WATER INFRASTRUCTURE INNOVATION WORKSHOP, MAY 2012

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WATER INFRASTRUCTURE INNOVATION WORKSHOP MAY 2012

Executive Summary

Resilience of infrastructure has been identified as one of the key factors in ensuring water and waste water security for supplies to domestic customers, industry and agriculture.

This is one of eleven topic areas identified for in-depth investigation by the UK Water Research and Innovation Partnership.

A workshop was held on 10 May 2012 involving 30 technical experts from academia, government agencies and industry, with objectives to identify the drivers, challenges, required outcomes and the needs for research, development and innovation.

Results from this workshop, which focussed on water infrastructure challenges, drivers and required outcomes together with supporting research and innovation needs, were analysed, prioritised and presented. The conclusions and recommendations were that the top 3 water infrastructure issues requiring innovation to support delivery of required outcomes were:-

- Balancing UK water demand and water resources
- Driving towards zero urban network failures to deliver water and wastewater services with minimal urban street disruption
- Reversing the current trend of increasing energy and chemical consumption to meet EU environmental water quality standards, driving towards sustainable energy and resource recovery from wastewater processing

An overarching framework of challenges to achieving water infrastructure resilience was identified as understanding and managing uncertainties in terms of climate change, extreme weather events, customer service expectations and future regulatory requirements. (Figure 3).

A further recommendation was that in achieving a more resilient UK water infrastructure it should be possible to grow and project the economic value of UK water capabilities for meeting global market needs.

The recommended next step was to engage 3 multi-stakeholder action groups through UKWRIF, LWEC and UKWIR to develop these 3 priority topic recommendations into a coherent series of research and innovation programmes, including timescales, resource needs and estimated costs. The action groups should identify and recommend funding, resources and delivery methods for each of the identified innovation actions presented in Figures 4, 5, and 6 of the report. It is recommended that these action groups are established in 2012 and charged with producing draft programmes for the period 2013-2020 in the first quarter of 2013.

It is recommended that 3 of the identified needs could be addressed as an immediate priority for action in 2012 by UKWRIF, LWEC and UKWIR with support from the workshop delegates.

UK infrastructure innovation testing facilities

Included in this recommendation was a strongly recognized need for a UK network infrastructure test centre(s) and register of urban sites where field trials of innovative technologies may be carried out. This should focus on water / multi-utility, network infrastructure buried under urban transport corridors. It should include a register of current innovative technology trials for opportunistic evaluation of other supply chain or academic innovation that may also be carried out at least "set-up" cost. It should also identify, co-ordinate and designate example urban streets for a period of technology trials. There was also a longer-term opportunity to link and develop a wider EU network and urban street infrastructure innovation framework.

Parties willing to co-operate on developing this action included; UKWIR, WRc, supply chain (represented by British Water, Balfour Beatty, Subterra and consultants) with interest also expressed by academics attending the workshop. It was also considered that EPSRC and TSB should be engaged in developing this network.

Support implementation of EPSRC funded Mapping the Underworld project

The multi-party, collaborative series of projects with the working title of "Mapping the Underworld" aims to develop multi-sensor technologies to locate buried infrastructure without excavation in urban streets. This internationally leading research has so far attracted over £4m of funding for the research phases from EPSRC, UKWIR, water and other utilities and their supply chain. The research work, by a consortium of UK universities, lead by Prof Chris Rogers of U. Birmingham is nearing completion (2013). It is recommended that an action group is established to support a commercial development and implementation phase for UK and international exploitation. The TSB should be engaged in this activity together with current funding members. UKWIR is willing to lead facilitation of this action.

A further research phase, entitled "Characterising the Underworld" is identified in the long-term research vision presented in Appendix 6. This was to find the science and develop technology to locate failures in buried infrastructure and preferably identify condition before failure. It is strongly recommended that EPSRC, STFC and TSB give consideration to developing a large collaborative call for this research in 2013. Industry members of the current "Mapping the Underworld" programme would be expected to contribute to this research. UKWIR is willing to lead the industrial partnership if the identified Research Councils provide funding of the academic research required.

Consumer behaviour research to support "Smart Metering and Tariffs" trials

Several UK water utilities are conducting or have plans to conduct large-scale trials of water metering to determine impact on water demand and the cost and benefits of different metering and reading technologies. UKWIR is already co-ordinating the water utility sector research on this topic. Workshop delegates recommended that engagement with the energy sector was included to evaluate the cost benefit of "Smart Metering" for both energy and water and that the relevant regulators (OFGEM and OFWAT) were consulted, particularly on the potential for future "Smart Tariff" structures for peak demand management. It was also recommended that ESRC supports academic research on consumer behaviour and economic demand models for the water or combined energy and water sectors in research calls for 2013. UKWIR is willing to lead the water sector aspect of this work.

