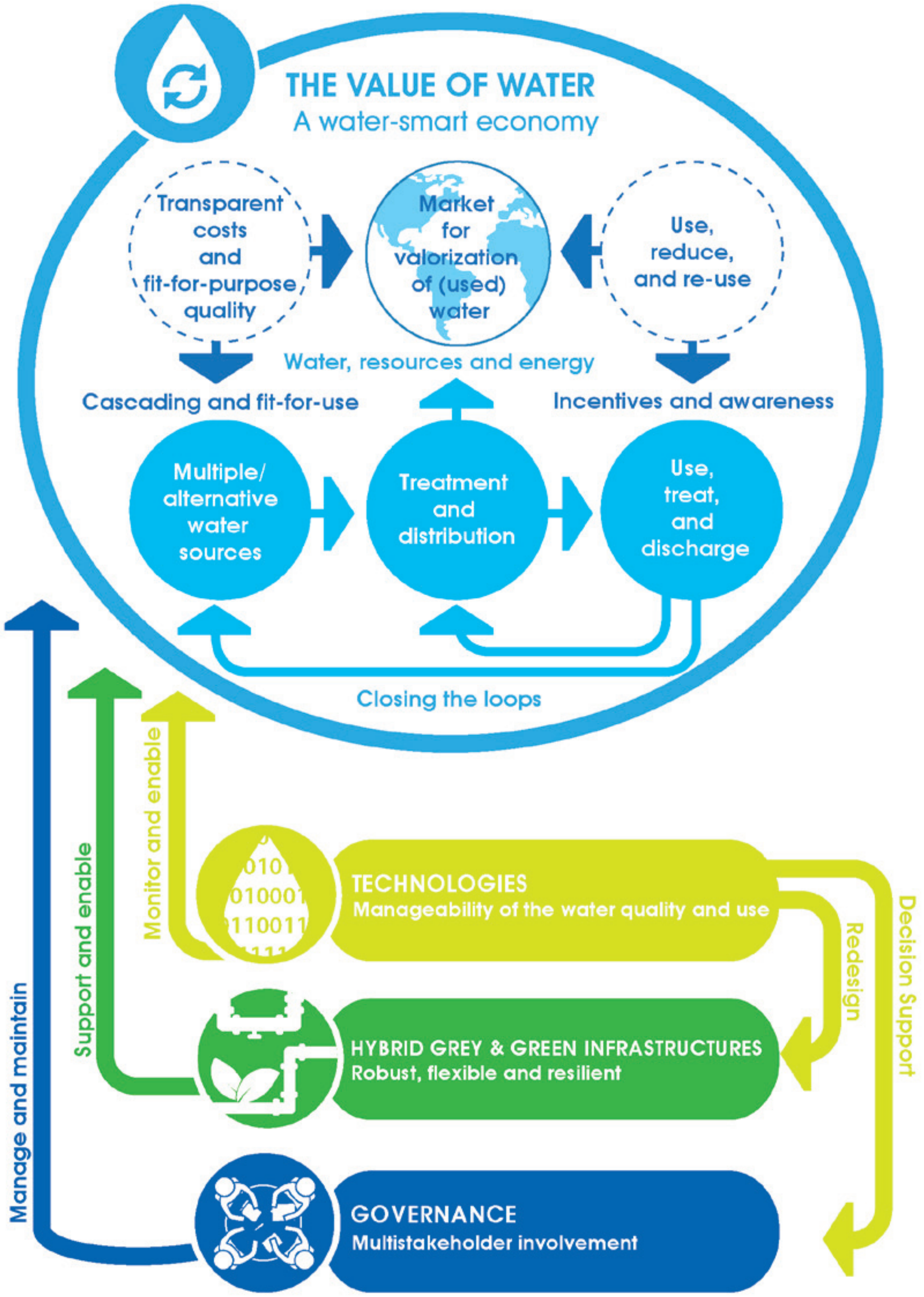
In the future water-smart society, more than 30% of the total water demand (e.g. hundreds of km^3/yr) will be delivered by alternative water sources, such as rain-water, brackish, saline, and re-used water streams. New water- and crop-growing technologies, the redesigned water infrastructure and advanced (self) management tools will increase water savings throughout our society: from agriculture to (bio) industries, homes as well as for energy production, reaching savings of up to 300 km^3/yr. Overall, the Water Europe water vision aims at a set of innovations leading to a 50% reduction of the pressure on our fresh ground and surface waters, making avoidance of water scarcity in Europe a reality and contributing significantly to solving the important water scarcity at world level.

By 2030 the transition to the water-smart society will have been in full swing, driven by visionary front-running urban areas and (agro) industries. They will have taken the lead in showing the migration paths towards the future water-smart society by implementing ambitious long-term investment and innovation programmes, as well as real life Living Lab experimental areas. They will have created a fertile innovation eco-system for solution developers, researchers, forward looking water users, and water-governing bodies to develop the leading solutions of the future. These will boost Europe's global competitiveness in the 2.5 Trillion Euro water-handling market, creating numerous new green jobs in Europe while providing important contributions in realising UN Agenda 2030 and water diplomacy to reach SDGs in Europe and beyond.

SIRA structure and implementations modes: draft working doc

The Water Europe Strategic Innovation and Research Agenda (SIRA) promotes a balanced mix of innovation measures that contribute to overcoming the main bottlenecks towards realising the Water Europe vision as described in "**Water Europe VISION: Towards a future-proof model for a European water-smart society**".

The VISION is built on 4 Key Components (KC) of innovations, all contributing to increasing and better valorising the Value of Water, and jointly defining the Water Europe future proof model for a water-smart and resilient society. These 4 components are presented in the figure below:



Water Europe Model for a future proof water-smart society

Source: Water Europe

This mix of innovation measures includes:

1. Dedicated research and innovation actions for each of the four vision layers, looking at non-technological innovations as well as technological research, development and close-to-market innovation. It encompasses low TRL research and development (FET and KET[2]), including open research on emerging technologies, that will have an impact on Europe's water system on the longer term and higher TRL (closer to market) enabling technology developments, validations and demonstrations to foster effective and efficient market introduction of relevant solutions for the water and water-dependent economic sectors;

2. Real-life living labs, very large scale operating in various territorial scales/levels[3] in which demand-driven, user-centred technologies and open innovation ecosystem developed under point 1 can be investigated, further advanced and integrated within real-life contexts that are representative for the European water sector (and abroad, promoting International cooperation). Through multi-stakeholder partnerships (between citizens, businesses, public authorities) based on user co-creation approach and taking into account social and economic implications, new technologies will become more accurate to ensure success in developing migration paths towards the water-smart society of the future;

3. Horizontal measures that promote a favouring innovation eco-system and level playing field for existing and novel solutions to be better used and combined towards solving the major issues and challenges as explained in this document, as well as improving the knowledge base and awareness on the value of water at all levels.

Dedicated research and innovation actions

The Water Europe Strategic Innovation and Research Agenda will combine real-life experimental environments (Living Labs) with dedicated research and innovation actions targeted at developing the 4 layers of the European model for a future proof water-smart society.

Dedicated research and innovation actions will range from low TRL 3-5 research (e.g., for smart membranes) to more applied and industrial research and development actions, up to TRL 5-8 pilot and demonstration actions, in which novel technologies and solutions will be tested and validated before market introduction. New technological and non-technological solutions will be developed within 4 Key Components (KCs):

Key Component 1: The Value of Water

Targeting at the development of a **water-smart society** for Europe, enabled by new technologies, economic and business models.

Key Component 2: Technologies

Aimed at developing those digital and water treatment technologies that enable **clean waters, higher levels of insight and manageability of our water system** and the "**multiple waters concept**" in closed loops.

Key Component 3: Hybrid Grey and Green infrastructure

Realising new materials and technologies, approaches, (asset) management models and practices to **maintain, improve and redesign our water infrastructure** into a smart, active and economically sustainable system to support the "multiple waters concept" and to increase the resilience against climate change effects.

Key Component 4: Governance

Developing new **inclusive governance models**, digital support tools and practices of the future, leveraging on new technologies enabled insights and decision support systems, also targeting new growth areas of the water economy. Following a multi-stakeholders approach, it will mainstream integrity and transparency practices in water governance frameworks for greater accountability and trust in decision-making. Developing future governance frameworks based on a multidisciplinary nexus approach (water-energy-food-land use-climate) that are more resource efficient and cost effective and enable synergies across sectors and across water users, rural and urban areas, and generations.

Key Component 5: Living Lab Pilots

The above mentioned 4 Key Components target the development of the enabling technologies and innovations and include smaller scale trials and demonstrations. KC5 has the aim of looking further ahead and pushing the development of these innovations through visionary, large scale experimentations in real-life environments to foster the development of migration paths and strategies towards the Water Europe model for a water-smart society.

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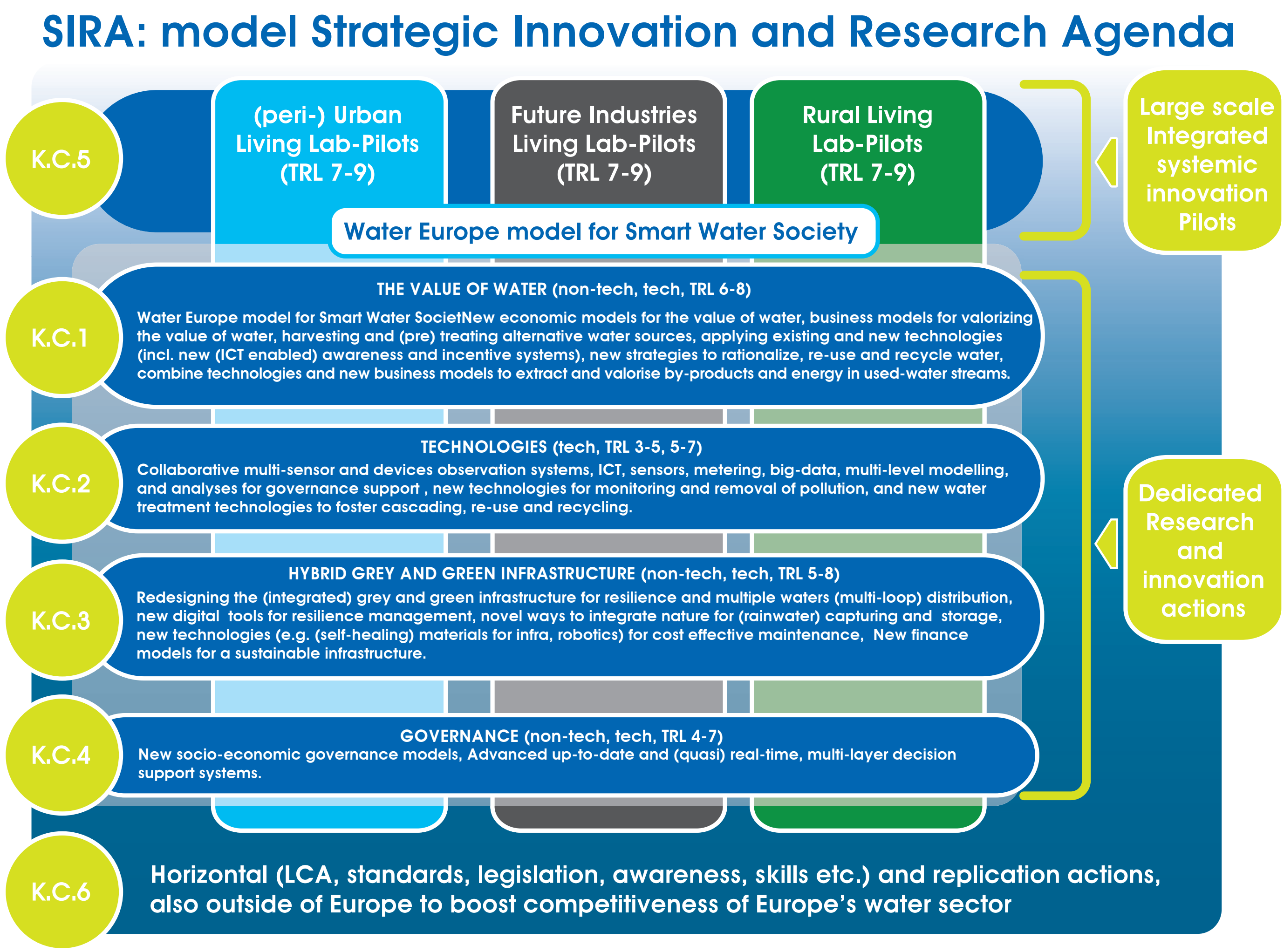
Multiple, real-life living labs will be identified forerunning water-systems in Europe and abroad (leveraging International Cooperation) to set-up realistic and full-scale users' environments in which complex new combinations of technology innovations, new socio-economic models and practices as well as new governance set-ups can be experimented. The following 3 living lab areas are foreseen:

1. **Rural Living Lab Pilots**: targeted at experimental environments with a focus on rural challenges, including collaborations with industries, urban, and natural environments.
2. **Future Industries Living Lab Pilots**: targeted at experimental environments in which industries (including bio-industries) collaborate with other users to govern regional water management systems.
3. **Smart (Peri-)Urban Living Lab Pilots**: targeted at real life experimental environments with a predominant focus on urban realities, including collaborations with industries, nature and possible link to rural areas.

On top also some Living labs will combine these three area types at regional or international river basin scales targeting across border sustainable, robust, resilient and dynamic water-smart systems strengthening Europe's contribution to overcome global societal challenges and strengthening the water market in Europe and beyond.

Key Component 6: Horizontal

A sixth Key action will focus on various horizontal issues, such as new cross-user stewardship schemes, Water Footprint Assessment methodologies, consideration of the Nexus of water-energy-food-land-use-climate, innovative capacity development measures to cultivate smart new skills and various training, education schemes (e.g. collaborations between water management organisations, industries, and educational institutes), supporting actions to effectively bring together all stakeholders during various research and innovation cycles, coupling open innovation with social awareness and responsibility and by building ownership approach to technological and non-technological innovations and public engagement in responsible research and innovation. This will allow the creation of a sound European Research and Knowledge Exchange Infrastructure, also open to the world. It will also widen and strengthen European water sector participation in the international business market improving competitiveness and leadership of the European water sector world-wide.



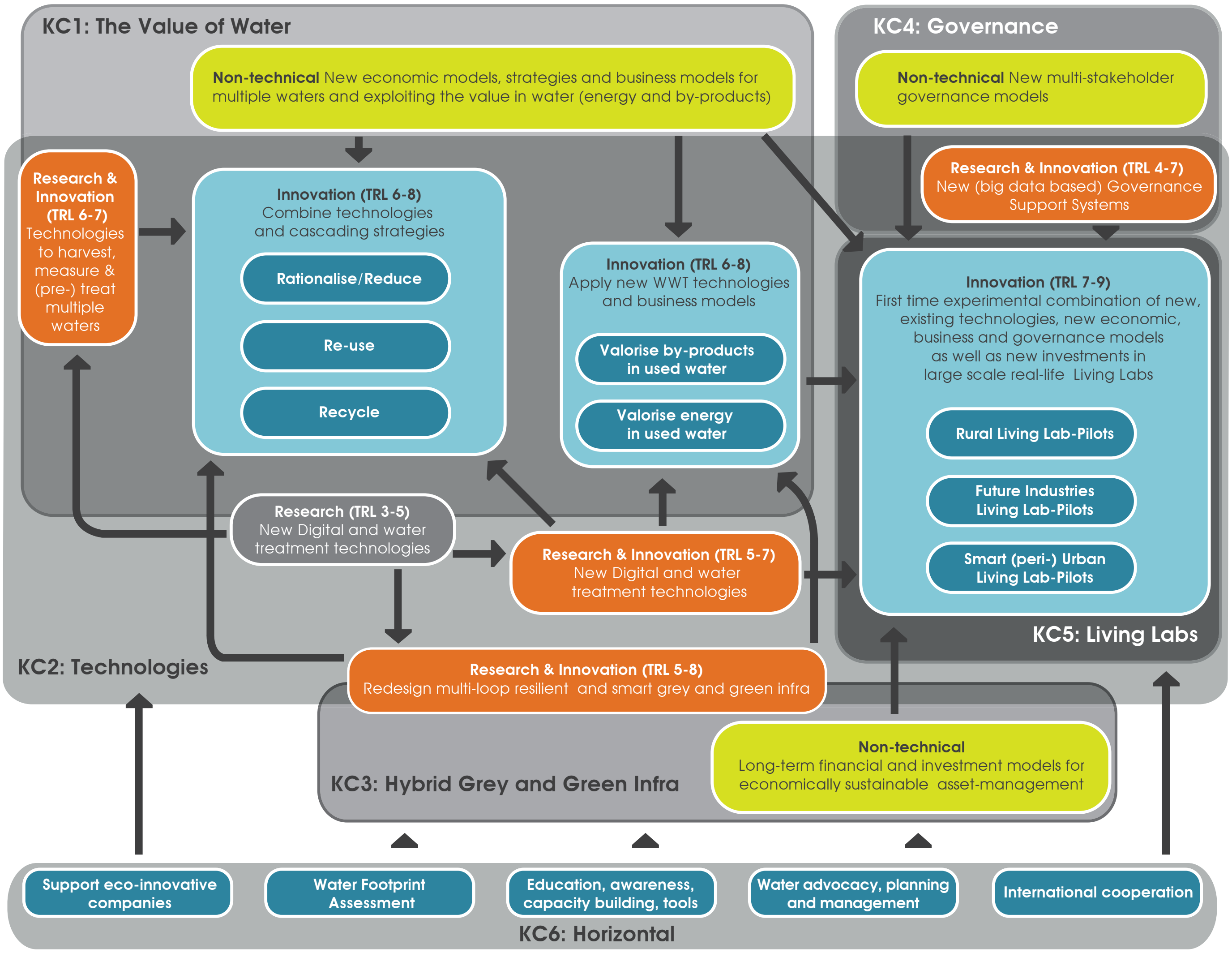
The conceptual model and the interdependencies between the Key Components are visualised in the following figure. KC1 – 4 create and deliver research and innovation results, which will be validated in dedicated research, development and innovation actions. KC5 cuts across these other KCs, indicating that different combinations of KC1 – 4 results will be experimented in these large scale Living Labs. KC 6 fosters the overall innovation eco-system surrounding KC1 – 5, realising a favourable environment for stakeholders to develop the required knowledge, technologies and applications while eliminating bottlenecks towards a "go-to-market" attitude and conditions.

Whereas there are synergies and overlaps between different Key Components, there is a clear logic in separating different innovation-oriented activities within the KCs, each of which provides the main building blocks (hence "Components") for building the Water Europe's vision for a water-smart society. These building blocks range from required non-technological innovations, to new technology development, testing first-of-a-kind commercial scale experiments in real life environments.

Non-technological innovations are an overarching element of all Key Components and it is related to the creation of **new business operations**, developing **new** marketing concepts **and channels to market** (market innovation), promotional strategies, and **new water pricing models**. Non-technological innovations in water via **organisational and business models** innovation will be designed, developed and implemented in all KCs to support the creation of new strategies, structures and organisational systems implementing 'multiple waters' concept across functional areas moving towards a flexible adaptive networked structure.

The generation of technological and non-technical innovations crucially relies on the **quadruple helix model of innovation**, i.e. the collaboration and co-creation of innovation by the public and the private sectors, research/ academia and civil society to foster sustainable innovations. This underlying logic is represented in the following figure and explained afterwards.

Logical building blocks of the Water Europe Strategic Innovation & Research Agenda



Legend: Fundamental Research & Innovation (TRL 3-5), Applied Research & Innovation (TRL 5-8), Close-to-market Innovation (TRL 6-9), Non-Technological Innovation (All TRLs)

KC1: The Value of Water (Non-technological, Research & Innovation and Innovation)

The Value of Water starts with giving the right value to different water sources and their applications. **Non-technological innovations** will be needed and pursued by the Water Europe SIRA within KC1 to develop new economic models (including new financial mechanisms, water pricing methods, incentives), and economically driven 'cascading' strategies[4] to be gradually introduced in our society when relevant technologies and enabling infrastructures will become available for the "multiple waters concept". Affordability of urban water services will need to be taken into account. On the other hand, in order to realise this concept, **research and development** will be required to elaborate advanced technologies and systems and digital technologies for water based on FET and KET with the aim to harvest, measure and (pre-) treat multiple water sources and streams. This will allow to make them available for different uses, for applications requiring high quality fresh water, e.g. for drinking water in homes and food and nutrition related industries, up to applications that may use recycled or pre-treated salty or brackish waters, e.g. for cooling water in industrial processes. Addressing the water-energy nexus of the implementation of these new technologies can help to understand better the value of waters they generate. Innovation Actions will be required to combine these new technologies and the cascading strategies and business models, to drive one of the key objectives of the Water Europe's vision to reduce the pressure on Europe's fresh water sources by 50% by:

1. **Rationalising the water use**, based on a fit-for-use approach to a multiple waters concept (the right quality and quantity of water, for the right purpose and the right user);
2. **Reducing total water use** within agriculture, industry and households by up to 30%;
3. **Increasing re-use and recycling water** within the concept of the circular economy reaching up to 30% re-use.

Existing and emerging technologies (KETs, FETs) from the research component KC2 will also be used in KC1 **innovation actions** to valorise by-products in used water, such as nutrients, metals, minerals, chemicals, and energy. Combining these technologies and new business models designed under the non-technological part in this KC, will enable new by-products and energy in water to be exploited and give entrepreneurs the possibility to develop new markets, create new jobs and strengthen Europe's position in the international water, resource and emerging circular economy market.

KC2: Technologies (Research and Innovation)

Research and new knowledge creation remains essential for Europe's water sector to tackle societal challenges and develop the enabling technologies. They will also be linked to address policy challenges, such as WFD goals and other related policies (energy, conservation, agriculture). **KC2** is predominantly targeted at the **research and technology developments** (as opposed to Innovation Actions) that are needed to realise the Water Europe's vision, overcoming technological bottlenecks, such as still too high cost of water treatment, but also to develop the new digital technologies that enable the water sector to be connected into the emerging cyber-physical world by smartening water services and cycles, and benefit from new water governance and (self) management capabilities. This required new and low-cost **sensor** and **key-enabling water treatment technologies** needed to be developed and tested at smaller scale **Research and Innovation Actions**, before wider deployment can be done in real life environments, e.g. in KC5 Living Labs. This counts equally for new big-data generation, processing, modelling and analyses methodologies and (software) technologies for water, which have to study how we will be able to capitalise on the "Internet of everything" in the water-world.

The results of KC2 will typically be at **TRL 5-7 levels**, before they can be "transferred" to the other KCs in the SIRA to be used in closer to market Research and Innovation Actions, to validate their viability in relevant experimental environments, e.g. in KC1 The Value of Water or even in KC5 Real Life Living Labs.

KC3: Hybrid Grey and Green Infrastructure (Non-technological, Research & Innovation and Innovation)

The European water infrastructure will need to be upgraded and partially redesigned, in order to be able to underpin both i) the visionary Value of Water, hence "multiple waters", as well as ii) a robust and resilient financially viable and energy efficient water infrastructure. **Non-technological innovation** will be required to develop the longer term financial and investment models as well as asset-management strategies. Also here affordability of urban water services will need to be taken into account Therefore, these will have to account for the costs of a partially redesigned water system (in the medium to long term, see Chap 2 below) that requires new **research and innovation actions (TRL 5-8)**, to develop **integrated natural and human built systems (including new materials), novel maintenance technologies and strategies**, but moreover a **system that enables multiple loops for multiple waters**, meaning different water treatment systems at all levels, and a system that is resilient against climate change effects, such as floods and droughts.

KC3 foresees actions to develop the new knowledge and technologies to be able to redesign and build the future infrastructure. R&D and advancements in new **business plans/models from KC1** and **technologies from KC2** (i.e. sensors, models, surveillance technologies, etc.) will be implemented in KC3 to increase the overall resilience of the European water infrastructure and mitigate the effects of floods and/or droughts. **Results from KC3** will be used to realise pilot set-ups in the **KC1 Innovation Actions** in function of the key objectives: 1) rational use of multiple waters, 2) reduction of use and 3) increase of re-use and recycling, which needs to be facilitated by the new infrastructure. Later on, the outcomes of these smaller scale pilot actions can be scaled-up and flow into **KC5 Living Lab experiments** at full societal scale[5].

The financial and investments models that make it possible to build these costly Real Life Experimental environments that will be developed under KC3 as part of the overall economic asset-management models. They will be experimented and fine-tuned in KC5 Living Labs, in order to develop and showcase the migration paths before roll-out throughout society.

KC4: Governance (Non-technological, Research & Innovation and Innovation)

In the future water-smart society the increased interrelations between different water users from different economic sectors will become significantly more evident, due to the shared risks related to potential water scarcity, and impact of climate change effects, as well as the interconnection between water users which is part of the solutions to reduce the stress on our natural water system. The former leads to the needs for the creation of new water stewardship schemes (to be further developed under KC 6 Horizontal) but also other **non-technological innovations** to be developed under **KC4**, to jointly govern our human water cycle and distribution, through new multi-stakeholder governance models.

Also under **KC4**, new digital technologies will be developed in dedicated **Research and Innovation actions** that leverage on the emerging capillary network of sensors, observation systems, modelling and analysis technologies from **KC2 Technologies**. Innovative application driven Decision Support Systems (TRL 5-7) will be developed under KC4, that use Big Data in advanced analytical software systems for longer term projections of water availability, the impact of climate change effects as well as energy, financial and asset management models from KC3. This will underpin the new multi-stakeholder water governance set-ups to take better management decisions based on adequate data, and enabling fair allocation of multiple waters to multiple users in cities, industrial areas, for agriculture in an ever more closely integrated geographical area.

KC5: Real Life Living Labs (Innovation)

Whereas several smaller scale trials and demonstrations of all types of innovations will take place within the other KCs (see above), KC5 will be set-up to select very large scale real life environments to offer the opportunity to **integrate all research and innovation results from KC1 – 4**, whether technological or non-technological.

Among the main barriers and bottlenecks for innovation in the water sector defined by EIP Water, there is high capital intensity (with built-in risk aversion), and lack of adequate business models[6]. Moreover, real-life long-term experimental programmes are needed, where the actual added value, societal and economic viability of the **combined innovations** can be validated within a representative visionary experimental innovation environment at a sufficiently large scale. In order to implement the Water Europe's vision towards water-smart economy and society, challenging decisions need to be made to transform the current water infrastructure and system **into a completely redesigned set-up, implicating large investments in multi-loop, smart, integrated grey and green infrastructure** (output from **KC3**) as well as completely novel decision and governance structure (**KC4**) to apply new economic models, incentive systems and cascading strategies (**KC1**). It is the intention of **KC5** to facilitate multi-stakeholder collaborations in Rural, Industrial and (Peri-)Urban, to plan such longer term (5 – 10 year) experimental programmes, based on solid (multi-) financial investment and governance or business plans. On top of this, some Living labs will also combine at regional or international river basin scales the 3 area types targeting across border sustainable, robust, resilient and dynamic water-smart systems strengthening Europe's contribution to solve global societal challenges and enhancing the water market. Specific Living Labs will be developed outside of Europe, with the aim of reaching SDGs targets and promote International Cooperation and water diplomacy including various water-related nexuses.

The following chapters elaborate more in detail on the challenges, goals and required research, development and innovation actions required for each of the Key Components.

Indicative timeline and time projection of the SIRA

As explained in the Water Europe's Vision, only through a real paradigm shift in the way Europe addresses current water challenges and transforms them into opportunities, it will achieve a true future-proof water-smart society.

In order to reach this paradigm shift and bring the actual situation in the European water system to achieve the objectives and the targets of the Vision, Water Europe proposes a three-stage approach over time:

1st Stage: Shorter to medium term impact measures (2017 – 2021)

Stage 1 will target actions that can generate and demonstrate "immediate" return on efficiency and management opportunities resulting from Water Europe's Vision, including the following actions:

- Multiply water sources: e.g., implement mature technologies to make available saline/brackish waters for societal needs;
- Support to closing the water loops in a circular economy: implement reuse/recycling/cascading and resource and energy recovery in large demonstration projects, focussing also on quality of water;
- Optimise the use in Rural (e.g., water-effective irrigation technologies), Urban (e.g., water efficiency campaigns at household level), Industry (e.g., foster industrial symbiosis);
- Retrofit or dote current water infrastructure with available technologies and ICT (e.g. sensors) to improve monitoring/managing capacities, reduce losses, improve resilience (including flood protection), improve energy efficiency;
- Support eco-innovation champions (especially SMEs);
- Green Public procurement to promote eco-efficiency;
- Other incremental innovations that have a significant resource and energy efficiency impact, also taking into consideration the water-energy nexus;
- Start 'smartening of the water system': implement sensor networks, big data, information (IoT) and control systems for water, network communications, advanced technologies and capabilities (i.e. HPC – high performance computing) for quasi-real time data analysis, forecasting, visualisation technologies for advanced decision support; tools for smart water value chains digital management at different geographical levels;
- Implement measures to tackle diffuse pollution (including source control);
- Improve our understanding of water value, though studies and new models on water/health, water/energy/waste nexuses, water cycles, value of ecosystem services, climate impact;
- New skills and educational programmes at National level enhancing smart specialisation for water;
- Capacity development, awareness raising and public engagement on the true value of water and water usage for all stakeholders (managing authorities, decision makers, water professionals, entrepreneurs, citizens, etc.).

2nd Stage: Medium term impact measures (2021 – 2025)

Stage 2 will target those actions that may not be implemented "immediately" in the installed base, but target a quick migration (evolution) towards improved water systems, including the following actions:

- Enlarge 'smartening of the water system': wider sensor networks, advanced technologies and capabilities (i.e. HPC) for quasi-real time data analysis, forecasting, visualisation technologies for advanced decision support from Big data for water towards complex systems, machine learning, and artificial intelligence;
- Develop and implement new sensors for progressive water quality and health monitoring; advanced control systems for network management, optimisation, prediction, diagnosis, digital systems' services for water assets;
- Increase manageability of water infrastructure and its resiliency to climate change and extreme events, also through higher integration of grey engineered and natural infrastructure into the grey-one;
- Implement decentralised water systems with advanced information and control systems and network communications implementing digital systems' services and systems' health monitoring;

- New water pricing schemes, based on a combination of i) cost recovery, including internalisation of environmental costs and a true valorisation of 'tangible' ecosystem services, ii) price diversification per sectors/users based on the polluters' paying principle, and iii) incentives for rational use of water. Re-shape (legal) accountability for water, build mutual trust;
- Embed the Nexus approach (water-energy-food-land use-climate) in governance models;
- Water component integrated into new or existing urban planning in major European cities;
- Apply new decision support systems to manage competing users of water resources and systems;
- Apply first multi-stakeholders' governance models into large living labs: create multi-stakeholder partnerships, public-private open innovation platforms, to foster collaborative and continuous open innovation between civil society, industry/RTO/SMEs, industrial symbiosis, and joint technology market places;
- New skills and educational programmes with cross-national, cross-sectorial and cross-competence focus;
- New tools for water impact assessment (including LCA – life cycle assessment, and nexus analysis);
- Strengthen international cooperation through the support to cohesive policy making (and financing) around UN Sustainable Development Goals - SDGs on Water and on Partnerships.

3rd Stage: Medium to Long term impact measures (2026 – 2030)

Stage 3 will target those actions that revolutionise the European water system through breakthrough development, and require significant capital and resource investment in new technologies, models and tools, including the following actions:

- Redesigned water infrastructure, following the "multiple waters" approach according to the needs of the local situation;
- Water component fully integrated into long-term planning of European cities, regions, Members States, with high focus on resilience;
- Multi-stakeholders water governance model in place in major water hubs in Europe (cities, regions, river basins, etc.) based on quadruple helix stakeholder interactions;
- Contribute to the creation of a global partnership for development in the Water sector (public, private, civil society).

Key Component 1:

The Value of Water

Water Europe's VISION

A future European society that fully recognise the value of water for all sectors, managing our precious multiple water sources as a holistically integrated system, treating and distributing the right water for the right purpose to the right users based on a circularity principle of water (i.e. cascading, reuse, recycling), considering the Nexus approach (water-energy-food-land use-climate) across sectors, addressing single sectors. New economic mechanisms based on the value of water will guarantee fair and efficient access for all, with diversifications based on availability, cost and value, taking into account the costs of making our water systems more resilient to climate change and extreme events (i.e. floods and droughts).

By 2030 the value of natural assets and ecosystems will have been incorporated in the total cost of infrastructure and pricing of water, as well as the value of recovered materials and energy as a new 'feed' for their reuse. Water-related development plans will have been based on regional cost-benefit analyses and economic tools and will have included the cost of water resilience plans as well as the benefits of prevented damages caused by water disasters. Furthermore, new business models will have emerged that enable and support the costly redevelopment of the water infrastructure. Water will have been an integrated and recognised element in policy making for all sectors, based on much deeper insights and foresight capabilities on availability, built on (Big) data and widely accepted Water Impact Indicators.

By 2030 the European water sector will have become a true, dynamic and world leading energy and resources industry and market, boosting 5 to 10 fold the exploitation of the economic value that is in water, ensuring no water limitations for end users and hence no disruption in economic production and further enhancement due to water shortage. Water scarcity, i.e. the mismatch of demand and supply, should be practically non-existent, even in periods of droughts.

Challenges, goals and actions

Sub-challenge	Goals	Actions
S1 • Towards new economic models for the value of water	• Realise the true value of water implementing cross-sectorial approach and nexuses; • Full cost recovery towards increased sustainability of water systems; • Define who pays for water (e.g., according to the Polluter Pays Principle), or alternatively, who benefits (e.g., Benefit Pays Principle).	• New pricing mechanisms; • New business models; • New financing schemes and instruments; • Internalised environmental impact and ecosystem services.
S2 • Towards multiple waters in a circular economy	• Decouple water demand and availability from natural water cycles (including climate change risks); • Provide fit-for purpose water to different users for different uses.	• Multiply water sources; • Support to closing the water loops in a circular economy: implement reuse/recycling/cascading; • LCA of 'new water' as a new resource/feed; risk assessment and abatement strategies, new standards.
S3 • Optimising the use of water in all sectors	• Reduce dependency on water availability and quality; • Make more with less water.	• In Agriculture, Industry, urban.
S4 • Creating new markets, valorising the value in water	• Strengthen and consolidate the leading position of the water market in and outside Europe; • Create growth and jobs in a multi-Billion market.	• Cost-efficient recovery of valuable resources from water; • Implementing mature technologies for more efficient water treatment.
S5 • Energy harvesting as integrated valorisation strategy of water	• Fully exploit the water-energy nexus.	• Extract energy from water fluxes; • Exploit energy gradients in waters; • Reduce energy-intensive water needs (e.g., heating, cooling, etc.).

General Objective:

This Key Component is targeting the development of a water-smart economy for Europe, enabled by new technologies, economic and business models while ensuring healthy natural inland (surface and ground) water ecosystems

KC1-Sub-Challenges

KC1-S1-Towards new economic models for the Value of Water

Challenges/opportunities

Defining **a price that reflects the true value of water** is critical, for both the effectiveness and the integrity of any proposed water pricing systems, contributing to the long-term sustainable management of water resources. However, calculating the right price is clearly not a simple task taking into account, as a minimum, the 'polluter-pays' and 'user-pays' principles. Article 9 of the WFD introduces the principle of cost recovery for water services and obliges Member States to provide adequate incentives for the sustainable use of water resources. In addition, it promotes the internalisation of environmental and resource costs that result from existing uses of water resources and of aquatic ecosystems[7].