Figure 3 Priority issues and required outcomes

FRAMEWORK GOALS	Planning for Uncertainties: Climate Change, Extreme Events, Levels of Service Future Regulatory Frameworks

	ISSUES & DRIVERS →	REQUIRED OUTCOMES
BALANCING WATER DEMAND AND RESOURCES (See Fig 4)	- Increasing risks and gap between UK water demands and sustainable UK water resources - Limitations in current catchment-scale focus on developing strategic investments for UK wide water security - Limited means to manage end-user demand and to balance between competing needs	- Sustainable long-term framework and tools for balancing UK water demands and UK water resources - Adaptable and sustainable solutions to meet changing demands

	ISSUES & DRIVERS →	REQUIRED OUTCOMES
BURIED PIPE NETWORKS (See Fig 5)	- Ageing infrastructure assets - Increasing risks of failure - Inabilities to cope with changing demands - Increasing disruption to urban environment	- Towards Zero Network Failures - Towards Zero Urban Disruption - Towards Sustainable Customer Service

	ISSUES & DRIVERS →	REQUIRED OUTCOMES
SUSTAINABLE ENERGY USE AND RESOURCE RECOVERY (See Fig 6)	- Increasing energy intensity and greenhouse gas emissions from wastewater operations to meet increasing EU water quality environmental standards - Increasing chemical usage and waste production - Resource potential of water sector waste products not fully exploited	- Catchment scale co-ordinated regulatory framework to balance water quality and GHG emission objectives - Towards zero or energy positive wastewater pollution control solutions - Towards sustainable recovery of resources from water and wastewater operations

ENABLERS NEEDED	- Engagement of all parties included Asset Owners, Operators, Academia and Supply Chain - Incentives for Innovation, Reduce Barriers in Regulation and Procurement Processes, Multi-Utility Approach - Development of R, D and I Programmes, based on identified issues and required outcomes

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1 Background – UK water infrastructure

Reliable, efficient and resilient water infrastructure is essential to our way of life. Agriculture, industry, energy generation and domestic consumers could not function without adequate water and drainage systems.

Water infrastructure includes engineered systems for water abstraction, storage, pumping, treatment, distribution, drainage, sewerage, wastewater treatment and flood control. The water sector is amongst the largest and longest-life infrastructure asset bases of any UK utility or industrial sector, with a current replacement value of the order of £500 billion (authors estimate) and average annual capital expenditure of £5 billion.

The UK water industry has made significant investment (circa £100 billion) in infrastructure since privatisation in 1989 and currently provides high quality drinking water and wastewater services to its customers. However evidence is building that the UK's current water infrastructure is facing increasing challenges to provide resilient services with ageing assets in a rapidly changing environment.

There are more than 0.6 million kilometres of water pipes and sewers buried beneath busy streets, often in close proximity to other utility services, with the risk of serious disruption whenever repair, maintenance or replacement activities are needed.

Much of our UK water and wastewater infrastructure is among the oldest in the world, as many cities and towns in the UK were the first to have 'modern' water supply and sewerage systems. Overall, this has been added to and considerably extended over the past 100-150 years and is in varying condition from "excellent" to "unknown" and has varying abilities to cope with future needs.

A changing climate, extreme weather events and growing population will bring significant challenges to existing UK water infrastructure and its ability to deliver secure and sustainable levels of service.

2 Methodology – identifying UK water innovation needs

2.1 Links to previous UK water innovation studies

This report builds upon a process that commenced in 2011 to investigate issues and challenges relating to UK water security. UKWIR was commissioned by the newly formed UK Water Research and Innovation Framework (UKWRIF) to study and analyse recently published technical reports and to identify key areas where research, development and innovation could contribute to achieving future UK water security. This report, Research and Innovation Mapping Study for the UK Water Research and Innovation Framework (1), was published and presented to UKWRIF in July 2011. A need to improve the resilience of UK water infrastructure supported by research and innovative solutions was one of the 6 key recommendations, details of which are presented in appendix 5.

Key reports referring to UK water infrastructure identified and analysed by this previous report are included in the reference section of this report namely:

Infrastructure, Engineering and Climate Change Adaptation – ensuring services in an uncertain future published in February 2011 published by the Royal Academy of Engineering on behalf of Engineering the Future (2); National Infrastructure Plan 2010 published by HM Treasury in October 2010 (3); Strategic Research Agenda 2010 published by EU Water Supply & Sanitation Technology Platform in 2010 (4); A Road Map of Strategic R&D Needs to 2030 published by UKWIR in July 2007 (5); together with the recent Institution of Civil Engineering, State of the Nation Water 2012 report (6) which also identifies water infrastructure issues and challenges.