Currently there are wide variations in water charges within and between countries in Europe, because of the wide range of factors that determine local water prices, and whether there is a full recovery of costs, including those for water treatment and supply, for sewage treatment and for environmental damage . In the last years, many countries have made significant progress towards more effective water pricing policies that should reduce water demand. However, far less progress has been made in the agricultural sector compared to the domestic and industrial sectors. Agriculture, which is still widely subsidised, pays much lower prices than the other sectors, particularly in southern Europe, also considering its impact on pollution of water bodies. A thorough understanding of the water-food nexus in Europe would be advisable to propose specific pricing mechanisms for agricultural water.

Increased prices are likely to produce a more marked effect on water use where supplies are metered, water prices are high in relation to income, exploitation is high and where public supply is a high percentage of total supply[9].

Effective **financial planning** for the water sector requires finding the right mix of revenues from the so-called "3Ts": tariffs, taxes and transfers (including grants). This will help to attract other sources of financing (i.e. loans, bonds and private investors), crucial for making the large, upfront investments normally required in the water sector, but they need to be repaid by some combination of the 3Ts in a continuous, reliable manner[10]. In support of this, there's also a need to combine multiple financial sources', including maximising synergies with already existing instruments. Ultimately, this will also lead to secure longer term availability of capital to invest and revamp Europe's water infrastructure for the future water-smart society.

New **economic mechanisms** (e.g. incentives) have proven to be effective in promoting the adoption of new paradigms in services and uses of resources, including behavioural change for different users at all levels (e.g., the remuneration for the collection/differentiation of specific waste streams for single users, or the incentives to adopt energy-efficient technologies for industries, among others). This can be applied also to the water sector, specifically targeting the promotion of behavioural changes by multiple users.

Research and innovation Priorities

• **New water pricing schemes and models**, based on a combination of i) cost recovery, including internalisation of environmental costs and a true valorisation of 'tangible' ecosystem services, ii) prices diversification per sectors/users also based on the 'polluter -pays' principle, and iii) incentives for rational use of water. New pricing systems should take into account the crucial role of the agriculture sector in the whole water cycle, as well its current unbalanced contribution to the full cost recovery, thus aiming at reconciling water and agriculture, as set in the Common Agricultural Policy (CAP) and other related policy instruments. New water pricing for agriculture should be proposed, combined with the provision of "smarter" water supply options enabled by ICT-based solutions that is also encouraged by the European Court of Auditors report conclusions on linking CAP and WFD[11]. Regional differences and climate change impacts should be taken into account in agriculture sector (i.e. this is a key priority in water-scarce area).

• **Innovative economic mechanisms** to stimulate water-efficiency by multiple users, i.e. i) financial incentives for recycling, industrial symbiosis, and water savings are needed to promote a more efficient use, reuse and recycling of water in industry, agriculture and urban endeavours; ii) new financing mechanisms to promote the uptake of green infrastructure, that effectively shoulder "technology" risks in a cost effective manner (e.g., loan guarantees and contingent finance). These new economic mechanisms should go in parallel with new financial models and corresponding tariff changes to promote Integrated Water Management, when direct reuse is not possible including aquifer recharge practices.

• **Innovative business models for the water sector**, aligning economic, financial, environmental, and social issues (customer cantered business model). This includes: i) designing Green Growth strategies and Resilient Growth strategies followed by the action plans for the water sector; ii) building solid business cases for green infrastructure, going beyond the strategic and economic business case towards the financial, commercial and management business case (links to Green Public Procurement); iii) incorporating real options analysis and analysis of weather Value at Risk[12] in different Water Infrastructure Investments to build the business case for Adaptation and Resilience within ongoing infrastructure investments.

KC1-S2 - Towards multiple waters in a circular economy

Challenges/opportunities

The vast majority of water supply in the world, as well as in Europe, derives from fresh-water sources such as ground and surface waters. Within a growing global population, as well as industrial activities, it will be necessary to reduce the growing stress on natural water sources, both in terms of pollution and in terms of water abstraction. We will need to gradually make multiple alternative water sources available to complement current abstraction from ground and surface waters, with useable water from additional sources (i.e. brackish, salt, and recycled water), in a cascading and "fit-for-use" approach. New rainwater harvesting approaches, cost effective and energy-efficient desalination and treatment of salt water and brackish water to the right quality level and re-use strategies, including industrial symbiosis need to be developed and gradually introduced in a migrating redesigned water infrastructure.

Industrial symbiosis has proven an effective paradigm for a step-change in the way European industry manages its flows of resources, waste/heat/energy flows and nowadays it is starting to be applied to water as well. So far most efforts have concentrated on reducing industrial water use and increasing reuse/recycling through the adoption of new technologies and the exchange of different water flows between industrial plants. These previous positive experiences need to be pushed forward, enlarging the scope of action beyond plant or district boundaries to fully harness the interlinkages of industry with urban and agricultural/rural areas. Advanced technological developments and better interlinkages with water are also urgently needed in the energy production sector, with the purpose to ensure water efficient use and reuse in internal and external energy industry water cycles and value chains, linking water security with the energy security for realising the European Energy Union.

The complexity of the water sector implies that, for the new solutions to take effective place, the entire multitude of stakeholders of the whole value chain are involved in decision making, balancing economic (market) mechanisms with the intrinsic value of water as a common good.

Research and innovation Priorities

Multiple water sources

• **New sources harvesting methods (TRL 6-7)**, i.e. i) rainwater harvesting methods and management techniques, and integration in urban and rural water provision strategies; ii) Drainage water harvesting methods and management techniques for urban, agricultural, and industrial purpose.

• Implement and deploy **new cost-effective combinations of salty and brackish water, desalination and (natural) pre-treatment (TRL 6-7)**, to replace fresh water use in all applications.

• **Develop structured and certified alternative water resources for irrigation (TRL 6-7)**, and different users, i.e.: i) technological solutions for reuse of industrial wastewater in agriculture, based on benefits/threats analysis, following the circular economy principle; ii) promote the role of saline agriculture in multiple waters for multiple uses.

Support in closing the water loops in a circular economy

• **New management tools and methodologies, partnerships and business models** for industrial process water reuse and recycling; this includes: i) developing (industrial) matchmaking platforms for the valorisation of waste water, based on the value for different industries (and sectors) and the value in water; ii) decentralised treatments in synergy with existing centralised treatments.

• **Enlarging the Industrial symbiosis concept to agricultural sector**, working on the industry-agri- and industry-urban interlinkages on use, reuse and recycling of (waste) water as water supply/source for agriculture following a circular economy approach; **New tools to support industrial symbiosis (TRL 6-7)** (sustainable development tools, LCA Water, LCA Waste).

• Fostering circular economy through **public-private industrial partnerships** (including SMEs) for the integrated water management via nexuses. (Foster the exchange of by-products among industries in order to improve resource efficiency; achieving participation from private entities).

• **Promotion and rationalisation of (quasi) Zero Liquid Discharge (ZLD) approaches in industrial applications (TRL 6-8)** through maximisation of reuse, recycling and cascading of water. Application of existing technologies and solutions for (quasi) ZLD processes and techniques, as well as on evaporation processes and techniques.

• **New schemes of water reclamation (TRL 6-8)** compatible with high quality demand of industrial sector.

KC1-S3 Optimising the use of water in all sectors (in and outside Europe)

Challenges/opportunities

In order to reach the Water Europe's vision of **ensuring availability of good quality multiple waters for multiple uses across Europe**, there is an urgent need to optimise the current use of water, especially by developing strategies, systems and practices to 1) dramatically reduce water pollution by users, 2) rationalise and reduce the use of (fresh) water for different applications by users, and 3) boosting water recycling/reuse/ cascading in all sectors and for all users.

To address the water scarcity issue, a number of actions are listed in the European Commission's Communication 'A Blueprint to Safeguard Europe's Water Resources'[13]. Among these actions, the EU plans to take measures to develop additional water supply options, including **water reuse**.

Water reuse may have a lower environmental impact than other alternative water supplies (e.g. desalinisation) and may offer a range of environmental, economic, and social benefits. This option, however, has been developed only to a limited extent in the EU. According to the EC, at present, only about 1,1 Bln m^3 of treated urban wastewater is reused annually, which accounts for approximately 2.4% of the treated urban wastewater effluents and approximately 0.4 of annual EU freshwater withdrawals[14].

There is a clear need to close the loops in all stages of water-use-discharge-re-use in all sectors, based on thorough analyses of the cost-opportunity of novel solutions, as well as taking into account regional and local differences. Advancement of knowledge in agronomy, hydrology and water-related disciplines, as well the use of digital technologies (e.g., for smart metering and monitoring) can dramatically help this process.

In parallel, strategies, systems and practices need to be developed, deployed and experimented to avoid pollution and stimulate rational use of fresh water, fostering a cascading approach, using the highest value water, for the highest value applications and optimising cost strategies for different value applications of water and ensuring risk assessment and adequate management.

Research and innovation Priorities

Optimise the use of Water in Agriculture

• **Optimal irrigation strategies (TRL 6-8)** focussing on efficient water reuse, energy saving, nutrient recycling/recovery, new techniques for water retention in soil and integrated agricultural water management under drought conditions; implementation of **innovative smart irrigation systems (TRL 6-8)**, taking into account regional differences.

• **Implementation of drain water management techniques (TRL 6-8)** to optimise water (re)use in aquaculture (crops and livestock).

• **Agri-environmental measures**: collaborative incentives (such as water quality groups) and financial incentives in limiting discharge of pesticides, nitrates and other emerging pollutants to any water body with the purpose of protection of drinking water resources.

• **Validate and deploy new digital (ICT) solutions for sustainable agriculture (TRL 6-8)** towards "more crop per water and energy drop", i.e.: i) smart management tools, including smart metering and monitoring water quality in real time to detect deviation, and for drinking water supply for livestock; smart solutions for the use of the alternative water resources in agriculture, improving distribution networks and support irrigation practices; ii) development of more efficient agricultural breeding and growing practices (reduce "drop per crop").

• **Decoupling the rise of agricultural production from the use of water resources**, i.e.: i) combination of hydrological and agronomical knowledge to diminish water consumption (drought resistant crops, etc.) and management in water scarce areas; water allocation scenarios and optimisation methods in the increasing of extreme events periods; and ensuring environmental protection (eutrophication, soil erosion, sustainable use of pesticides).

Optimise the use of Water in Cities/Urban

• **Combining water and energy efficiency in the urban context**, integrating this nexus **with smart urban management and planning solutions**, including decentralised treatments; promote synergies with waste management; water efficiency and recycling in energy production and supply sector, energy/heat recovery from water, looking at maintaining safe drinking water systems. Energy efficiency needs to be addressed in Water Conveyance and Water Circuits at different scale in urban and rural areas. R&I actions need to address: (a) Tools for demand forecasting (urban + industry + domestic), (b) SMART Operation to target the water-energy linkage (Utilities and household level), (c) Decentralised systems (technology), (d) Reduction of energy losses[15] (links with KC1-S5 below).

• **Increase awareness and improve perception** on direct reuse as drinking water (by means of education and demonstration of the technology) and, where not possible, promote indirect reuse through recharge. (Link to KC6 – Horizontal).

• **Urban-environmental measures**: collaborative incentives (such as water quality trading groups[16]) and financial incentives in limiting discharge of pollutants to any water body with the purpose of protection of drinking water resources.

• Interdependencies between urban and non-urban areas for **watershed management problem solving**.

• **Smart digital water management systems in cities via nexus and circularity approaches**: Living labs for smart water management in the city linking 'digital waters' city concept with nexuses of water-energy –waste and integrated city planning and management.

• **Urban/industrial symbiosis**: use of urban biomass, water, waste streams in industrial applications. Innovative solutions addressing water footprint in urban & peri-urban areas. Symbiotic approaches to enhance cross-sectorial cooperation in the city context in closing water loops. In-site recovery of valuables to increase viability (links to Living labs KC5).

Optimise the use of Water in Industry

• **Sustainable process water production by water recycling at various scales (TRL 6-8)** (regional, local, urban) in a circular approach, with an integrated water/resources/energy approach, closing the loops, to multiply benefits for industry at single level (efficiency) and among industries (symbiosis). Need to demonstrate at large scale, in several sectors (especially water intensive industries, e.g. process industry, energy industry and mining). The demos should include on a thorough study of the additional infrastructure and investments required to make such flows of waste water and cascading of different processes possible, and how should these investments be shared by the stakeholders in those value chains. Apart from the different scales it is also important to analyse the possibility of different water qualities depending on the final need. (Links to S2 - Towards multiple waters in a circular economy).

• **New solutions for an increased upstream process integration (TRL 6-8)**: water & energy, water & waste, water & chemicals or other raw materials.

• **Standardisation of materials, specifications and technical solutions** aiming at lowering the cost of network maintenance and replacement (including lining, trenchless technologies, and low cost sensors to assess infrastructure status).

• **Integrated water management technologies (TRL 6-8)**: for evaluating and optimising water flows and balances in the industrial processes enabling water conservation, reuse, cascading, recycling realising industrial symbiosis concepts in water-consuming industries (i.e. process and manufacturing industries, food processing/production, etc.). This includes technological, digital and managerial solutions to address water scarcity and reduce water footprint in process industries.

• **Water-energy-waste nexus in industrial environments (TRL 6-8)**: through making understandable the influence of water consumption in energy consumption as mechanisms to reduce costs and make production sustainable (in process and manufacturing industries).

• **Development of methodologies and pilot applications of LCA for water** in the value chains of the process and manufacturing industries.

All the optimisation actions mentioned above need to use various digital solutions as an overarching component of innovations that are based on the elaboration of specific digital models, hardware tools, sensors, techniques, and software service systems to ensure smooth optimisation of water (re)use and integrated management various water cycles (at rural, industrial, peri-urban, etc. levels).

Water Europe
Technology & Innovation

KC1-S4 Creating new markets, valorising the value in water

Challenges/opportunities

There are huge opportunities for economic development, growth and jobs in the water sector for Europe, by stimulating various industries in the water value chain to develop novel solutions, business models and even new value chains. As stated in the recent EC Communication on WFD and FD: 'EU water policy has also made it possible for the EU to develop a dynamic, world-leading water sector that includes 9.000 active SMEs[1] and provides almost 500.000 full-time equivalent jobs.[2] It is therefore much more than a response to an environmental imperative: it is a building block for the EU to spark green and blue growth and become more resource efficient'[17].

European industries are leaders in relevant technologies and solutions for a future smart-water Europe, in several fields, such as membranes (e.g. ultra-filtration), software systems and algorithms for decision support systems, electrochemical technologies for industrial waste valorisation, and many others. A crucial role is played by European SMEs (i.e. technology providers, engineering firms, consultancy companies, etc.), which hold a huge potential for innovation that should be better exploited for the benefit of European society.

Europe has the opportunity to strengthen its position as world leader of smart water solutions and to export abroad its model for a future smart-water society, which combines these new technological solutions with modern inclusive governance practices.

Most part of the value that is in water is currently unexploited (i.e. heat, energy, nutrients, minerals, metals, chemicals, etc. - informal estimations are in the range of **potential 60-70% yet to be exploited**). This means that Europe is already losing a huge opportunity in terms of economic development, EU competitiveness and jobs not only in the EU water sector, but also in other related sectors of the EU economy. Technological solutions and management models are already mature in many cases but need to be supported by full demonstration, market validation, changes in policy, regulations and normative, to promote their large employment in different markets and applications, fully expressing their potential. (New and emerging technologies are instead addressed in KC2).

As a result, making resources from (waste) water available for our society establishes a crucial contribution to the new available water resources via circular economy and long term sustainable society for ever more scarcely available finite raw materials. Water treatment plants and water-intensive industries have the opportunity to increasingly become sources of valuable water resources, energy, and new secondary raw materials and to exploit the value of these in an economic perspective, fully valorising water streams from all sectors (industry, agriculture, urban). Selection of best solutions should be made on the basis of cost-benefit and cost-threats analyses. Their development and implementation should be based on positive business models and plans.

Research and innovation Priorities

Cost efficient recovery of valuable resources from water

• **Nutrients, minerals and metals (TRL 6-8)**: New cost-effective technologies for advanced resource/energy recovery from fresh and waste waters (including decentralised treatments); integration of nutrients and other recycled materials into a local circular economies, with the potential to replace importation of critical finite resources /critical raw materials; developing sustainable use and economic returns from nutrients in agricultural and agri-energy by-product streams; foster innovation and entrepreneurial business cases for the exploitation of value in water (especially for SMEs).

• **Valorisation of industrial brines (TRL 6-7)** for production low quality and high quality fertilisers: there's a growing attention to an unsolved problem in (industrial) treated water: brines and their content. If appropriately extracted, this could lead to a substantial volumes of valuable organic elements, such as P, N, K, Mg, for different types of fertilisers. Moreover, brines can be reused as sources for salts, minerals, nutrients, acids and alkalis but also for salty aquatic cultures (algae and fish).

Implementation of improved technologies for water treatment

• **Boosting the value of membrane and other separation technologies in water (TRL 6-8)**: Market Replication and Business Models; (a) Production of large quantities of membrane and modules, reducing the production costs through economy of scale, and scaling-up and integrating modules in large systems; chemical free membrane operation and relation to pumping costs. (b) Integration of electrochemical technologies for industrial waste valorisation: electro-dialysis (mono and bipolar technologies metathesis) production of chemicals (acids and alkalis); development of low cost technologies for efficient separation of interferences;

• **Pilots for new nano-membrane technologies applications for water purification and treatment (TRL 6-8)**: Safe water purification, filtration, desalination via nanotech systems; nanoparticles as powerful adsorbents to remove contaminants, nano-silver ceramic filters (antibacterial action) ; nano-membranes (e.g., organic polymer-based nanocomposites at molecular level); MIM- molecular imprinted materials with strong membrane permeability; nano applications pilots for water: anti-biofouling nanopattering, nanoscale optical instrumentation and integrated sensors to detect fungi, bacteria for environmental use;

• **Pilot systems and tools of nano-technologies applications to ensure clean water (TRL 6-8)**: Detection of contaminants in water systems; innovative detection, protection and identification methods, detection systems for biosensor monitoring of bacterial and viral contamination of e.g. drinking water supplies. Testing of technologies/ demonstration pilots of **engineered nanomaterials (ENs) detection** and risk assessment **in water systems and cycles**: closing the knowledge gap of hazardous effects on engineered nanomaterials for human health and in water ecosystems.

Non-technological support to the EU water market

• Promotion of **new policy developments, new regulation and incentives**, to support full deployment of new technologies in the market, e.g. set up clear standards for new membranes, incentivise deployment of digital systems, etc. (links to KC6-S1);

• **Fostering a level playing field for the EU water market**, promoting synergies and collaborations towards a European smart-water market place, based on the open innovation approach.

KC1-S5 Energy harvesting as integrated valorisation strategy of water

Challenges/opportunities

Highly interlinked with the availability and use of water of desired quality and quantity is the **water-energy nexus**. On the one hand, several steps of the water use and management cycle (transportation/distribution, heating, treatment, etc.) are associated with high use of energy. On the other hand, water is a natural carrier of heat and energy gradients, which could be re-used to improve energy efficiency in several ways (e.g., static and kinetic energy gradients, low/ medium temperature heat for industrial processes, biofuel, and biogas production from sewage sludge).

The water-energy needs to be taken into account at all levels, from the overarching water management (combining smart-water and smart-energy), to new solutions in various steps of the water chain (energy harvesting and production at source, heat recovery from different waters, decreased cooling needs).

Research and Innovation Priorities

• **New technologies for energy-efficient water treatment, including new decentralised systems (TRL 6-7)**: disinfection/ germ reduction without chemicals (e.g.-UV technology), innovative desalination/mineral reduction, innovative water treatment; aeration technologies to reduce energy consumption; energy (heat) recovery from wastewater treatment;

• **New energy-efficient measures in water-intensive industries (TRL 6-7)**: industry methods and techniques to reduce the use of cooling water and its impact on water systems; energy efficiency in energy production industry/power plants, in sludge and other biomass drying systems and its coupling to renewable energy supply; **smart energy management systems (TRL 6-8)** and technological solutions in water cycle for increased efficiency in the energy nexus 'generation-storage-consumption'; integration of smart water and smart energy in water and in energy sectors;

• **Water-energy nexus in energy sector (TRL 6-7)**: water for energy production (cooling), energy/heat harvesting from water: employing water efficiency, reuse, cascading via new technological developments (water and digital) and organisational/business models; pilots in energy sector to decrease water consumption, increase water use efficiency and energy/heat harvesting from water;

• **New ICT solutions for energy and water efficiency (TRL 6-8)**: autonomous monitoring in water networks (drinking, sewers, industrial water cycles), energy/heat harvesting and reuse from water; optimisation of water use in cooling / heating in other process industries (big water consumers);

• **Increase energy production from water sources (TRL 6-8)** and/or energy recovery in water flows through efficient turbine technologies;

• **Reduction of energy losses (TRL 6-8)** along the water system: well management, scaling, fouling, corrosion, leakage, pipe sizing, material behaviour and ageing, warm water and hygiene in clean water installations (Links to KC3 – Infrastructures);

• **Digital Tools and systems for demand forecasting (TRL 6-8)** (urban + industry + domestic) for efficient network, buffer and pumping management.

Key Component 2:

Technologies – enabling insight and manageability

Water Europe's VISION

By 2030 we will have had insight in water quantity and quality, and will have been in control of the water cycle, will have had no major water limitations for end users, or disruption in production due to water shortage, we will have been able to manage allocation of multiple water resources for multiple uses/users, thanks to a dynamic monitoring and decision support systems ("Digital Water"). Furthermore, we will have been able to plan medium term actions to avoid future supply shortages and overloading of the infrastructure by using trend analysis and forecasting capabilities.

Open innovation and open-science will have harnessed Europe's global leadership in water technologies, e.g. for water source protection, water treatment, water information systems, for quasi-real time decision support. Innovations in water treatment, increased awareness and better user-oriented management tools, will have led to strong reduction of water pollution and will have enabled waste water in Europe to be recycled up to more than 30%. In various areas in Europe the water loop is almost closed to a 100% for important water users, such as industry and citizens.

Ambitious living-labs in cities, rural and industrial areas will have involved different multi-stakeholder governance collaborations, to develop and test new technological and non-tech solutions and to foster accelerated market introduction, thus helping Europe exporting its model for a smart-water society abroad (links to KC5).

Challenges, goals and actions

Sub-challenge	Goals	Actions
S1 • Digital enabling technologies for a water-smart society	• Measure, monitor, control the status of water bodies; • Smartening of the water infrastructure; • Achieve improved data-driven insight, forecasting and decision making.	• Develop and deploy innovative sensors; • Develop and deploy innovative technologies, methods and tools to collect, store, analyse data; • Forecasting technologies and visualisation for advanced decision support.
S2 • Technologies for safeguarding surface and drinking water from pollution	• Prevent pollution at source and in all the water cycles; • Better understand the links between pollution and health; • Remove/minimise pollution in water systems and bodies.	• New technologies, analytical and digital instruments and systems, and strategies for pollution detection, monitoring, analysis and identification of actions/roadmaps; • New water and digital (nano-membranes based and other) technologies for pollution removal.
S3 • Enabling cost efficient water treatment technologies to foster re-use, recycling and cascading	• Improve water quality, with a multiple waters approach; • Extract and make available valuable resources and energy; • Support the application of the multiple waters concept through the right mix of centralised/decentralised systems.	• New treatment solutions for recovery and (re)use of recovered resources (and energy); • New solutions for decentralised treatment.
S4 - Advanced technologies and approaches for water management in agriculture	• Increase water efficiency in agriculture sector.	• R&D on new technologies for "omics" and precision farming.

General Objective:

This Key Component is aimed at developing the novel underpinning digital and water treatment technologies that enable higher levels of insight and manageability of our water system and will enable the "multiple waters concept" in closed loops, as well as new markets based on the value in water.

KC2 Sub-Challenges

KC2-S1 Digital enabling technologies for a water-smart society

Challenges/opportunities

As stated in the last EPoSS Augmented SRA 2015[18], among main challenges related to water there are:

- Rehabilitation of degraded water zones (surface and groundwater) challenges:
  - Adaptation strategies for climate change (polders, buffer zones creation, reclamation strategies, etc.);
- Hydro-climatic extremes:
  - Forecasting extremes events (including floods), drought forecasting and monitoring; long-term planning on extremes' management, new remote sensing for forecasting and monitoring.

To address these challenges, Europe has the opportunity to leverage on the huge potential that the recent "digital revolution" is making available to enable a much more efficient and "smart" management of our water.

On the one hand, new digital paradigms are ready to be used for **data retrieval and analysis** (e.g., Big Data, Earth Observation data, real-time meteorological data), real-time and quasi real-time data collection, processing, efficient data storage and sharing/exchange at various scales between systems: local/urban, regional, and river basin. **Data-driven and process-based models** can be valorised to drastically increase our insight and foresight capabilities, thus enabling precise monitoring, forecasting methods and visualisation techniques.

On the other hand, recent advancement in **modelling, simulation, control and optimisation** techniques can be further pushed forward for improving overall efficiency in water utilities supply and distribution systems.

The complexity of the interactions hinders the ability to make decisions concerning technology development/ implementation focus. New **system-wide computing and measuring tools** are required that allow informed decision making on varying scales in space and time concerning water, food, energy, biodiversity and other water-related nexuses. The spatial scale reaches from water basin to global, the time scale from long-term for policy development, to (almost) real-time, allowing e.g. informed short-term water distribution decisions.

Finally, R&D advancements are needed to develop **new sensors for water** and detection capabilities to produce data and **High Performance Computing (HPC) systems** and applications to handle them/extract valuable content. There's a need to assess on how far micro and nano-sensors will really fit the water industry requirements and how it will be economically feasible to deploy those new sensors in large volumes in water and wastewater networks and facilities.

Research and Innovation Priorities

Screening strategies, techniques and innovative sensors for advanced measurement and monitoring

- **New sensors for detection and chemical measurement of pollutants (TRL 3-6)**, with the aim of lowering costs and increase their stability and longevity. **Development of sensors** and other specific instruments to detect indicator pollutants (or groups) and to measure specific compounds. Sensors and instruments from detection in natural waters (Links to S2).

- **Passive sampling techniques (TRL 6-8)**: Passive sampling is able to measure a periodic average that includes the potential peak concentrations. It also enhances better measurement at low concentrations due to accumulation of contaminants on the absorbent over time. Passive sampling for hydrophobic organic contaminants, but also pharmaceuticals is already used, but mostly in pilot studies. The step to routine use as a cost effective solution shall be further developed. Passive sampling of hydrophilic compounds requires further development.

- **Active sampling techniques (TRL 3-5)**: Active sampling devices represent a relatively new challenge in sampling processes and require further research. Active sampling should be able to record the dynamics of a polluting event in such a way that it is possible to calculate the actual pollutant flux. Relevant research actions could include (i) a combination of techniques derived from the sensor techniques in real time with use of labile adsorption phases allowing a continuous regeneration of the receptor, and (ii) the development of mathematical models for the analysis of the signals to provide information on the phenomenon dynamics.

- **New sensors for biological measurement of micro-organisms (TRL 3-6)**: New sensors real time, on-line/inline sensors for measurements of microbiological risk markers, low-cost imaging technologies for micro-organisms detection; low cost spectroscopic absorbance and fluorescent sensors (UV-VIS).

- **New sensors for protection, security and resilience (TRL 3-5)** of systems to cyber-attacks. Research and innovation on improving security, backup systems, joined up intelligence sharing.

• **Cost-effective sensors for large scale capillary deployment throughout the water network (TRL 5-7)**: cost reduction of sensors to monitor water quality and use, in broadly diffused networks, such as in pipes, but also at users, to capture detailed data on water distribution, quality and use up to the final user, in support of the multiple waters concept.

• **Sensor systems and online monitoring tools for quality assurance of water sources in industrial processes (TRL 5-7)**: smart online analytical systems (including Big data collection and processing) for continuous monitoring, analysis and assessment methods, including development of sensors to monitor water disinfection (micro-organisms, e.g. legionella); development of water recycle/reuse processes and loops with continuous water quality control, process feedback loops and process control (e.g., in chemical industries).

• **Continuous online measurement, sensor systems and (big) data generation and assessment tools of micro-, nano-, and other pollutants in various types of waters (TRL 5-7)**: in industrial systems and processes, natural water bodies, water distribution networks, and other applications.

Data-driven insight, forecasting and decision making

• **Forecasting (TRL 3-6)**: i) new algorithmic approaches to assessment and forecasting extreme climatic events at various scales (global, regional, river basin/sub-basin, and local). ii) developing integrated forecasting and Early Warning Systems using real-time data, indicating hydrological parameters, pollution loads, and water quality.

• **Improve (big) data collection, fusion, analysis, data-driven process-based models development, and visualisation techniques (TRL 5-7)** to support more accurate decision-making for i) urban water management ii) farmers (runoff, irrigation, advanced sensors for the assessment of soil-water content, evapotranspiration, etc.); iii) disaster risk reduction and response tools (disaster emergency control room facilities and data/model provision). This includes methods to process and digest big data and visualise results for decision making (e.g. serious gaming). It will substantially improve the resilience of our European water systems to climate change and other water challenges (floods, droughts, extreme events).

• **Advanced modelling, simulation, control and optimisation techniques (TRL 5-7)** for improving efficiency in the use of resources in utility supply and distribution systems. Special focus on water cycle systems (including storm waters), synergies between centralised and decentralised treatments, synergies with energy grids, oil and gas networks.

• Smart water networks (drinking and waste water): **cloud computing and real time monitoring (TRL 5-7)** (EIP Water theme) for operators and all other stakeholders; digital systemic solutions for monitoring water bodies' eutrophication, restoration and management of water systems affected by toxic elements (e.g. algae blooms).

• **High Performance Computing systems and applications' development (TRL 5-7)** in water-dependent sectors, for example, to support industrial symbiosis, water-energy-resource-efficiency-food nexuses.

• **Data and metadata standardisation, data security, interoperability, protection and privacy (TRL 5-7).**

KC2-S2 Technologies for safeguarding surface, ground and drinking water from pollution

Challenges/opportunities

In a world with a constant surge of water demand, there is a high need to preserve our water sources from pollution, including thermal pollution, and maintaining sufficient environmental flows to ensure ecosystem stability and services. Diffuse pollution significantly affects 90% of river basin districts, 50 % of surface water bodies, and 33 % of groundwater bodies across the EU[19].

A deeper and more comprehensive knowledge on the impact of emerging (micro) pollutants present in water bodies on human health and the environment is still to be developed and current findings pose already high challenges to our current water treatment systems.

In order to reach higher level of sustainability and quality in our waters, as well as to really implement circular approaches, we need to improve our understanding in the formation and characterisation on a growing number of emerging pollutants, (including micro-pollutants detailed in the Water Framework Directive, new chemical compounds, pharma, plastics, nano- and micro- particles) as well to study their impact on the natural ecosystems and human health.

On the other hand, Future and Emerging Technologies (FET) are needed to detect, monitor, assess the risk and finally remove these (emerging) pollutants from several uses and from several water sources, including the influence of their 'hot spots'. There's also a need to characterise the water matrix of the raw water source, in order to better understand the interactions of these sources with pollutants, as well as enhance their preservation.

Research and Innovation Priorities

New technologies and strategies for pollution detection and monitoring

- **FETs for alternatives for harmful substances and methods to avoid pollutants entering the environment (TRL 3-5).**
- **Develop solution-oriented strategies and perform surveillance and impact studies to support the prioritisation of emerging pollutants or indicators (TRL 3-5).**
- **Bioaccumulation in the food chain** as well as **effects of direct consumption of water containing emerging pollutants (TRL 3-5).**
- **Hygiene and safety (TRL 3-5)**: determine sources, fate and transport of pathogenic micro-organisms and antibiotic resistance in the water cycle and the potential impact on human health of exposure via drinking, irrigation, recreation, water reuse, etc. (One Health concept). Develop knowledge and tools to evaluate the safety of water systems, the efficacy of treatment processes and other measures to control the risk of transmission of infectious diseases or antibiotic resistance via water systems.
- **New pollution detection and laboratory comprehensive methods (TRL 5-7)**, techniques and eco-toxicological risk assessment systems to ensure safe exposure level avoiding any critical early adverse toxicity induction (e.g. DSS).
- **Assessment of micro-pollutants breakdown products (TRL 5-7)**: enhance the efficiency and cost-effectiveness of the monitoring of chemical pollutants, and check whether laboratory tests represent field conditions.
- **Emerging nanotechnology approaches (TRL 5-7)** for the detection of microbial pathogens.
- **Pathways and exposure of nanomaterials to waters (TRL 5-7)**; advanced analytical measurement/monitoring techniques and methods.
- The use/impact of nanoparticle-based assays and nano-devices to innovative **bio-diagnostics** (e.g., for bio-molecular detection of microbial pathogens, etc.).
- **New Models (TRL 5-7)**, embedding all the aspects (sources, transport, and effects) to a holistic view. They can also be used to fill data gaps, e.g. emissions can be modelled based on the use and pathways to surface and groundwater. Model development should include the tracking of production, use and releases of chemicals in society and be linked to abatement measures both upstream and end-of pipe. The development of new measurement techniques, treatment technology and toxicological tests should be accompanied by new model developments to allow links to impacts. The overall ambition is to support policy implementation and abatement strategies and to communicate with stakeholders.
- **Technologies and management scenarios addressing groundwater over-exploitation in coastal zones and shallow aquifers (TRL 5-7).**

New technologies for pollution removal

- **FETs for removal of micro-pollutants, emerging pollutants and chemicals (TRL 3-5)**, including pharmaceuticals and micro plastics.
- Development of highly effective technologies (e.g., oxidation, adsorption), for **removal of micro-pollutants (emerging pollutants) from drinking, industrial and domestic waste waters (TRL 5-7)**. This includes **smart and intelligent membranes for advanced water (TRL 3-5)** (drinking water, waste water, stormflow) and sludge treatment from emerging pollutants: applications for water and health.
- Source control measures and advanced end-of-pipe technological solutions for **nanomaterials removal (TRL 5-7)** from global and internal water cycle.
- Emerging nanotechnologies, nanomaterials and nano-sciences for **water remediation (TRL 5-7)** in industrial effluents, groundwater, surface water, and drinking water.
- **Technological and managerial solutions reducing the pressures exerted by 'hot spots' (TRL 5-7)** of emerging pollutants.

KC2-S3 Enabling cost efficient water treatment and management technologies to foster re-use, recycling and cascading

Challenges/opportunities

Much more advanced and cost effective **water treatment and management technologies** are being developed in Europe and by its international collaboration partners, which increase opportunities to avoid pollution, manage the quality of alternative water sources (i.e. waste water, brackish, and salt water), tuning the water quality for its right use, improve operational costs, transform WTPs from cost-based treatment plants to full value-driven business industries.