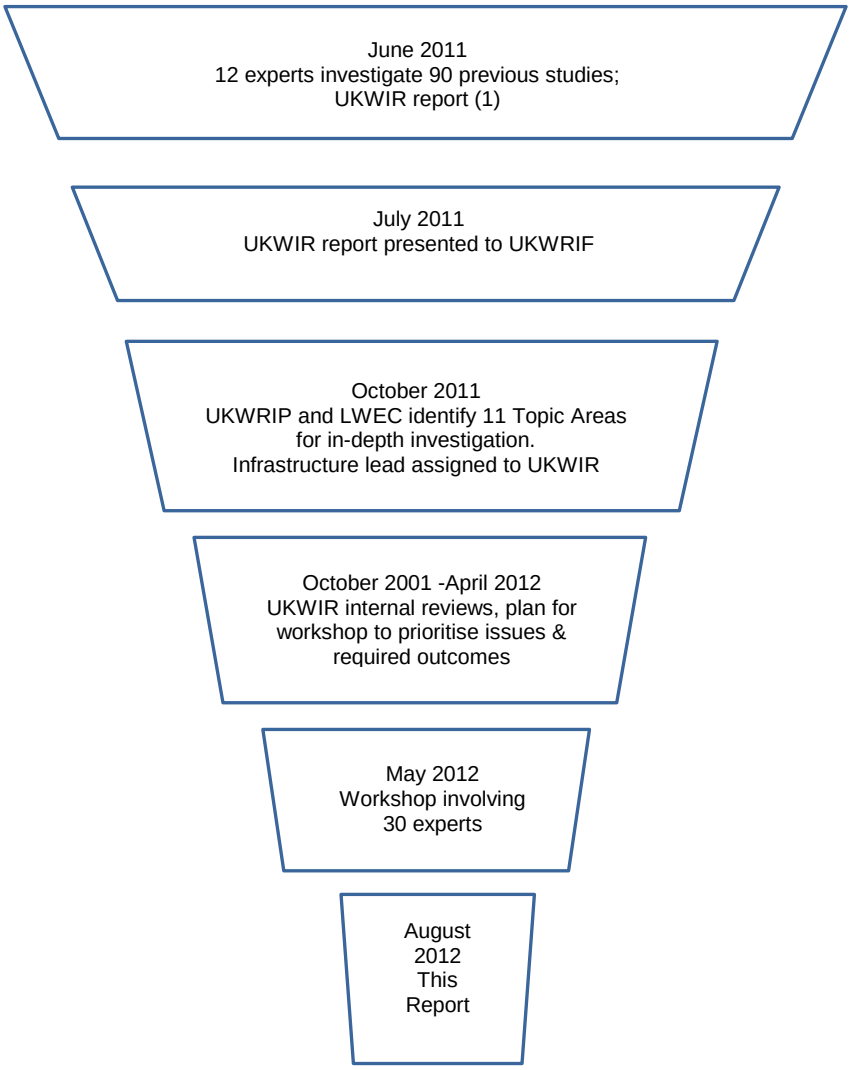
UKWRIF (now UKWRIP where the P is for Partnership) and the Living With Environmental Change membership mapped the water challenges into the wider environmental change challenges illustrated in Figure 1.

Figure 1 Identified living with environmental change challenges

2.2 Brief and methodology for this study

UKWIR was subsequently assigned to lead an action group to further develop and prioritise the issues and innovation needs for UK water infrastructure as illustrated in Figure 2.

Figure 2 Development of the process to identify UK water infrastructure innovation needs



The brief for this review and resulting workshop is presented in appendix 1. The requirement was to identify and prioritise research, development and innovation needs to support future resilience of UK water infrastructure.

Experts with a wide range of water and related technical backgrounds were identified from utility, academic, regulatory agency, government, consulting and supply chain backgrounds and invited to contribute to the workshop. 30 delegates (appendix2) contributed to the workshop. The agenda and methodology adopted during the workshop process is presented in appendix 3.

3 Workshop results

A full record of ideas generated at the workshop together with their prioritised votes are presented in appendix 4.

3.1 Key identified challenges and drivers

Summaries of recent water infrastructure innovation needs reports were presented and built upon during the workshop (reference 1). Delegates identified the following key challenges and drivers for innovation to improve water security, infrastructure resilience and reliable service provision to UK customers (without priority ordering).

- Halt ageing of UK water infrastructure asset base
- Achieve security of water resources / supply in changing UK population and climate
- Regulatory uncertainty for investment to adapt to climate change and extreme events
- Understand customer service expectations & willingness to pay for water security
- Determine UK water demand impact, cost and opportunities from increased (smart?) metering
- Lack of a national strategy on developing strategic water resources and catchment transfers
- Reduce operational energy costs and greenhouse gas emissions (EU WFD impact)
- Manage performance, and risks from pipe networks before a negative impact on customers
- Understand serviceability, risks and need for investment in private sewer infrastructure.
- Future UK impact of changing water demands by agriculture and energy sectors
- Long-term urban infrastructure planning between multiple utility services and transport corridors
- Regulation incentive balance between capital expenditure and whole-life-cost solutions
- Understand impact on infrastructure investment of proposed increased retail competition
- Pace of technology change, framework to evaluate, incentivise and engage with UK supply chain
- Ageing workforce, linked to increasing levels of ‘out-sourcing’ and loss of skills

Selected challenges and drivers linked to the top 3 prioritised workshop required outcomes are illustrated in Figure 3

Figure 3 Priority issues and required outcomes

FRAMEWORK GOALS	Planning for Uncertainties: Climate Change, Extreme Events, Levels of Service Future Regulatory Frameworks

	ISSUES & DRIVERS →	**REQUIRED OUTCOMES**
BALANCING WATER DEMAND AND RESOURCES (See Fig 4)	- Increasing risks and gap between UK water demands and sustainable UK water resources - Limitations in current catchment-scale focus on developing strategic investments for UK wide water security - Limited means to manage end-user demand and to balance between competing needs	- Sustainable long-term framework and tools for balancing UK water demands and UK water resources - Adaptable and sustainable solutions to meet changing demands

	ISSUES & DRIVERS →	**REQUIRED OUTCOMES**
BURIED PIPE NETWORKS (See Fig 5)	- Ageing infrastructure assets - Increasing risks of failure - Inabilities to cope with changing demands - Increasing disruption to urban environment	- Towards Zero Network Failures - Towards Zero Urban Disruption - Towards Sustainable Customer Service