Research and Innovation Priorities

- **New solutions for recovery and (re)use of recovered resources (TRL 3-5)**: nutrients, metals, minerals and salts, energy, organic carbon (e.g., for soil improvement) and/or recoverable organic substances, e.g., alginate, cellulose, bio-based products (linking water and waste mining in a circular economy approach). It includes **new biotechnological solutions for resource recovery (TRL 3-5)**: e.g., nano-adsorption, membranes and membrane processes. As well as **intensified water purification/filtration concepts (TRL 3-5)** based on nano-structured, nano-functionalised membranes and nano-film deposition for micro-pollutants and virus removal;

- **Smart and intelligent membranes (TRL 5-7)** for advanced water (potable water, waste water, stormflow) and sludge treatment from emerging pollutants: applications for water and health;

- **Generation of new treatment technologies, e.g., hybrid membrane systems (TRL 3-5)** for water treatment increasing synergy between membrane systems and biology, oxidation, adsorption, coating, etc. **Improvement of advanced oxidation and adsorption/absorption technologies (TRL 5-7)**. (e.g., active carbon, ozonation);

- **Solutions for storm water overflows (TRL 5-7)**. Even if we treat our waste water by using advanced technologies, we have to deal with storm water and even more extreme events in the future due to climate change. It is a challenge to prevent overflows of (combined) sewage water;

- **New solutions for decentralised treatment (TRL 3-5)**, especially for waste water treatment in synergy with centralised treatment (for Europe and developing countries). Synergy with the organic waste valorisation;

- **Membrane nanotechnologies and technologies (TRL 3-5)** for fit-for-purpose water: i) nano-products for advanced industrial and hotspots wastewater treatment; ii) support in internal and external industrial and domestic waste water reuse, iii) advanced water purification and desalination technologies;

- **Use of antimicrobial nanomaterials** in disinfection and microbial (and biofouling/biofilm) control for water treatment, **including nanozymes for biofilm removal (TRL 5-7)**: assessment of their merits, imitations, applicability and further large-scale market deployment possibilities;

- **New materials for a more sustainable and resilient water infrastructure (TRL 3-5)**, including smart, self-repairing (nano-) materials.

KC2-S4 Advanced technologies and approaches for water management in agriculture

Challenges/opportunities

Agriculture is the largest contributor to water bodies' abstraction and the primary source of diffuse pollution. Together with the actions proposed in KC1 to improve the application of new circular models for water linked to agriculture, linked to new pricing schemes and business models for farmers, there's a need to carry out research and develop advanced technologies that will allow agriculture to drastically reducing water abstraction and use.

Research and Innovation Priorities

- Develop **advanced, new generation effect-based monitoring methods based on "omics" and bioinformatics (TRL 3-5)** approach (e.g., genomics, trans-criptomics, proteomics or metabolomics) for safe and efficient water systems and services;

- **Advanced technologies and sustainable management techniques (TRL 3-5)** and methods of the rational use of water resources and **agrochemicals in precision agriculture (TRL 3-5)**;

- **The role of aquaponics in multiple waters for multiple uses (TRL 3-5).**

Key Component 3:

Hybrid Grey and Green infrastructure

Water Europe's VISION

By 2030 the water infrastructure will have been a smart integrated managed system of up-to-date engineered as well as natural assets, which will have been able to cope with the challenges of flooding and water scarcity through dynamic allocation of multiple water resources (multi-loop), based on novel levels of insight and manageability and that will have been able to absorb the impacts of climate change effects in an efficient and environmentally acceptable way.

The future water infrastructure will have been modernised, drastically improving resilience to extreme hydro-climatic events, reaching less-leakage and a flexibly adaptive water management system with nature as an integrated asset and regional governance leading to no water limitations for end users and no disruption in production due to water shortage. New economic, financial and investment models and support tools will have changed the way asset management is done, securing long-term financeability, including cost-recovery and the impact of externalities.

Challenges, goals and actions

Sub-challenge	Goals	Actions
S1 • Resilience against Climate and Seasonal Change effects	• Mitigate the effects of extreme water events in urban and peri-urban areas; • Increase the resilience to seasonal change effects.	• Integrating green engineered and natural assets in the grey water infrastructure and near real time measurement of the water system (from KC2) enable active and adequate management; • Implement reclaimed/recycled water distribution networks in a multiple waters perspective in urban and rural areas; • Comprehensive urban planning integrated in other developments plans of cities, such as green areas and biodiversity, health, infrastructure; • Validating functionality of green, blue and grey infrastructure under extreme conditions.
S2 • Longer term financial sustainability of the water distribution system	• Secure financial models and practices that integrate long-term cost effective maintenance and inclusion of externalities in financial asset management of our water infrastructure.	• New cost effective maintenance solutions and practices, including advanced sensors for better maintenance planning; • New longer term forecasting models and tools for refurbishment, maintenance, and financial management; • Implement novel financial and business models in financial management tools and practices. • Development of faster, cheaper and non-intrusive building, maintaining and rehabilitating techniques for networks.
S3 • Redesigned integrated hybrid grey and green infrastructure	• Restored and renovated water infrastructure for reduced environmental impact and resilience against climate change effects; • Enabling dynamic allocation of multiple water resources for multiple uses/users.	• New integrated infrastructures and related control systems to treat multiple water sources, and allocate different (treated) water streams for different purposes while ensuring high levels of health protection; • Creating small local loops for multiple waters and multiple uses, closing water infrastructure between different users in urban and rural areas making maximum use of existing infrastructures, avoiding risks of cross-contamination, and ensuring cost-effectiveness; • Design novel ways to integrate natural solutions in the grey infrastructure.

General Objective:

This Key Component is realising natural, nature-based and engineered solutions where new materials and technologies, approaches and practices revamp and maintain our water infrastructure into a smart, active and economically sustainable system to support the "multiple waters concept" and resilience against the climate change effects in innovating urban/peri-urban, urban- rural, and rural areas.

Water Europe
Technology & Innovation

KC3 Sub-Challenges

KC3-S1 Resilience against Climate and Seasonal Change effects

In December 2015 large parts of Scotland and the north of England suffered from widespread flooding due to storms and extreme rainfall, resulting in evacuations and power cuts affecting thousands of homes and industries. Unfortunately, extreme hydro-climatic events like the December 2015 floods are expected to become more common in the coming decades as **climatic changes could lead to increased events of rivers and coastal floods, storms and droughts**. The effects of climate change differ across Europe: where southern and central Europe is expected to see more frequent heat waves and droughts, northern parts of Europe are getting significantly wetter[20]. In most countries the water infrastructure is not yet sufficiently adapted to these changed water conditions and without significant changes our water distribution and quality will be affected and be at risk.

Climate change and mitigation is not only about droughts and floods. **Climate change will also influence the water quality** due to increased transport of organic compounds from forest and agriculture areas to the water sources and changing colour and increasing natural organic matter concentrations in raw waters requiring new innovative drinking water processes. Flooding involves the risk of contamination of water sources as the water flushes/leaches hazardous chemical substances from urban and industrialised areas as well as contaminated soils.

To improve the resilience of the European water infrastructure several challenges have to be addressed. As hydro-climatic events are expected to increase, precise forecasting and visualisation (from KC2) are needed to support efficient management and decision-making for water-related disasters and threats while ensuring quality and availability for all users. Utilising this knowledge base, **smart and effective management solutions, decision support systems and long-term mitigation and adaptation strategies** and approaches should be in place. These solutions (nature-based, hybrid green, and grey infrastructures) should incorporate various services **at various geographical scales, including urban, regional, and river basin**. Another challenge **is the adaptation and improved resilience of the water infrastructure** to these changes. In addition, both the engineered and natural water infrastructures also need to be able to cope with varying conditions due to seasonal change effects. The benefits of ecosystems and other nature-based solutions should be exploited and utilised to keep cities un-flooded and reduce the hydraulic load on water assets. An optimal use of all assets needs to be realised.

"Ecosystem services remain under-valued, under-recognised and under-utilised within most current economic and resource management approaches. A more holistic focus on ecosystems for water and development that maintains a beneficial mix between built and natural infrastructure can ensure that benefits are maximised[21]."

Research and innovation priorities

Forecasting and insight on water-related disasters and threats

• Climate change and water challenges: Implementation of **improved Big Data collection, assessment, data-driven and process-based models development (TRL 5-7)** to ensure precise forecasting methods and visualisation techniques to support more accurate decision-making for water-related disasters and threats (floods, extreme events), ensuring on-time water pollution detection methods and enabling neutralising actions to overcome water-related climate change challenges.

• **Novel urban water systems and infrastructures to cope with Climate and Seasonal effects (mitigation and adaptation) (TRL 5-7)**, effluent use for various purposes (flexible control and surveillance systems, functionality of infrastructure under seasonal changes, systems for early flood warning, technology and controls for operation of storm water systems);

Future management and decision-making for resilience

• **Research the causes and significance of microbial growth (including opportunistic pathogens) in water distribution networks and other engineered water systems (TRL 4-6)**, the influence of water treatment and water distribution processes thereon and a framework of assays and analytical target values to support management decisions.

• Enhance decision making related to climate impacts on ecosystems and environmental quality by **advancing knowledge base (procedures and warning tools) (TRL 5-7)** to manage and mitigate effects of extreme events; providing robust assessments on the impacts of climate change to water systems at various levels[22];

◦ From catchment to coast: sustainable water management in coastal ecosystems addressing climate-based and anthropogenic pressures to ensure ecosystem services;

◦ Ecosystem services, eco-innovation and eco-engineering;

• Adapt community water management to climate variability and end-of-pipe bottlenecks based on enhanced and newly developed practical **strategies and decision support systems (TRL 5-7)** for green and blue zones;

• Improve resilience of urban services in various geographical scales (urban, regional, river basin) under changing climate and extreme events **based on new knowledge bases, predictions, smart management and cost-effective solutions, new community and catchment based business models (TRL 6-8)** to improve, e.g. flood risk management;

• **Inclusive multi-stakeholders and multi-sectorial technological and non-technological approaches and partnerships incorporating water into new Urban agendas** for (1) adapting climate-impacted water grey & green infrastructures and (2) ensuring water quality and availability in implementing water-based disaster risk reduction measures (linked with KC4 and KC5).

Adapting and improving the water infrastructure to climate change effects (i.e. water safety in the city under climatic extremes)

• The **role and functionality of natural ecosystems functions (TRL 4-6)** into building resilience and adapting to climate change at river basin/ sub-basin /catchment level;

• **Validating the functionality of hybrid grey and green infrastructure under extreme conditions (TRL 5-7);**

• **Nature-based solutions to fight extreme precipitation events/flooding (TRL 5-7)** (rainwater, flushes, erosion, buffering, floodplains, wetlands) via green flood protection infrastructures, as natural sand supplements, green /vegetated dikes, coastal wetlands, 'soft' dikes (from reuse of dredging sediments) in combination with water supply opportunities to deal with (extreme) drought. Sustainable flood protection, flood risk management, integrated landscape planning in urban and rural areas developing large scale demonstration projects and setting up collaborative action group to overcome climatic challenges;

• **Adapt community water management to climate variability (TRL 5-7)**: keep the city unflooded, water clean/ uncontaminated, reduce the hydraulic loading on the sewage treatment plants, system solutions for reduction and detention of urban runoff, design of climate adapted treatment facilities.

• **Green infrastructures in rural, urban and coastal areas (TRL 5-7):**

  ◦ Pressures on the freshwater resources and the coastal ecosystems; saltwater intrusion, land subsidence and disappearance of wetlands;

  ◦ Focus on water safety, purification and storage;

  ◦ Nature-based solutions for coastal erosion, supported by the restoration of natural sediment fluxes;

• Coping with challenges of climate change and its impact to groundwater level and quality, and aquifer storage. **Information basis and technologies to ensure drinking water supply; sustainable subsurface storage of aquifer and recovery systems on the regional perspective (TRL5-7)**. Exchange of experiences among the regions;

• Soil/sediment aspects. **Technologies and strategies to** decrease pollution dispersion during extreme hydro-climatic events **(TRL 5-7)**. Morphodynamics and sediment strategies. Downstream erosion and sedimentation poses, in particular in urban areas, significant problems for water and sediment management. The scientific basis about the effects of existing and future (green) infrastructure needs deepening to increase more reliable, predictable designs of infrastructure. Specific attention needs to be given to combined and basin wide effects.

KC3-S2 Longer term financial sustainability of the water infrastructure

For decades the investments in infrastructure has been declining in most European countries and the global financial crisis further contributed to this decline. Investing in water infrastructure is hampered by low levels of cost recovery and depleted state budgets. However, in most European countries the water infrastructure has been in place for several decades and needs to be revamped. Investments in the water infrastructure are not only necessary to be able to cope with climate change effects; the deterioration of the existing infrastructure, demographical changes, digital revolution, and new standards and developments also result in a significant need for maintenance, renewal and upgrading of the infrastructure[23]. Adaptation is a key area of intervention for mitigating the detrimental impacts of these changes, in particular on water resource availability and quality. Moreover, the multiple waters concept promoted by the Water Europe's vision, requires smart investments to introduce multiple loops in the water distribution system, including piping as well as different water treatment systems at all levels, which needs to be taken into account in new financial and investment models and plans.

To improve the long-term financial sustainability of the European water infrastructure several challenges have to be addressed. To achieve a sustainable water infrastructure, future asset management is to include the effects of the changes foreseen. Furthermore, the water infrastructure needs to minimise the carbon footprint of water distribution and water use, and reduce the impact of materials used, reducing leakages and improving sustainability. Hence, the assessment of the long-term sustainability of water technologies also needs to be based on their carbon footprint.

Research and innovation priorities

Asset finance and management

- **New "value" framework, enabling better balance of benefits vs costs**: valuation of benefits on the long-term is difficult to assess and is more often underestimated; i.e. "bank rate", so that actual costs and benefits do prevail vs future benefits. Cost benefit assessments should give more weight to health and environment parameters vs economic parameters.

- **Innovative financing schemes and investment models for the water sector** able to attract other sources of finance (i.e. loans, bonds, and private investors), and combining multiple financial sources, including synergies with already existing instruments, such as from European Structural and Investment Funds (ESIF), European Investment Bank (EIB) and European Investment Fund (EIF) (links with KC1 – new economic models under the Value of Water and KC5, in which first time innovative combinations of instruments will be used to finance the infrastructure for Living Lab experiments).

- Asset management, including the effects of climate change and carbon footprint:
  - Lifetime **prediction tools in managing failure (TRL 5-7)** to drinking water assets, cost- effective solutions for direct/indirect/social costs, failure of joints;
  - **Environmentally effective and optimally/sustainably managed water installations (TRL 5-7);**
  - **Assessment of long-term environmental sustainability (TRL 3-5) of water infrastructure** based on multi-dimensional assessment methodologies, including the carbon footprint as one of indicators. (Financial sustainability must consider carbon footprint.)

Cost reduction of longer term maintenance of the water infrastructure

- **Integration of advanced, low-cost monitoring systems (TRL 5-7)** to ensure timely detection of faults of functioning of the infrastructure in order to better plan in advance timely, cost-effective and efficient maintenance of infrastructure.

- Optimisation of renovation planning methods and introduction of new **decentralised remediation technologies** in the distribution network and at the discharge spots on the river catchment.

KC3-S3 Redesigned integrated hybrid grey and green infrastructure

To cope with the challenges of our times and facilitate the multiple waters concept in a circular economy, a renewed flexible, robust and resilient water infrastructure is needed. Unfortunately, our current water infrastructure is not able to manage such problems, as it can be characterised as **ageing and outdated** in many places throughout Europe. Adding the impact that leakages and water losses caused by the deteriorating infrastructure have on our environment, it is clear that changes are needed.

To reduce the vulnerability, improve the resilience and flexibility of the European water infrastructure we see **integration with green infrastructure, multi-loop designs and smartening as key characteristics of the future system.**

Flexibility is achieved by upgrading and redesigning the water infrastructure for the dynamic allocation of multiple water resources for the right purpose to the multiple users while ensuring cost-effectiveness and high levels of health protection. Currently a single quality of water is supplied from centralised water sources to decentralised water users without differentiation in required water quality.

By including new concepts into the water infrastructure design – such as decentralised treatment and storage systems, and localised micro water grids (water loops) connected to the existing infrastructure – the right quality of water can be increasingly supplied to the right user, reducing treatment costs.

Active sensoring, measuring and monitoring technologies will enable adequate management and cross-sector decision-making at a regional level. This **smartening of the water system** will enable the dynamic allocation and distribution of different qualities of water from multiple sources. In addition to monitoring, this system could assist in designing reactive and pro-active policies and strategies, to safeguard the sustainability of regional water resources.

Research and innovation priorities

Revamping and upgrading the water infrastructure

• **Innovations in the grey infrastructure (TRL 5-8)** (flood defences, urban draining, irrigation, sanitation, and supply): New technologies to reduce costs in design/build/maintain (DBM) while increasing performance and introducing multi-loops for dynamic multiple waters delivery.

• **Restoration methodologies for degraded urban ecosystems (TRL 5-8)**, relying on water related biogeochemical modelling, green infrastructures and natural methods for ecosystem services; solutions for recovery of nutrients from wastewater effluents, constructed wetlands; addressing seasonal water shortage, overexploitation of groundwater resources.

• **Design of nature-based or nature-inspired technologies**, stimulating natural water treatment and self-purification in peri-urban areas, river basins and storm ponds as an integrated part of the overall water system.

• **Nature-based wastewater treatment systems and urban storm water treatment (TRL 5-8)** into adapted receiving water bodies. Including know-how transfer to sensitive regions in developing countries (link with KC6- S5).

• **Integrated planning and operation of urban drainage and waste water treatment plants infrastructures** to enhance waterbodies protection (while minimising impacts of untreated wastewater and storm-water in receiving water bodies).

• **Cost effective nature-based or nature-inspired technologies for decreasing the carbon footprint associated to the mobilisation of multiple water resources (TRL 5-8)**. New water resources (reclamation, water harvesting, and desalination) must be implemented in the most sustainable way.

• **Hydropower as a European battery**: How can the old and new hydropower installations be optimally used to reduce Europe's carbon footprint while maintaining sufficient water availability for other purposes?

Smartening the water infrastructure

• Smartening the water infrastructure, **technological (including ICT) and management solutions for a sustainable, energy-efficient and flexible cost- effective and safe multiple waters supply (TRL 5-8)**; distribution and possible internal and external recycling in urban and rural areas (e.g., control of pumps, alarm systems, biological stability, on-line detection of microbial contaminants, etc.);

• New validated technological solutions for water networks sustainable management. **Improved survey and inspection techniques in sewer networks (TRL 5-8)**;

• **Validate the performance functionality and stability of green infrastructure** under climate change and anthropogenic pressures and long-term socio-economic scenarios.

Integrating grey and green infrastructure

• **Strategies for optimising the integration of (new) green and grey functionalities**, for example in treating diffuse micro pollutants as one of the biggest challenges in reaching good quality status as per the WFD targets;

• Increasing alternative water resources through **desalination based on green technologies (TRL 5-8)**. Desalination can be an alternative to water reuse if its sustainability is assured (i.e. if renewable energy is used and impact of brine disposal is minimised).

Key Component 4:

Governance

Water Europe's VISION

By 2030 decentralised, improved and new multi-stakeholder governance models and set-ups will have managed and exploited our redesigned adaptive water management systems within a network of internationally connected regional governance collaborations. They will have involved all relevant actors, including cities, industries, agriculture, energy, transport and nature, addressing local characteristics. Collaborative and participatory decision-making that includes diverse stakeholder views will have led to improved services and transparency, resulting in fair decision making based on water footprint assessments, new pricing, and economic mechanisms.

Awareness creating measures and new forms of participation will have led to educated smart water users, who are aware of the value of water and water usage, enabling them to play their role in the future water-smart decision making processes

Challenges, goals and actions

Sub-challenge	Goals	Actions
S1 • Decision Support Systems for multi-stakeholder Governance	• Advanced near-real time decision support systems and information exchange at all levels.	• Develop decision support systems for competing users of water resources; • Improvement of the knowledge base and ICT tools of nutrient management and recycling; • Development, deployment and integration of digital DSS and communication technologies and tools; • Develop new methodologies for climate impact analyses and decision-making.
S2 • Stakeholder engagement for good water governance	• Smart and engaged stakeholders that appreciate the value of water and share responsibilities.	• Engaged dialogue among diverse stakeholders in water resources management; • Capacity development of all stakeholders on the value of water and water usage, stressing that water access also implies responsibility; • Innovative use of advanced ICTs for communication/dissemination campaigns/ and public engagement including citizen science
S3 • Integrated planning and water management at all levels and across sectors	• New multi-stakeholder governance models that manage availability of water for all users and sectors; • Fit-for-purpose, adaptive and evolving economic and governance mechanisms.	• Create multi-stakeholder partnerships, co-innovation between industry/RTO /SMEs, industrial symbiosis and joint technology market places; • Integrated water management between all stakeholders in industrial parks; • Establish and structure regional multi-stakeholder platforms; • Create public-private open innovation platforms, to foster collaborative and continuous open innovation; • Re-shape (legal) accountability for water, build mutual trust; • Implement broader, regional tools to optimise all water assets/functions amongst different sectors; • Develop new multi-stakeholder organisational set-ups for collaboration on infrastructure management.

General Objective:

This Key Component is developing new inclusive multi-stakeholder governance models and practices for the future, leveraging on new technologies enabled insights and decision support systems.

KC4 Sub-Challenges

KC4-S1 Decision Support Systems for multi-stakeholder Governance

New multi-stakeholder governance collaborations will have to implement new ways to combine smart water management and preservation of nature, within an integrated hybrid grey and green water infrastructure. Joint governance and decision making will have to be based on advanced insight in water-quality and use, as well as in projected potential water scarcity and/or potentially upcoming climate change effects and their impact on the water system.

Governance will hence need to be supported by novel (quasi)real-time and continuously updated information systems based on diverse data sources. This includes information based on a widely spread sensor network in the water system, citizen science, as well as climate and water forecast models and maps, provided by high end information technologies, such as global GIS based knowledge management systems.

Higher levels of insight are provided to and co-created by governance systems at all levels, by combining advanced forecasting models with data from metering of water production, use and re-use activities. To manage and regulate the distribution, sanitation, use and re-use of water, governance will also incorporate and use financial mechanisms and legal arrangement for these water related activities at (inter)regional level.

Research and innovation priorities

Digital solutions supporting governance (sensing, DSS, communication, systems & technology)

• **Develop digital solutions for competing users of water resources (TRL 4-7)** within multi-stakeholder governance platforms; creating dynamic, incremental, adaptive and flexible ICT platforms to ensure water-agri-energy-transport-ecosystems interlinks taking into account regional downscaling of the climate scenarios, such as floods and droughts, and ecological-flows in. It includes innovations and knowledge base on disaster risk resilience and reduction (technologies, models, DSS) implementing and testing management options;

• **Improvement of the knowledge base and ICT tools of nutrient management and recycling (TRL 4-7)** (interactions with agronomy, water management, ecology, animal feeds, human food and diet, fertilisers, recycling technologies) making it accessible and comprehensible to stakeholders and companies in different sectors.

Decision support systems for planning and management of sectors and nexus issues

• **Develop and deploy sensing technologies, decision support systems and communication instruments (TRL 4-7)** to improve information for operational water management and to supporting the rational use of water resources of different origins (i.e. in agriculture, cities, industries, etc…);

• **Decision support systems (TRL 4-7)** to manage nexuses (on different geographical scales), possibly integrating existing sectorial ones (e.g., food/bioeconomy, urban, industry, energy, transport, environmental flows, etc.);

• **Integration of new digital technologies and tools (TRL 4-7)** (GPS, RS (satellite, drone, proximity), GIS) for runoff management in i.e. agriculture, industry, cities and use of alternative raw water sources for irrigation and different users, incorporating climate change uncertainties into water planning.

Methodologies for climate impact analyses and decision-making

• **Analyse the feasibility, flexibility and governance of water-related infrastructure and technologies**, in relation to the impact of climate change effects, based on an institutional and socio-cultural analysis, as a basis for investments in water-related infrastructure and technologies.

• **Integrating climate projections** for the short, medium and long-term, and at various levels, in particular at local, district, urban, peri-urban areas as well as at small river catchment areas into adaptive water management planning: **modelling, monitoring, and communicating measure efficiency for supporting decision making**.

• **Develop climate services for policy and operational water management**, specifically forecasts and associated uncertainties leading to services based on probabilistic reasoning.

KC4-S2 Stakeholder engagement for good water governance

The water sector is characterised by a high degree of fragmentation of actors and decision-makers, often due to unclear and overlapping roles and responsibilities. For many decades, stakeholder engagement in the water governance has been mostly incidental. The increasing importance of stakeholder engagement in the water sector is being recognised as a principle of good governance[24] and in principle (rather than in practice) public participation is considered essential for the implementation of the Water Framework Directive. Stakeholder engagement provides the means for sound decision-making, for raising awareness of the risks and value of water, and for handling conflicts among water users from different sectors and in transboundary settings. The digital age generates advanced ICT tools and mechanisms that can be harnessed to achieve a paradigm shift in the engagement of diverse and previously often unengaged stakeholder groups.

Research and innovation priorities

Improve and realise stakeholder engagement

- **Develop and deploy innovative tools and mechanism to support and improve multi-stakeholder engagement (TRL 5-7)** and support inclusiveness by providing a shared base for exchange of knowledge and information.
- **Novel ways to involve all relevant stakeholders in the storm water planning process** (e.g., civil servants from the water and wastewater utility), and in the development of river basin plans (e.g., the public), in order to develop better solutions.
- **Engaged dialogue among diverse stakeholders in water resources management and capacity development on the value of water and water usage**, stressing that water access also implies responsibility.
- **Harness innovative and evolving ICTs for communication/dissemination campaigns, and public engagement actions** including citizen science (joint monitoring and data collection, analysis and interpretation) (link to KC6– S3).

KC4 – S3 Integrated planning and water governance at all levels

Water governance involves managing surface, ecosystem, and groundwater sources. Changes and alterations involve and affect many groups and individuals from various sectors and large geographical areas. Unless structural measures are taken towards better shared-responsibility and governance of water, growing scarcity of the right quality and quantity of water may result in a strong competition between agriculture, industries, cities, environment, etc. These varying users influence, determine and affect the quality and allocation of water, but not all of these users are coordinating or in control. Roles and responsibilities for managing water are spread across different levels of government, broad range of stakeholders, such as public authorities, service providers, regulators, and river basin organisations[25].

Increasingly complex water problems require negotiated solutions: even if technical solutions to better manage and match supply and demand will be available, proven and continuously improved, proper coordination and effective governance of sources are needed to ensure a fair and secure allocation of water resources for everyone. To address this, the new paradigm of **Water Diplomacy**[26] has recently emerged, that shifts the discussion from "allocation of water" to "benefit from water resources" to open up new avenues for resolving water conflicts.

Global demographic trends will lead to ever closer and more integrated urban-agro-industrial (incl. energy and transport) and natural environments in which scarce water resources (together with a surplus of water) need to be managed to ensure that they are not too scarce or too abundant. This will necessarily lead to new governance models where – depending on geographical specificities – different combinations of stakeholders and tailored decision making models will be applied to secure fair water governance.

Research and innovation priorities

Develop strategies and approaches for joint decision making

• **Develop multi-stakeholder Water Diplomacy approaches and practices at regional levels** (regional water-smart societies) by developing strategies for competition between users of water resources (incl. serious gaming), also taking into consideration the climate change effects (flood and drought).

• **Improvement of WFD implementation through advanced multiscale modelling, better River Basin Management and Programme of Measures design**, rigorous methodologies for assessing cost-effectiveness of water management measures, combining economic analysis with stakeholder engagement to assess effectiveness, linking to basin-wide water use models (in particular, in the field of energy and agriculture) and including results of scenario and technology foresight studies. Such progress allows developing more efficient and viable basin plans based on mosaics of detailed models, pressures and measures and which provide the basis to implement the innovations proposed across KCs.

• **Flood risk and drought strategies in urban, industrial and rural context** in river sub-basins:

- Sharing advanced decision-making in Europe and world-wide;
- Creating deliberative spaces for integrated water management: innovative water governance and decision-making strategies supporting adaptation to climate variability and changes in the water sector.

• **Water Diplomacy approaches for climate change response to ensure availability for all purposes of water** in peri-urban and rural contexts; addressing challenges for water security; improving the resilience of urban services in cities; improving flood frequency estimations and adaptation measures.

• **Alignment of policies**: Solve contradictions and bottlenecks between policies, e.g., the relation between blue energy and WFD and Habitat Directive; food production and policy versus WFD and Habitat Directive; overcome restrictions on/prohibition of reuse of municipal waste water as a resource for industry.

• **Joint decision frameworks to shift to a more chemical-free society** to identify priority micro pollutants or environmental markers representing pollutants that need to be targeted due to their high costs of identification or/and removal. A sector oriented approach to avoid use, circular use and ultimately encourage the use of environment-friendly chemicals. Develop better holistic risk analysis framework (beyond REACH) to avoid new chemicals and future hazards from the ever increasing mix of chemicals of potential concern.

Collaboration, integration and partnerships

• **Setting-up and strengthening collaborative actions and regional multi-stakeholder partnerships**, such as catchment-based water quality multi-stakeholder and multi-sectoral groups, to address pressures on water bodies and strengthen the implementation of Water Framework and Nitrates Directive (action plans for nitrate vulnerable zones), sustainable use of Pesticides directive (national/regional action plans for sustainable use of pesticides).

• **Streamlining of multi-stakeholder and multi-sectorial actions and decisions** in implementing River Basin management plans (RBMPs of WFD), Rural development plans (of CAP – greening measures and RBMPs), National action plans in sustainable use of pesticides (Sustainable use of Pesticides regulation), Climate adaptation and mitigation strategies (EU Climate adaptation and mitigation strategies and linking them to RBMPs).

• **Public-private and cross-sectorial partnerships** at various scales (regional, basin, local) for nexus management and implementation in rural and urban contexts and for producer-consumer involvement in source control of (emerging) compounds to ensure the protection of groundwater and surface water by prevention.

• **Support to reduce the risk perception of "green" versus "grey" infrastructure**, by facilitating the exchange of best practices and the building of a common language between green infrastructure designers and key implementation stakeholders (project developers, public procurement authorities, etc.).

• **Collaborative actions among stakeholders** on the applications of good agricultural and environmental practices and raising awareness of sustainable agriculture and the reduction of water stress at various levels (local, regional, river basin, and cross-country).

Key Component 5:

Real-life living labs

Water Europe's VISION

Water Europe envisions a world-wide leading European water sector that will be significantly transformed with respect to the current situation. New concepts, such as "Multiple Waters" and "Digital Water", will be driving decision makers and new water-smart economics. All will be enabled by new technologies fostered within an open innovation environment and a redesigned water infrastructure, as well as by a strong International Cooperation approach, to solve common global water challenges and reach commonly defined targets (i.e. SDG). New governance structures, pricing mechanisms and novel more profound water stewardship programmes, will manage the water market towards fair allocation of water and 50% reduced pressure on our natural water system.

By 2030 this transformation will have been in full swing, driven by visionary front-running (peri-)urban areas and industries that have taken the lead in showing the migration paths towards the future water-smart society, implementing ambitious longer investment and innovation programmes, and real life Living Lab experimental areas. As such they have created a fertile innovation eco-system for technology developers, researchers and forward looking water-governing bodies to develop the leading solutions of the future, boosting their global competitiveness. This contributes to job creation in Europe.

Water Europe
Technology & Innovation

Challenges, goals and actions

Water services' assets have a long lifetime and cannot be rethought and transformed in short periods of time. There is a real **need for a transition period** in which the water industry can implement innovative solutions into long lasting infrastructures, services, and practices.

Water Europe will promote **systemic innovations in the water system** towards significant and measurable improvements, focussing on a set of measurable Key Impact Parameters, for real life situations. This approach is inspired on the Innovation Systems theory, which promotes innovation not as a linear process but as a complex dynamic innovation system, in which different and complementary stakeholders in a real-life context contribute to solving the key issues in a collaborative and iterative approach, leveraging on underlying academic research and competitive industrial research, development, and innovation.

It is essential that complex innovative transformations of society, such as the one promoted by the Water Europe's Vision, will be carried out and "owned" jointly by all stakeholders. Especially where policy and governance changes need to be experimented together with novel enabling technologies and systems and afterwards mainstreamed, buy-in from policy and decision makers from the outset is key. For this reason, **Water Europe proposes** to engage on systematic and longer term coalition building with front-running geographical areas in Europe, set-up a thorough selection process together with their governing bodies, and **identify strategic and large-scale, long-term programmes for real life Living Lab experiments**. Part of the **selection process**, should be a transparent and fair evaluation of:

- Ambitious and credible plans for a longer term investment plan based on novel financial and investment models to redesign the infrastructure;
- A comprehensive experimental technology as well as governance programme, that leverages on the real-life Living Lab environment to validate the added value, societal and financial viability of proposed innovations;
- Contributions to the Water Europe Key Impact Parameters outlined in its Vision paper;
- Clear plans to mainstream successful results of experiments within its own Living Lab geographical area;
- Commitment to support replication and roll-out of the successful innovations throughout Europe.

Climate experimentation can lead to new ways of thinking and learning, new types of consumer, citizen or business practices, new governance or policy designs, new forms of networking, novel technologies and business models, or new types of infrastructure or planning in the built environment.
(**Kivimaa et al., 2015**).

General Objective:

This Key Component is developing the migration paths towards the future water-smart society, by applying the innovations developed within the other Key Components of the present Water Europe SIRA.

Progress in the water sector towards solving our major challenges not only results from technology developments, but especially by combining **6 levels of innovation**:

1. Technology developments on digital technologies, such as big data and satellite based monitoring, forecasting and advanced decision support systems for smart water management;

2. Emerging technological developments towards better and upgraded infrastructures, cost-effective water treatment, extraction and pre-treatment of valuable substances in waste water and enabling closed loops;

3. Innovations in more advanced water storage and capillary distribution systems, integrating both **grey engineered and green-infrastructures** to leverage on the inherent capabilities of nature, while closing the larger and smaller water loops and enabling diversified allocation and distribution of different water qualities for different purposes;

4. Novel participatory and **inclusive governance models** to develop and implement regionally embedded water management policies that establish incentives for efficient water use (including reuse and cascade use) while securing fair distribution and access for all, also under adverse circumstances caused by climate change effects such as increased intensity and frequency of floods or droughts;

5. Novel business models, which increase the exploitation of the value of and the value in water within a circular multi-stakeholder economy linked with energy harvesting;

6. Other **horizontal measures** related to policies, standardisation, skills development and entrepreneurship that enable the transformation of Europe into the Smart-Water Society as foreseen in this vision.

"Living-Labs: Real-life environments to test, fine-tune and introduce novel water-smart solutions"

"Excessive abstraction significantly affects 10% of surface water bodies and 20% of groundwater bodies"[28]. The agriculture sector contributes largely to over-abstraction with water-intensive irrigation and cropping techniques (especially in Mediterranean and Black Sea countries).

KC5-Living-Labs

The Water Europe SIRA promotes the alignment of regional (including ESIF[27]), national and European public funding as well as private and public finance (e.g., of the European Investment Bank) within a number of complementary "Real life Living Labs for Water-smart Society" that establish a critical mass of stakeholders, innovation actions and budget, to converge towards joint innovation objectives, combining the above-mentioned 6 different levels of innovation. Each Living Lab will have its own character reflecting the different geographic, economic and political water realities in Europe.

Living labs will be real-life environments, such as cities, regions, agro-industrial clusters, waterborne transport or similar that will be used to experiment the required innovations for the water-smart society, under realistic conditions. As real breakthroughs and impact can only be realised by combining technological and non-technological solutions (see the 6 levels of innovation), and test, validate and demonstrate them against real-life conditions in different geographical and environmental contexts. To achieve the Vision's objectives, the Water Europe SIRA identifies 3 types of long-term Living Labs to be organised in the future, as described below.