	ISSUES & DRIVERS →	**REQUIRED OUTCOMES**
SUSTAINABLE ENERGY USE AND RESOURCE RECOVERY (See Fig 6)	- Increasing energy intensity and greenhouse gas emissions from wastewater operations to meet increasing EU water quality environmental standards - Increasing chemical usage and waste production - Resource potential of water sector waste products not fully exploited	- Catchment scale co-ordinated regulatory framework to balance water quality and GHG emission objectives - Towards zero or energy positive wastewater pollution control solutions - Towards sustainable recovery of resources from water and wastewater operations

ENABLERS NEEDED	- Engagement of all parties included Asset Owners, Operators, Academia and Supply Chain - Incentives for Innovation, Reduce Barriers in Regulation and Procurement Processes, Multi-Utility Approach - Development of R, D and I Programmes, based on identified issues and required outcomes

3.2 Near-term (2012-2020) innovation needs

Delegates identified and proposed shorter-term innovation needs (not in priority order):-

- National UK infrastructure innovation test centre(s)
- Incentives for innovation / reduce barriers in regulatory / procurement frameworks
- Reduce energy and chemical demand to operate existing infrastructure
- More reliable sewerage and pumping systems, including sustainable drainage (SUDs)
- Trial smart metering with variable tariffs for demand management
- How to future proof infrastructure to meet changing customer service expectations?
- "No-dig" management of urban networks, "monitor and fix pipes from the inside"
- Common data standards for sharing, comparison and modelling ("Sim-City" tools)
- Integrated, multi criteria, approaches to water security decision making
- Urban planning to optimize resilient utility and transport infrastructure services

3.3 Longer-term research outcomes needed (2020-2040)

Delegates identified and proposed longer-term innovation needs (not in priority order):-

- Move from a high carbon energy consumer towards being a renewable energy recycler / producer
- Chemical free water treatment.
- Intelligent network infrastructure with zero leakage and failures and minimal urban disruption.
- Improve the UK strategic planning framework for water security at national and local scale
- Improve water security for the UK through understanding usage and demand management.
- Understand and implement large-scale, inter-catchment water transfers.
- Develop low carbon desalination solutions for UK saline water resources including estuaries.
- How to future proof infrastructure to meet changing customer service expectations?
- Achieve global recognition and international market growth for "UK Plc" water offers.

3.4 Priority outputs

Appendix 4 provides a full record of ideas generated at the workshop from challenges and drivers to short and longer-term innovation and research needs and desired outcomes. All results of the workshop delegate voting on priority assigned to these challenges and desired outcomes are also presented.

In this consolidated and prioritized outputs section these results are further clustered and analysed, retaining the component priority votes, to produce the water infrastructure resilience, top 3 priority output recommendations for delivering solutions via short-term innovation and longer-term research.

The top 3 consolidated recommendations were:-

3.5 Balancing water demand and resources

A strong need, for improved customer communication and social attitudes to water usage and willingness to pay research, was identified with potential stakeholder collaboration between customers and Utilities, OFWAT, EA, DWI, CCwater, Waterwise, ESRC and academic routes.

In the near-term, planned expansion of metering should allow for implementation of smart metering techniques enabling identification of time and rate of water use for linking to potential future tariff structures to support demand management.

Delegates proposed moving towards a long term target of 80 litres per capita domestic water consumption for all new properties and for retrofit solutions to reduce by 30%, current 155 litres per capita norm in the existing UK housing stock. This is expected to require smart metering, customer acceptable demand management and customer purchase of future, smart, water efficient appliances with appropriate and secure water reuse systems. This may be integrated with smart home energy management and heat reuse.

There was a perceived lack of a national strategy, incentive or co-ordination framework for planning, investing and developing strategic, water resources and water transfers across multiple catchments / water utility boundaries and multiple stakeholders. Delegates proposed a stronger framework for UK water resource planning at a national level and improved governance frameworks for strategic national (inter-river basin) resource development and local scale multi-party resource development (eg in conjunction with agriculture water resource storage or local to regional scale aquifer storage and recharge schemes).

Academic research could contribute to improved, strategic decision support models for analysing and predicting future supply demand scenarios, integrating customer demand behaviour, seasonal and climatic water resource impacts and future infrastructure storage and transfer options at national, catchment and local scales.

This topic requires a wide range of academic research disciplines covered by NERC, EPSRC, ESRC and end-user / stakeholder engagement.

The identified challenges, drivers, required outcomes and potential needs for achieving a future balance in water resource supplies and end-user demands are illustrated in Figure 4.