KC5-LL1 Rural Living Labs

Challenges/opportunities

Reducing pollution in European water bodies has become an impellent need and is at the core of several Directives and initiatives launched by the European Commission in the last decade (i.e. the WFD, the Urban Waste Water Treatment Directive, the Nitrates Directive, the Directive on Sustainable Use of Pesticides, and the Industrial Emissions Directive), aiming at tackling both point source and diffuse pollution. The agricultural sector is the primary source of diffuse pollution. "Diffuse agricultural pollution poses significant pressure on 38% of the European Union's (EU) water bodies."

"…more than 90% of irrigators do not evaluate crop irrigation requirements using more efficient on-farm water management practices such as moisture-sensing devices and commercial irrigation-scheduling services" (Schaible and Marcel, 2012).

Main characteristics of LL1:

- Targeted at reducing the impact of agriculture on over-abstraction of ground water and overuse of surface water;
- Using advanced sensor systems and monitoring technologies, including Earth Observation, to obtain detailed and real-time insights in water use;
- Environmental regulations and standards, e.g. for controlling agro-chemical use;
- Novel green-agricultural technologies to reduce water use for crop production;
- Application of new economic instruments towards more efficient use of water;
- Integration of agriculture, industry, nature representatives into novel participatory governance models;
- Spatial integrated planning including buffering of water.

KC5-LL2 Industries of the Future Living Labs

Challenges/opportunities

"It is incumbent upon the political and legal authorities to develop appropriate incentives for industries (standards, permissions, prohibitions, fines, charges, etc. with objectives to align business decisions with the public interest." To this end, an ever-improving regulatory and policy framework has been developed by the EC in the last decade, with the establishment of crucial Directives (i.e. WFD and IED) and substantial efforts have been made by Europe to steer the process of application of these in the single Member States, through their PoMs.

"Most companies have a supply chain water footprint much larger than their operational one, and it may be more cost-effective to shift investment in sustainability in that direction (Hoekstra et al., 2011). More than 80% to 90% of a company's footprint, and most of its water risks, may be beyond its direct operations (Place et al., 2012)."

On the other hand, the industrial sector alone will not solve all the issues related to a better water management and use: the interlinkages between industrial, urban and rural water ecosystems need to be leveraged towards a true future water-smart Europe.

Main characteristics of LL2:

- Targeted at 100% closing of the water loop between industries and other water users (e.g., cities, agriculture, waterborne transport, etc.);
- Using advanced filtering technologies in combination with green-infrastructure to realise cost-efficient water recycling systems and the valorisation of valuable substances in water, including energy and nutrients;
- Novel business models to stimulate optimal and diversified allocation of different water qualities for different industrial and other (e.g., urban, energy, rural, waterborne transport, etc.) uses in an integrated water management system;
- New regional multi-stakeholder governance models in which utilities, industry, the public sector, agriculture and representatives of nature, design and trial novel inclusive water management policies;
- Innovative ICT enabled decision support systems for the dynamic allocation and management of different water qualities for multiple functions, including showcasing reactivity and resilience against climate change induced events (floods and droughts) and water-based possible climate change threats to the economic activities, water quality/ human health, and ecosystems;
- Showcasing how inclusive and participatory governance favours the combination of water security for industry, urban and agricultural use, and redevelopment of nature and bio-diversity.

KC5-LL3 Smart (Peri-)Urban Living Labs

Challenges/opportunities

"In 2014, 3.9 billion people, or 54% of the global population, lived in cities, and by 2050, two-thirds of the global population will be living in cities (UNDESA, 2014)." There's an urgent need of increasingly decouple the cities' population growth from resource depletion, including water, through new solution for water efficiency and new models for water management in European cities.

" .. cities provide opportunities for more sustainable use of water, including treating used water to standards that enable it to be used again" (**UNESCO, Water report 2015**).

This aspect is linked to the implementation of new technologies, the redesign of water infrastructure in urban and peri-urban endeavours towards the "multiple waters concept", but also to a paradigm shift in the perception of decision-makers and users of reclaimed waters, about the possibility to use them again safely in the water cycle.

Main characteristics of LL3:

- Targeted at realising reduction of water use for urban purposes based on multiplying water sources, closing loops and increased awareness and citizens' participation;
- Using advanced sensors and capillary metering of water use up to the individual user, to obtain novel levels of insight in water use and favour the development of new business models (including pricing) and water management capabilities to reduce and re-use;
- Integration of conscious water management in urban planning and policies towards environmentally sustainable urban redevelopment (e.g., through urban farming), including soft-measures, such as awareness campaigns and incentives for reduce and re-use;
- Novel long-term urban water policies, urban planning, investment plans and financial engineering models, towards resilience against Climate Change induced events;
- Converting wastewater treatment plants into resource industrial entities providing water, energy and recovered materials as a feed to other components of the symbiosis networks, i.e. having a relevant position in strategies for climate neutral cities or regional energy policies;
- Participatory governance models with industries, agriculture and nature representatives towards fully circular models and practices of water.

Key Component 6:

Horizontal

Water Europe's VISION

Cities, rural and industrial areas will be involved in different multi-stakeholder governance collaborations, and collaborate with research and development partners, to develop and test new technological and non-tech solutions in the European model for a smart-water society, and to foster accelerated market introduction, within a vibrant and stimulating innovation eco-system.

Open innovation, Open-science and Open Data will have harnessed Europe's global leadership in water technologies. Europe will lead in new cost-effective water treatment technologies, based on more advanced nano-materials, thermo-chemical solutions and new combinations with inherent water filtering and storage capabilities of nature. It will also lead in water information systems, for quasi-real time decision support, and Europe will be exporting its model for a smart-water society, which combines these new technological solutions with modern inclusive governance practices. International Cooperation will be crucial to achieve these objectives, targeting new growth areas for the EU water sector competing in the world economy, connecting European R&I capabilities to global research and innovation allowing Europe to take a global leading position in creating a new knowledge-based economy for water.

In these new governance models, the main water users, managing authorities, but also representatives from nature, will jointly govern water management systems on a regional, national and cross-national level using collectively agreed Water Footprint assessment standards. Water users will have stepped-up to play a responsible role through voluntary Water Stewardship schemes and all users are contributing to the optimal use, based on profound awareness on the value of water for our society, and advanced digital tools to monitor and self-manage their water use habits and practices, leading to significant reduction of pressure on Europe's fresh water sources as a result of rational use, and drastic increase of water re-use and recycling, using the multiple waters concept as an integrated part of our daily life.

Challenges, goals and actions

Sub-challenge	Goals	Actions
S1 • Create a level playing field for eco-innovative companies	• Promote eco-innovative solutions.	• Support eco-innovation champions (especially SMEs); • Green Public procurement to promote eco-efficiency.
S2 • Standards for Water Footprint Assessment and Stewardship	• Promote water stewardship at all levels (cities, industries, cross-sectorial) all along the value chain and the water cycle; • Improve monitoring of water impact and related accountability allocation based on commonly shared KPIs.	• Implement water stewardship in agriculture, cities; • Innovation in Green accounting system; • New tools for water impact assessment (including LCA).
S3 • Enhanced sharing knowledge and best practices in water: education, awareness, capacity development tools	• Create a "water-aware" European workforce of the future; • Change perception and behaviour of European citizen towards a future water-smart society.	• Develop and deploy new, ad-hoc skills and training programmes for upskilled workers in digital technologies, managing authorities, water sector specialists, innovators, etc.; • Actions for awareness raising and behaviour change towards waters in citizens and large public.
S4 • Water advocacy, planning and management capacity	• Embed water component into existing governance practices; • Develop radically new approaches for water governance (including Water Diplomacy).	• Integrate water into roadmaps, regional and urban investment strategies; • Innovations in regulatory framework, utility pricing systems/ transparency of value/price for water, social awareness, life-cycle assessment including water, smart specialisation in water reflecting water-economy, markets, and ecosystem services for water; • Open access specific guides, security issues, IPRs for water; • Innovation capacity development tools for the entire innovation process.
S5 • - International Cooperation	• Support identification and implementation of highly transformative water innovations in support of the SDGs through policy support, innovation capacity, and active/effective partnerships.	• Support cohesive policy making (and financing) around SDGs on Water and on Partnerships; • Identify innovation opportunities and entrepreneurial opportunities to address global challenges on water; • Contribute to the creation of a global partnership for development in the Water sector (public, private, civil society).

KC 6 Sub-Challenges

KC6-S1 Create a level playing field and incentives for eco-innovative companies

Challenges/opportunities

Realisation of innovation requires a balance between push and pull of technological and non-technological solutions all along the innovation value chain of water. For the diverse and fragmented water sector and in particular for small and medium solution-providers in addressing various water challenges a favourable business environment has to be created. In addition, innovation diffusion requires development of flexible conditions and in particular collaborative models towards the increase of the scale of dissemination and the speed of realisation of smart innovative solutions for water. This action will aim to accelerate the creation of favourable conditions and incentive environment to foster innovation transfer to the market for eco-innovative companies. Particular attention to be paid to create favourable conditions to support SMEs and mid-caps proposing new water eco-technological and managerial solutions to ensure succeeding the last step towards the market.

The activities to implement this objective will be concentrated around the following actions:

• Green public procurement enhancing innovation in urban water management for the circular economy;

• SME platforms to foster easy partnerships for water;

• Develop or make a better use of the existing EU-wide financing instruments (e.g. COSME) for water in support to develop business models to bring to the market innovative SMEs solutions on water;

• Fast Track Innovation for water-related value chains and life cycles including the possibility of testing and demonstration at local/regional scales and opening opportunities for the access to the ETV – environmental technologies verification testing.

KC6-S2 Standards, Water Footprint Assessment and Water Stewardship

Challenges/opportunities

Water stewardship is about the use of water that is socially beneficial, environmentally responsible and economically sustainable. This creates an opportunity for a potential to line business enhancements created by voluntary sustainable water management actions. Water Security is about the reliable availability of an acceptable quantity and quality of water for health, livelihoods and production, coupled with an acceptable level of water-related risks. Main actions include:

• Innovation in Green and Water Accounting Systems for the European Water Sector;

• Agricultural water stewardship for food security;

• Sustainable food security: water footprint of products;

• Towards New Urban Agenda: Water Stewardship approaches in the cities;

• Water stewardship certification for large water users in industry and agriculture and water stewardship collective action in the shared catchment;

• Energy certification methodologies for water cycle facilities;

• Methodologies and tools for sustainability assessment of circular economy systems and demonstrations for water;

• Implementation and demonstration of methodologies to assess water technologies in cross-sectorial business cases in various water cycles;

• LCA for water in various domains;

• Software-based sustainability (water & energy) rating tools for assessment of water& energy performance in water and water-dependent economic sectors; including the agricultural sector.

KC6-S3 Enhanced sharing of knowledge and best practices in water: education, awareness, capacity development tools

Challenges/opportunities

There's a need to improve the knowledge base related to water in Europe at all levels.

On the one hand, a set of new skills and competences is needed to design, develop and deploy new solutions and methodologies in the water sector, with a much more multi-disciplinary, open-innovation approach. On the other hand, capacity development measures are needed to enable policy-makers and managing authorities to apply new water governance schemes and solutions. Awareness raising campaigns and actions are needed to make citizens, consumers and users more sensitive to water themes and to promote behavioural change. Main actions include:

• New education and training programmes for an upskilled workforce in the future digital water sector;

• Awareness actions towards water managing authorities on new economic mechanisms and joint governance processes;

• Creation of smart skill building tools for water and water-related sectors to facilitate replicability and applicability of water related technological solutions and facilitate capacity development;

• Talent building programme on KETs and FETs for water and water in a circular economy;

• Vocational training for smart water systems, technologies, management / governance, and water economy;

• Education programmes / smart people = smart consumers;

• Awareness raising actions on social perception of water reclamation and reuse: water reclamation and reuse are technically feasible even for the most demanding applications (e.g., direct potable reuse) but often find very strong opposition due to users' perception and "political" biases.

KC6-S4 Water advocacy, planning and management capacity

Challenges/opportunities

Water is not given the right order of priority in decision-making and planning at local (e.g. city), regional or national levels. Managing authorities and public servants sometimes consider water as part of the larger "sustainability" theme, underestimating the true value of water and the linked benefits for our society.

There's a need to advocate more towards policy-makers at Member State and regional level to put the water agenda more at the centre of their plans and implementation actions, as well as to review and update the regulatory framework to fully enable the potential of the water system to be expressed.

Main actions of this Key Component include:

• Support measures to integrate water component into the implementation of roadmaps (such as agricultural policy implementation actions via rural development plans), regional and urban investment strategies;

• Innovations in regulatory framework, utility pricing systems / transparency of value / price for water, social awareness, life-cycle assessment including water, smart specialisation in water reflecting water-economy, markets, and ecosystem services for water;

• Open access specific guides, security issues, IPRs for water;

• Innovation capacity development tools for the entire innovation process (supply and demand side, users of innovation, etc.).

KC6-S5 International Cooperation

Challenges/opportunities

Main common ground of understanding for prominent role of international cooperation and prioritisation of SDG: Europe's prosperity depends on global sustainability and Water is traditionally a strong, cohesive, and cross cutting topic.

Main actions are:

• New **entrepreneurial opportunities** for solution providers (Support Actions): Support the promotion of the European model for smart-water abroad, through: i) first-of-a-kind demonstration of novel technologies and solutions in extra-EU countries and regions; ii) strengthening collaborations and synergies with water management and innovation platforms with strategic regions (e.g., Israel, the US, Japan, Middle-East);

• Topics related to **International Cooperation and Water SDG contribution**:

◦ Water Innovation and the SDGs:

- Structural linkages between innovation and sustainable development, including inclusion of SDG in corporate strategic planning;
- Identification of "transformative potentials" for the achievement of SDGs from other KC (e.g., the impact of circular economy and all its aspects to SGDs, Citizen Science as an essential tool for the monitoring aspect of the SDGs), in cooperation with relevant international actors (the UN, development banks, etc.).

◦ SDG as tool for more cohesive policy making and financing:

- Alignment of Policies and Financing mechanisms within the EU and beyond the EU around the overarching SDG agenda (matching EU funds with international scale financing around SDG achievement);
- Support international cooperation on Water, as a means to achieve EU priorities in terms of jobs and growth considering the prominent role of Water in jobs creation).

◦ SDG and International cooperation on Water:

- Complementing and upscaling initiatives at EU level (ERA-Net, coordination, and support actions) with emerging international initiatives, in support on the Global Partnership goal of the SDGs (e.g., twinning mechanisms between cities at international scale Water Sensitive Cities);
- Developing capacities in the EU and abroad (or joint capacity) to successful research and co-generation of knowledge and innovation to address real life demands and societal challenges.

Annex I: Terms and Definitions

The Value of Water • Expression of the importance of water for our society at large, including the enabling function for all our economic activities, societal functions related to health and well-being as well as the (potential) economic value of resources (nutrients, chemicals, metals, minerals) and energy, embedded in our water streams, including ecosystems services, natural water systems are providing.

The Value in Water • Indicating the economic and societal value that can be realised by extracting and valorising substances, such as nutrients, minerals, chemicals and metals as well as energy, that are embedded in water streams.

Water-smart society • A society in which the true value of water is recognised and exploited, and all available water sources are managed in such a way that water scarcity and pollution of groundwater is avoided, water and resource loops are closed to a large extent to realise a circular economy and optimal resource efficiency, while the water-system is resilient against the impact of climate change events.

Water-system • The combination of water infrastructure (grey and green), processes, governance mechanisms, rules, organisations related to the extraction, treatment, distribution, use and re-use of water, as well as the resilience of the water infrastructure.

Hybrid grey and green infrastructure • A combination of grey engineered infrastructure, green engineered infrastructure and natural systems, part of the water-system that will be used for water extraction, treatment, distribution, re-use, and resilience.

Multiple waters • Important underpinning concept of the Water Europe's water vision, picturing a future in which different alternative water sources and qualities (fresh ground and surface water, rain water, brackish water, saline water, brines, grey water, black water, recycled water) will be available to our society, and applied for different functions by multiple users.

Digital Water • Important underpinning concept of the Water Europe's vision, based on the predicted development of a world where all people, "things" and processes are connected through the "Internet of everything" leading to capillary networks and sensors, meters and monitoring of the water-system up to the individual user, as such generating large amounts of valuable data (big data) for innovative Decision Support and Governance systems.

Water Europe future-proof model for a water-smart society • A model and framework that structures the required research, development and innovations with respect to the current water-system, in order to realise the vision of a "water-smart society".

Technology Readiness Level (TRL) • A method of estimating technology maturity of Critical Technology Elements (CTE) of a programme during the acquisition process (source: Wikipedia). A comprehensive approach and discussion about TRLs have been published by the European Association of Research and Technology Organisations (EARTO), in the report "The TRL Scale as a Research & Innovation Policy Tool, EARTO Recommendations" (30 April 2014)[29].

Types of innovation • According to the EC[30] and the OECD (2005) there are "four types of innovation: product innovation, process innovation, marketing innovation and organisational innovation. Another very important distinction in the economics is between disruptive (or "radical") and incremental (or "follow-on") innovation. The (technological) innovation process comprises the chain beginning with applied R&D, prototyping and development, and commercialisation." Non-technological innovations are: marketing and organisational innovations, which supplement and complement technological innovation, thus driving to the innovations in new business models. Non-technological issues furthermore can cover - human behaviour, service innovations, technology transfer, market developments, innovation policy and industry-related sectorial policies, etc. - necessary for staying competitive in the markets and supporting existing industries and large enterprises in Europe.

Key Enabling Technologies (KETs) • Are knowledge intensive and associated with high R&D intensity, rapid innovation cycles, high capital expenditure and highly-skilled employment. They enable process, goods and service innovation throughout the economy and are of systemic relevance. They are multidisciplinary, cutting across many technology areas with a trend towards convergence and integration". KETs are[31]: 1) Nanotechnology, 2) Micro- and nano-electronics, 3) Photonics, 4) Advanced materials, 5) Biotechnology, 6) Advanced manufacturing systems.