Figure 4 Priority topic: supply - demand

FRAMEWORK GOALS	Planning for Uncertainties: Climate Change, Extreme Events, Levels of Service Future Regulatory Frameworks

	ISSUES & DRIVERS	**REQUIRED OUTCOMES**
BALANCING WATER DEMAND AND RESOURCES	- Increasing risks and gap between UK water demands and sustainable UK water resources - Limitations in current catchment-scale focus on developing strategic investments for UK wide water security - Limited means to manage end-user demand and to balance between competing needs	- Sustainable long-term framework and tools for balancing UK water demands and UK water resources - Adaptable and sustainable solutions to meet changing demands

ENABLERS NEEDED	- Engagement of all parties including Asset Owners, Operators, Academia and Supply Chain - Incentives for Innovation, Reduce Barriers in Regulation and Procurement Processes, Multi-User Approach - Development of R, D and I Programmes, based on innovation needs identified below:

NEEDS FOR INNOVATION ACTION

Research social attitudes to water usage, value and service levels, linked to "willingness to pay" to shape future demand management and water resource investments
Include smart metering and smart tariffs in near-term metering trials for demand management, including potential multi-utility service synergies
Determine achievable, long-term, per capita water demand goals for new build properties (<80 l/person/day?) including future innovative water and energy efficient home appliances
Identify and trial current water efficiency technologies, including smart metering, to reduce water demand of current UK housing stock by 30% (from 155 to 110 l/person/day)
Create a UK wide strategic framework for water resource and demand scenario modelling to guide planning of future investment across multiple catchments including novel, large and local scale solutions for multiple end-users

ADDITIONAL GOALS	Grow Economic Value of UK Water Capabilities for Global Markets

3.6 Towards zero network failures

Included in this recommendation was a strongly recognized need for a UK network infrastructure test centre(s) and register of urban sites where field trials of innovative technologies may be carried out. This should focus on water / multi-utility, network infrastructure buried under urban transport corridors. It should include a register of current innovative technology trials for opportunistic evaluation of other supply chain or academic innovation that may also be carried out at least “set-up” cost. It should also identify, co-ordinate and designate example urban streets for a period of technology trials. There was also an opportunity to link and develop a wider EU network and urban street infrastructure innovation framework.

The objectives of “towards zero network failures, service disruption and sustainable customer service” could be achieved through more intelligent infrastructure and asset investment modelling, driving both operational service delivery and efficient asset capital planning. Includes remote sensing for asset location, performance and condition assessment, linked to real-time optimisation and “no-dig”, in-pipe repair and replace solutions. The phrase “monitor and fix pipes from the inside” summarized the desired outcome. It includes new sensing, optimization and control techniques to reduce asset and service delivery failure and energy used for pumping water and wastewater through pipe networks.

Research and innovation required included; ultra-low power or power-harvesting sensors to convert existing, “dumb”, network infrastructure to smart, self-diagnosing condition and performance management with in-pipe or no-dig repair and replacement solutions. Develop smart, multi-utility, buried infrastructure location, condition and fault location services for zero-urban-disruption, 24/7, smart street-works contractors and utility service providers. All new infrastructure assets have smart condition and performance assessment and remote communication (“Internet of Things” concept). Cost efficiencies should drive down “Economic Level of Leakage” for long-term, enhanced network renewal investment planning.

This topic requires academic research input mainly in the EPSRC arena together with end-use, supply chain and TSB engagement.

The identified challenges, drivers, required outcomes and potential needs for addressing urban infrastructure water network needs are illustrated in Figure 5.

Figure 5 Priority topic: urban infrastructure - buried pipe networks

FRAMEWORK GOALS	Planning for Uncertainties: Climate Change, Extreme Events, Levels of Service Future Regulatory Frameworks

ISSUES & DRIVERS → **REQUIRED OUTCOMES**

BURIED PIPE NETWORKS	- Ageing Infrastructure assets - Increasing risks of failure - Inabilities to cope with changing demands - Increasing disruption to urban environment	- Towards Zero Network Failures - Towards Zero Urban Disruption - Towards Sustainable Customer Service

ENABLERS NEEDED	- Engagement of all parties including Asset Owners, Operators, Academia and Supply Chain - Incentives for Innovation, Reduce Barriers in Regulation and Procurement Processes, Multi-Utility Approach - Development of R, D and I Programmes, based on innovation needs identified below:

NEEDS FOR INNOVATION ACTION

- Create register of current technology trials
- Identify and create register of designated urban streets for technology trials
- Develop UK network infrastructure test centres for field trials of innovative technologies developed by supply chain
- Develop wider EU network and urban infrastructure innovation framework
- Develop “No-Dig” technologies for remote sensing, asset location and condition assessment
- Develop “No-Dig” in-pipe repair and replacement solutions to monitor and fix pipes from the inside
- Develop more intelligent infrastructure, linked to real-time optimisation, service delivery, energy use, failure reduction and capital planning
- Research: ultra-low power and power-harvesting sensors, self-diagnosing condition and performance management
- Develop 24/7 smart street works and utility service providers: fault location, pre-failure warnings, methods to minimise disruption
- Develop methods to drive down performance deficiencies (eg Economic Level of Leakage) for long-term network renewal investment planning

ADDITIONAL GOALS	Grow Economic Value of UK Water Capabilities for Global Markets

3.7 Sustainable energy use and resource recovery

Environmental regulations (WFD) are driving contradictory impacts between improving wastewater quality whilst increasing carbon and chemical footprint of the water sector's treatment processes.

An identified priority was innovation to reduce operational energy costs in the shorter-term. A longer-term goal was to reduce carbon footprint over the whole life cycle of constructing and operating infrastructure.

Trials of innovative and cost effective techniques for sensing, optimisation and control techniques and process retrofit technologies to reduce energy and chemical usage/waste production are recommended.

Delegates proposed that longer-term research should step beyond incremental, retrofit optimization, focusing on step change, low carbon, wastewater process solutions to become a net energy producer for wastewater operations.

Research, innovation and large scale trials are required to enhance recovery of biomass energy and fertiliser nutrients (phosphates and nitrogen compounds) from current UK wastewater treatment process operations and infrastructure.

Research, innovation and large scale trials are required to maximise the potential for production and use of renewable energy from wastewater (methane / other fuels / heat from sludge).

This topic requires research input mainly in the EPSRC arena together with end-user supply chain and TSB engagement.

The identified challenges, drivers, required outcomes and potential needs for addressing energy reduction and resource recovery needs are illustrated in Figure 6.

Figure 6 Priority topic: energy and resource recovery

FRAMEWORK GOALS	Planning for Uncertainties: Climate Change, Extreme Events, Levels of Service Future Regulatory Frameworks

ISSUES & DRIVERS → **REQUIRED OUTCOMES**

SUSTAINABLE ENERGY USE AND RESOURCE RECOVERY	- Increasing energy intensity and greenhouse gas emissions from wastewater operations to meet increasing EU water quality environmental standards - Increasing chemical usage and waste production - Resource potential of water sector waste products not fully exploited	- Catchment scale co-ordinated regulatory framework to balance water quality and GHG emission objectives - Towards zero or energy positive wastewater pollution control solutions - Towards sustainable recovery of resources from water and wastewater operations

ENABLERS NEEDED	- Engagement of all parties including Asset Owners, Operators, Academia and Supply Chain - Incentives for Innovation, Reduce Barriers in Regulation and Procurement Processes, Multi-Utility Approach - Development of R, D and I Programmes, based on innovation needs identified below:

NEEDS FOR INNOVATION ACTION

Develop catchment-scale understanding and models for a sustainable and dynamic balance between achieving environmental water quality objectives and greenhouse gas emission goals
Develop sensors and models to adapt “smartphone” type technology concepts to achieve affordable, real-time control and optimisation of existing wastewater infrastructure to match dynamic catchment needs
Develop new, “retro-fittable” process elements to improve the energy efficiency of existing wastewater process infrastructure
Research and develop, step-change process concepts to achieve zero net energy or net energy positive wastewater treatment
Investigate barriers to implementation of known technologies for resource recovery from wastewater (e.g. phosphates)
Research and develop “biorefinery from waste” concepts for future combined wastewater and waste recovery operations

ADDITIONAL GOALS	Grow Economic Value of UK Water Capabilities for Global Markets

4 Conclusions and recommendations

4.1 Conclusions

Resilience of infrastructure has been identified as one of the key factors in ensuring water and waste water security for supplies to domestic customers, industry and agriculture.

Results from this workshop, focussing on water infrastructure challenges, drivers and required outcomes together with supporting research and innovation needs have been analysed, prioritised and presented. The conclusions and recommendations were that the top 3 water infrastructure issues requiring innovation to support delivery of required outcomes were:-

- Balancing UK water demand and water resources
- Driving towards zero urban network failures to deliver water and wastewater services with minimal urban street disruption
- Reversing the current trend of increasing energy and chemical consumption to meet EU environmental water quality standards, driving towards sustainable energy and resource recovery from wastewater processing

An overarching framework of challenges to achieving water infrastructure resilience was identified as understanding and managing uncertainties in terms of climate change, extreme weather events, customer service expectations and future regulatory requirements.

A further recommendation was that in achieving a more resilient UK water infrastructure it should be possible to grow and project the economic value of UK water capabilities for meeting global market needs.

4.2 Recommended long-term action plans

The recommended next step was to engage 3 multi-stakeholder action groups through UKWRIF, LWEC and UKWIR to develop these 3 priority topic recommendations into a coherent series of research and innovation programmes, including timescales, resource needs and estimated costs. The action groups should identify and recommend funding, resources and delivery methods for each of the identified innovation actions presented in Figures 4, 5, and 6. It is recommended that these action groups are established in 2012 and charged with producing draft programmes for the period 2013-2020 in the first quarter of 2013.

An example research and innovation action map liked by workshop delegates; a 25 year vision and programme of research, development and innovation activities to address one aspect of water infrastructure (EPSRC project Mapping the Underworld) is presented in appendix 6.

It is recommended that 3 of the identified needs could be addressed as an immediate priority for action in 2012 by UKWRIF, LWEC and UKWIR with support from the workshop delegates. These are identified in sections 4.3 to 4.5

4.3 UK infrastructure innovation testing facilities

Included in this recommendation was a strongly recognized need for a UK network infrastructure test centre(s) and register of urban sites where field trials of innovative

technologies may be carried out. This should focus on water / multi-utility, network infrastructure buried under urban transport corridors. It should include a register of current innovative technology trials for opportunistic evaluation of other supply chain or academic innovation that may also be carried out at least "set-up" cost. It should also identify, co-ordinate and designate example urban streets for a period of technology trials. There was also a longer-term opportunity to link and develop a wider EU network and urban street infrastructure innovation framework.

Parties willing to co-operate on developing this action included; UKWIR, WRc, supply chain (represented by British Water, Balfour Beatty, Subterra and consultants) with interest also expressed by academics attending the workshop. It was also considered that EPSRC and TSB should be engaged in developing this network.