Fast Growing Technologies (FGTs)[32] • Are indicated KETs that are growing/developing in a high speed in the EU regions during the certain period of time. Joint Research Centre report[33] indicates that, "the relative fast rate of growth of a technology is one of the most frequent attributes for KETs considered as a condition for emergence. To identify FGT of KET, the JRC has developed certain criteria presented in their report.

Future Enabling Technologies (FETs)[34] • Go beyond what is known! Visionary thinking that can open up promising avenues towards powerful new technologies. FET actions are expected to initiate radically new lines of technology through unexplored collaborations between advanced multidisciplinary science and cutting-edge engineering.

Water governance • Is the set of rules, practices, and processes through which decisions for the management of water resources and services are taken and implemented, and decision-makers are held accountable. (OECD (2011) Water Governance in OECD countries: A Multi-level Approach, OECD Publishing, Paris. OECD website).

Scale of application • Water management implies actions at very different scale and magnitude, from the single household, cultivated field or industrial plant, to a city or industrial district, up to a region, a country or even a cross-country river basin. Within this framework, technological development and application depends on its level of development, e.g. a new membrane to be used in a specific industrial process will be firstly applied at a pilot plant scale, before being applied at full industrial scale to a full plant. On the other hand, another innovative technology that serves large Water Treatment Plants will be deployed. In this document the different scale of deployment (small, large, very large) is understood taking into account geographical, technological and level of deployment of the technologies and solutions.

Living Labs • Large scale user-centred, open innovation systems or experimenting environments for deployment, testing, replication and upscaling of innovative systemic and yet locally attuned solutions where water plays a central role. Living Labs use co-creation approaches integrating research and innovation systems and entailing a paradigm shift for the whole innovation process towards a water smart society.

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Annex II: TRL Definition and Table

TRL	1	2	3	4	5	6	7	8	9
TRL-scheme adapted to HLG´s three-pillar-bridge model	Basic principles observed	Technology Concept formulated	Experimental proof of concept	Technology validation in lab	Tech valid in relevant environment	Demonstration in relevant environment	Demostration in operational environment	System complete and qualified	Successfull mission operation
	Fundamental Research	Pillar 1: technological research			Pillar 2: Product demonstration				Pillar 3: Competitive Manufacturing
OECD Frascati Manual RDI State Aid framework	Fundamental Research		Industrial Research				Experimental development		
Risk Capital Guidelines/ Regional Investment Aid									SMEs risk capital & Regional aid
Horizon 2020					Research and innovation actions				Market replication
						Prototyping, testing, demostrating, experimental, development, piloting			
European Regional Development Fund	Basic Research		Technological and applied research			Pilot lines, early product validation actions, advanced manufacturing capabilities			First production

European Investment Bank										
	Intellectually driven investigation with no foreseeable economic application	Investigation within established disciplines/ technologies	Appl. research within exist. techn. boundary w/ pract. applic. in mind	Technology start-up to developed practical applic. for research ideas	Collab. Develop. within exist. industries to produce new of next generation tecnology	Tech. Develop. of products following a defined longer-term technology "roadmap"	Develop. of new general products involving substantial modification /innovation	Process/ product innovation designed to modify/ improve/ different late exist. prodcuts	Process innovation designed to reduce Cost/extend life to exist. product range	Product Support
	Research				Development			Innovation		

Annex III: Water Europe SIRA Sub-Challenges Inventory Table

Key Component 1: The Value of Water

Sub-challenge	Goals	Actions
S1 • Towards new economic models for the value of water	• Realise the true value of water implementing cross-sectorial approach and nexuses; • Full cost recovery towards increased sustainability of water systems; • Define who pays for water (e.g., according to the Polluter Pays Principle), or alternatively, who benefits (e.g., Benefit Pays Principle).	• New pricing mechanisms; • New business models; • New financing schemes and instruments; • Internalise environmental impact and ecosystem services.
S2 • Towards multiple waters in a circular economy	• Decouple water demand and availability from natural water cycles (including climate change risks); • Provide fit-for purpose water to different users for different uses.	• Multiply water sources; • Support to closing the water loops in a circular economy: Implement reuse/ recycling/cascading; • LCA of 'new water' as a new resource/ feed; risk assessment and abatement strategies, new standards.
S3 • Optimising the use of water in all sectors	• Reduce dependency on water availability and quality; • Make more with less water.	• In Agriculture, Industry, urban.
S4 • Creating new markets, valorising the value in water	• Strengthen and consolidate the leading position of the water market in and outside Europe; • Create growth and jobs in a multi-Billion market.	• Cost efficient recovery of valuable resources from water; • Implementing mature technologies for more efficient water treatment.
S5 • Energy harvesting as integrated valorisation strategy of water	• Fully exploit the water-energy nexus.	• Extract energy from water fluxes; • Exploit energy gradients in waters; • Reduce energy-intensive water needs (e.g., heating, cooling, etc.).

Key Component 2: Technologies – enabling insight and manageability

Sub-challenge	Goals	Actions
S1 • Digital enabling technologies for a water-smart society	• Measure, monitor, control the status of water bodies; • Smartening of the water infrastructure; • Achieve improved data-driven insight, forecasting, and decision making.	• Develop and deploy innovative sensors; • Develop and deploy innovative technologies, methods and tools to collect, store, analyse data; • Forecasting technologies and visualisation for advanced decision support.
S2 • Technologies for safeguarding surface and drinking water from pollution	• Prevent pollution at source and in all the water cycle; • Better understand the links between pollution and health; • Remove/minimise pollution in water systems and bodies.	• New technologies, analytical and digital instruments and systems, and strategies for pollution detection, monitoring, analysis and identification of actions/roadmaps; • New water and digital (nano-membranes based and other) technologies for pollution removal.
S3 • Enabling cost efficient water treatment technologies to foster re-use, recycling and cascading	• Improve water quality, with a multiple waters approach; • Extract and make available valuable resources and energy; • Support the application of the multiple waters concept through the right mix of centralised/decentralised systems.	• New treatment solutions for recovery and (re)use of recovered resources (and energy); • New solutions for decentralised treatment.
S4 • Advanced technologies and approaches for water management in Agriculture	• Increase water efficiency in the agriculture sector.	• R&D on new technologies for "omics" and precision farming.

Key Component 3: Hybrid Grey and Green infrastructure

Sub-challenge	Goals	Actions
S1 • Resilience against Climate and Seasonal Change effects	• Mitigate the effects of extreme water events in urban and peri-urban areas; • Increase the resilience to seasonal change effects.	• Integrating green engineered and natural assets in the grey water infrastructure and near real time measurement of the water system (from KC2) enables active and adequate management; • Implement reclaimed/recycled water distribution networks in a multiple waters perspective in urban and rural areas; • Comprehensive urban planning integrated in other developments plans of cities, such as green areas and biodiversity, health, infrastructure; • Validating functionality of green, blue and grey infrastructure under extreme conditions.
S2 • Longer term financial sustainability of the water distribution system	• Secure financial models and practices that integrate long-term cost effective maintenance and inclusion of externalities in financial asset management of our water infrastructure.	• New cost effective maintenance solutions and practices, including advanced sensors for better maintenance planning; • New longer term forecasting models and tools for refurbishment, maintenance, and financial management; • Implement novel financial and business models in financial management tools and practices.
S3 • Redesigned integrated hybrid grey and green infrastructure	• Restored and renovated water infrastructure for reduced environmental impact and resilience against climate change effects; • Enabling dynamic allocation of multiple water resources for multiple uses/users.	• New integrated infrastructures and related control systems to treat multiple water sources, and allocate different (treated) water streams for different purposes; • Creating small local loops for multiple waters and multiple uses, closing water infrastructure between different users in urban and rural areas; • Design novel ways to integrate natural solutions into the grey infrastructure.

Key Component 4: Governance

Sub-challenge	Goals	Actions
S1 • Decision Support Systems for multi-stakeholder Governance	• Advanced near-real time decision support systems and information exchange at all levels.	• Develop decision support systems for competing users of water resources; • Improvement of the knowledge base and ICT tools of nutrient management and recycling; • Development, deployment and integration of digital DSS and communication technologies and tools; • Develop new methodologies for climate impact analyses and decision-making.
S2 • Stakeholder engagement for good water governance	• Smart and engaged stakeholders that appreciate the value of water and share responsibilities.	• Engaged dialogue among diverse stakeholders in water resources management; • Capacity development of all stakeholders on the value of water and water usage, stressing that water access also implies responsibility; • Innovative use of advanced ICTs for communication/dissemination campaigns/ and public engagement, including citizen science.
S3 • Integrated planning and water management at all levels and across sectors	• New multi-stakeholder governance models that manage availability of water for all users and sectors; • Fit-for-purpose, adaptive and evolving economic and governance mechanisms.	• Create multi-stakeholder partnerships, co-innovation between industry/RTO /SMEs, industrial symbiosis, and joint technology market places; • Integrated water management between all stakeholders in industrial parks; • Establish and structure regional multi-stakeholder platforms; • Create public-private open innovation platforms, to foster collaborative and continuous open innovation; • Re-shape (legal) accountability for water, build mutual trust; • Implement broader regional tools to optimise all water assets/functions amongst different sectors; • Develop new multi-stakeholder organisational set-ups for collaboration on infrastructure management.

Key Component 5: Real-life living labs

Sub-challenge	Goals	Actions
LL1 - Rural Living Lab Pilots	• Reduce the impact of agriculture on over-abstraction of water Improve agriculture sector commitment to water goals.	• Using advanced sensors and EO to obtain detailed and real-time insights in water use; • Novel green-agricultural technologies to reduce water use for crop production; • Application of new economic instruments towards more efficient use of water; • Spatial planning including buffering of water.
LL2 - Future Industries Living Lab Pilots	• Closing of the water loop (100% in some cases) between industries and other water users (e.g., cities, agriculture, waterborne transport, etc.); • Realise new business models, opportunities and markets.	• Foster and enlarge industrial symbiosis; • Implement technologies, new business models and water diplomacy solutions towards multiple waters; • Implement innovative ICT-enabled Decision Support Systems for water management.
LL3 - Smart (Peri-) Urban Living Lab Pilots	• Reduction of water use at urban level; • Implementation of multi-stakeholder governance and planning models for cities.	• Multiplying water sources, new pricing mechanisms, closing loops and increased awareness and citizens' participation; • New insight through digital technologies up to single user level; • Long-term urban planning with high focus on water towards resilience against climate change induced events.

Key Component 6: Horizontal

Sub-challenge	Goals	Actions
S1 • Create a level playing field for eco-innovative companies	• Promote eco-innovative solutions.	• Support eco-innovation champions (especially SMEs); • Green Public procurement to promote eco-efficiency.
S2 • Standards for Water Footprint Assessment and Stewardship	• Promote water stewardship at all levels (cities, industries, cross-sectorial) all along the value chain and the water cycle; • Improve monitoring of water impact and related accountability allocation based on commonly shared KPIs.	• Implement water stewardship in agriculture and cities; • Innovation in Green accounting system; • New tools for water impact assessment (including LCA).
S3 • Enhanced sharing knowledge and best practices in water: education, awareness, capacity development tools	• Create a "water-aware" European workforce of the future; • Change perception and behaviour of European citizens towards a future water-smart society.	• Develop and deploy new, ad-hoc skills and training programmes for upskilled workers in digital technologies, managing authorities, water sector specialists, innovators, etc.; • Actions for awareness raising and behaviour change towards waters in citizens and large public.
S4 • Water advocacy, planning and management capacity	• Embed water component into existing governance practices; • Develop radically new approaches for water governance (including Water Diplomacy).	• Integrate water into roadmaps, regional and urban investment strategies; • Innovations in regulatory framework, utility pricing systems/ transparency of value/price for water, social awareness, life-cycle assessment, including water, smart specialisation in water reflecting water-economy, markets, and ecosystem services for water; • Open access specific guides, security issues, IPRs for water; • Innovation capacity development tools for the entire innovation process.
S5 • International Cooperation	• Support identification and implementation of highly transformative water innovations in support of the SDGs through policy support, innovation capacity and active/effective partnerships.	• Support cohesive policy making (and financing) around SDGs on Water and on Partnerships; • Identify innovation opportunities and entrepreneurial opportunities to address global challenges on water; • Contribute to the creation of a global partnership for development in the Water sector (public, private, civil society).

End Notes

1) FET- future emerging technologies, KET – key enabling technologies, e.g. nanotechnologies.

2) e.g. city, agglomeration, region.

3) Applying the cascade principle to water would mean to introduce a priority use based on the value and the quality of water. The "cascade principle" is taken from the biomass sector, e.g. for wood resources (as for the recent Forest Strategy of the European Union) implies the priority use of wood material based on the higher added value that can potentially be generated along the wood value chain.

4) i.e., district, urban, rural, regional, river basin.

5) EIP WATER - Barriers and bottlenecks for Innovation in the Water Sector (2014), p. 5

6) 'Assessment of cost recovery through water pricing' - EEA Technical report No 16/2013.

7) See further clarifications on the right price to water in the European case law: ECJ decision of 2014.09.11 on the Case C-525/12.

8) 'Water Prices' - EEA Report 2003.

9) 'Managing Water for All - an OECD perspective on pricing and financing' – OECD 2009.

10) See ECA report "Integration of EU water policy objectives with the CAP: a partial success" – p.6" The Court concludes that cross compliance and rural development funding have thus far had a positive impact in supporting the policy objectives to improve water quantity and quality, but these instruments are limited, relative to the policy ambitions set for the CAP and the even more ambitious goals set by the CAP regulations for the 2014–20 period".

11) Value at Risk (VaR) is a measure of the risk of investments. It estimates how much a set of investments might lose, given normal market conditions, in a set time period. (Wikipedia). 'Weather Value at Risk' (sometimes referred also as 'Climate Value at Risk') was introduced to measure the economic risks resulting from current weather fluctuations and climate change.

12) COM(2012) 673.

13) Optimising water reuse in the EU – Final report.

14) 'Innovation and research needs for the water-energy linkage', Position Paper of the Water Europe Working Group on "Water and Energy", July 2016.

15) Water quality trading (WQT) is an incentive-based approach to reducing or controlling water pollution. Under such a system, polluters are granted a permit to pollute, and these permits can be bought and sold among polluters. The central idea is that trading puts a price on pollution, encouraging cost savings, efficiency, and innovation. (Source: Incentive-Based Instruments for Water Management - The Rockfeller Foundation, Dec 2015, p.15)

16) COM(2015) 120 'The Water Framework Directive and the Floods Directive: Actions towards the 'good status' of EU water and to reduce flood risks' – March 2015.

17) Augmented Strategic Research Agenda (SRA) of the European Smart Systems Integration Ecosystem – EPOSS 2015.

18) COM(2015) 120 final: The Water Framework Directive and the Floods Directive: Actions towards the 'good status' of EU water and to reduce flood risks.

19) http://www.ibtimes.co.uk/europe-faces-increasing-floods-droughts-storms-due-climate-change-1556530
http://link.springer.com/article/10.1007/s10584-016-1661-x

20) WWAP (United Nations World Water Assessment Programme). 2015. The United Nations World Water Development Report 2015: Water for a Sustainable World. Paris, UNESCO.

21) Urban, peri-urban, rural, river basin;

22) Prospects of Investment in Water Infrastructure: standing for Sustainable Development.

23) OECD. (2015), Stakeholder Engagement for Inclusive Water Governance, OECD Studies on Water, OECD Publishing, Paris.

24) OECD (2016), Water Governance in Cities, OECD Studies on Water, OECD Publishing, Paris.

25) "A theory and practice of implementing adaptive water management for complex water issues, developed at Tufts, MIT, and Harvard." (http://waterdiplomacy.org/)

26) European Structural and Investment Funds.

27) COM(2015) 120 final "The Water Framework Directive and the Floods Directive: Actions towards the 'good status' of EU water and to reduce flood risks"

28) See also TRL Table used by the EC in H2020 in Annex I.

29) https://ec.europa.eu/research/innovation-union/pdf/expert-groups/eriab_final_policy_brief_eu_legislation_enabling_or_disabling_innovation.pdf

30) http://s3platform.jrc.ec.europa.eu/documents/20182/117542/S2E_Fiche_KETs.pdf/72f2e425-9fbc-4e99-a26a-10122b53ce31 and COM(2009) 512 final

31) http://publications.jrc.ec.europa.eu/repository/bitstream/JRC98111/jrc98111_regions%20kets%20and%20fgt%20-%20technical%20report%20-%20final.pdf

32) http://publications.jrc.ec.europa.eu/repository/bitstream/JRC98111/jrc98111_regions%20kets%20and%20fgt%20-%20technical%20report%20-%20final.pdf

33) https://ec.europa.eu/programmes/horizon2020/en/h2020-section/future-and-emerging-technologies

About Water Europe

Water Europe is the European Technology Platform for Water. Initiated by the European Commission in 2004 as an industry-lead stakeholder forum. 12 years after and over 160 members, Water Europe has become the recognized voice and promotor of water-related RTD and innovation in Europe. We strive to increase coordination and collaboration, to enhance the performance of the water service providers, water users, and technology providers, in a sustainable and inclusive way.

Water Europe has developed different Programs which are key to the functioning, objectives, and implementation of the Water Europe strategy:

- **Collaboration and Working Groups Program** to foster collaborative initiatives between members that create value for members and society.
- **The Membership Program** to diversify and enrich the membership base to empower the exchange and collaboration amongst actors of the whole water value chain.
- **The Communications Program** to disseminate and raise the visibility of European research results and solutions, and the water sector in general.
- **The Advocacy Program** to create an enabling and business environment for water related RTD and innovation.
- **The Innovations Program**, to bring solutions and knowledge to the market.
- **The Investor Program** to facilitate the growth of investments in the sector.

Colophon

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Notes

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