4.4 Support implementation of EPSRC Mapping the Underworld project

The multi-party, collaborative series of projects with the working title of "Mapping the Underworld" aims to develop multi-sensor technologies to locate buried infrastructure without excavation in urban streets. This internationally leading research has so far attracted over £4m of funding for the research phases from EPSRC, UKWIR, water and other utilities and their supply chain. The research work, by a consortium of UK universities, lead by Prof Chris Rogers of U. Birmingham is nearing completion (2013). It is recommended that an action group is established to support a commercial development and implementation phase for UK and international exploitation. The TSB should be engaged in this activity together with current funding members. UKWIR is willing to lead facilitation of this action.

A further research phase, entitled "Characterising the Underworld" is identified in the long-term research vision presented in Appendix 6. This was to find the science and develop technology to locate failures in buried infrastructure and preferably identify condition before failure. It is strongly recommended that EPSRC, STFC and TSB give consideration to developing a large collaborative call for this research in 2013. Industry members of the current "Mapping the Underworld" programme would be expected to contribute to this research. UKWIR is willing to lead the industrial partnership if the identified Research Councils provide funding of the academic research required.

4.5 Consumer behaviour research for "Smart Metering and Tariffs" trials

Several UK water utilities are conducting or have plans to conduct large-scale trials of water metering to determine impact on water demand and the cost and benefits of different metering and reading technologies. UKWIR is already co-ordinating the water utility sector research on this topic. Workshop delegates recommended that engagement with the energy sector was included to evaluate the cost benefit of "Smart Metering" for both energy and water and that the relevant regulators (OFGEM and OFWAT) were consulted, particularly on the potential for future "Smart Tariff" structures for peak demand management. It was also recommended that ESRC supports academic research on consumer behaviour and economic demand models for the water or combined energy and water sectors in research calls for 2013. UKWIR is willing to lead the water sector aspect of this work.

5 References

(1) UKWIR report no. 11/RG/10/6, *Research and Innovation Mapping Study for the UK Water Research and Innovation Framework* (July 2011)

(2) Royal Academy of Engineering on behalf of Engineering the Future Infrastructure, *Engineering and Climate Change Adaptation – ensuring services in an uncertain future* (February 2011)

(3) HM Treasury, *National Infrastructure Plan 2010* (October 2010)

(4) EU Water Supply & Sanitation Technology Platform http://www.wsstp.eu, *Strategic Research Agenda 2010* (2010)

(5) UKWIR report no. 07/RG/10/3, *A Road Map of Strategic R&D Needs to 2030* (July 2007)

(6) Institution of Civil Engineers, *State of the Nation Water 2012* (June 2012)

Appendix 1 UKWRIF brief for water infrastructure action group

1. Please give a brief description of the challenge / problem that your sub-group will seek to address; and the justification for focusing on this in the context of the UK Water Research and Innovation Framework (UKWRIF) and the current UK knowledge and skill base knowledge and skill base.

The possibility of more extreme weather events, a growing population and likely increased demand for water will bring significant challenges to UK and global water infrastructure. The capacity, quality and resilience of UK infrastructure directly impacts the potential for growth and competitiveness in the global economy. An understanding of the characteristics and performance of an ageing infrastructure in the UK is a growing need. Development of a resilient UK water infrastructure also requires better understanding of societal behaviours (and their potential for change) and customer acceptable and affordable service levels.
The water infrastructure challenges scope includes planning, condition assessing, repairing, renewing and operating water infrastructure and the use and development of relevant sensors and carbon footprint reduction techniques. In order to assess these adequately, input from utilities, public agencies, RCUK, TSB, academia and the industrial service and supply chain is required. A focus on buried network infrastructure and reducing the carbon footprint of water infrastructure and processes is proposed since other UKWRIP work streams are addressing water resources, flooding, valuing water and integrated river basin management research needs.

2. Please give a brief description of the approaches and/or methodology (e.g. workshops / working groups, network development, research proposal, etc.) you plan to employ to work toward the challenge / problem stated in question 1. If possible, please indicate which individuals and/or organisations should be involved in this activity.

A workshop focusing upon R&D & Innovation needs and delivery routes to support future resilience of UK water infrastructure will be undertaken. 25-30 invited delegates from water utilities, industry, government, RCUK and academia will meet on 10th May 2012. Aims: i) review and build upon recent recommendations on key UK water infrastructure challenges that may require additional R&D&I; ii) identify and prioritise current R&D initiatives where implementation trials have been identified and require support; iii) identify potential partnerships and funding routes to support innovation trials; iv) shape a longer term R&D action plan for support by the wide ranging membership of UKWRIP & LWEC.
A workshop report which sets two/three bullets against the four aims listed above will be produced. A plan addressing the short, medium and long term needs, present activities (funded by RCs, TSB, UKWIR and utilities) together with highlighting who would be willing and able to deliver future activities will be described. There will also be a comparison with EU WssTP priorities to highlight any relevant priorities for UKWRIP in Europe

Appendix 2 Workshop expert delegates

Surname	Organisation
Bell, S	University College
Bernard, I	British Water
Brockhurst, M	Balfour Beatty Utilities
Broyd, T	Halcrows
De Rosa, J	Subterra
Farmani, R	U.Exeter
Farrimond, M	EU WssTP
Farrow, J	Consultant
Harou, J	University College
Hatcher, K	U.Surrey –SWIRL
Holt, D	UKWIR
Jeffreys, P	U.Cranfield
Jensen, H	UKWIR
Jones, E	LWEC/ NERC
Jones, L	SW Water
Khu, S	U.Surrey
Kruger, R	Thames Water (R&D)
Metcalfe, E	Inst. Sustainability
Osborne, D	LWEC / NERC
Parker, J	Consultant WatershedUK
Parsons, S	Scottish Water
Pilbin, M	RWE Npower
Rachwal, T	TRA/UKWIR
Rogers, C	U.Birmingham
Royce, C	Anglian Water
Runnells, N	CEH NERC
Saul, A	U.Sheffield
Shepherd, M	Consultant – pipes
Styles, M	Cambridge Water
Tillotson, M	U.Leeds
Walker, I	WRc plc
Wharfe, J	Env Agency
Stoianov, I	Imperial College London

Appendix 3 Workshop agenda and action plan

Agenda for 10th May 2012

Venue 1VS Conference Centre, 1 Victoria Street, London SWIH 0ET

Welcome and objectives of the workshop Hans Jensen, UKWIR

Facilitators, Tony Rachwal and Jeff Farrow.

Session 1. Review UKWRIP/UKWIR current progress on RD&I needs

10 minute presentation; Hans Jensen *Draft UKWIR views*

5 minute presentation; Tony Rachwal – *Report review to UKWIR/UKWRIP July 2011*

Workshop delegate task 1:- *Identify priority drivers and needs for RD&I for near term water infrastructure issues (2012-20) and longer term challenges (2020-40+).*

Session 2 Delivering / implementing solutions in the near term 2013-2020

What is already being done, or could be done, by academia / utility / supply chain that requires trials, implementation, evaluation for possible adoption in 2013- 2020?

10 minute presentation; Mike Brockhurst , *Balfour Beatty Utility Solutions on supply side innovation ideas*

10 minute presentation ; Chris Rogers, *U.Birmingham, on example of current major academic R&D approaching implementation phase.*

Workshop delegate task 2:- *identifying innovation priorities for near term delivery*

Session 3 Developing longer term, step change, R&D solutions for challenges in 2020-2040 horizon

10 minute presentation; Mike Farrimond, EU WssTP vison *infrastructure R&D*

5 minute presentation; Jeff Farrow, *on example ideas for step change UK solutions*

5 minute presentation; Neil Runnels, NERC CEH *on UK / International funding opportunities*

Workshop delegate task 3:- *identifying step change research priorities for longer term*

Matching needs from session 1 to proposed RD&I from sessions 2&3 + priority voting

Session 4 Overview on outputs and action plan

Close out summary

Appendix 4 Workshop outputs – full details and priority voting

CONTENTS

1. Summary of prioritised outputs

Sections 2, 3 and 4 provide a full record of ideas generated at the workshop from challenges and drivers to short and longer-term innovation and research needs and desired outcomes. All results of the workshop delegate voting on priority assigned to these challenges and desired outcomes are also presented in these sections. (Format may be improved as tables).

In this consolidated and prioritized outputs section these results are further clustered and analysed, retaining the component priority votes, to produce the water infrastructure resilience, top 3 priority output recommendations for delivering solutions via short-term innovation and longer-term research.

In priority order the top 3 consolidated recommendations were:-

1.1 Towards zero network asset and service delivery failures (leakage, bursts, sewer collapses) and zero urban street-works disruption.

Achieve through more intelligent infrastructure, driving both operational service delivery and efficient asset capital planning. Includes asset location, performance and condition, remote sensing and optimization and no-dig, in-pipe repair and replace solutions. The phrase “monitor and fix pipes from the inside” summarized the desired outcome. It includes new sensing, optimization and control techniques to reduce asset and service delivery failure and energy used for pumping water and wastewater through pipe networks.

Research and innovation required included; low or power harvesting sensors to convert existing “dumb” network infrastructure to smart, self diagnosing condition and performance management with in-pipe or no-dig repair and replacement solutions. Smart, multi-utility, buried infrastructure location, condition and fault location services available to zero urban disruption, 24/7, smart street-works contractors and service providers. All new infrastructure assets have smart condition assessment and communication (“Internet of Things” concept). Cost efficiencies should drive down “Economic Level of Leakage” for long-term, enhanced network renewal investment planning.

Included in this recommendation was a strongly recognized need for a UK network infrastructure test centre(s) and register of urban sites where field trials of innovative technologies may be carried out.

Focus on water / multi-utility, network infrastructure buried under urban transport corridors. Include register of current innovative technology trials for opportunistic evaluation of other supply chain or academic innovation that may also be carried out at least "set-up" cost. Identify, co-ordinate and designate example urban streets for a period of technology trials. Link and develop a wider EU network and urban street infrastructure innovation framework.

1.2 Achieve sustainable UK water resource security through enhanced demand management and national strategic planning of new large scale water resources, storage and inter-river basin transfers

A strong need, for improved customer communication and social attitudes to water usage and willingness to pay research, was identified with potential stakeholder collaboration between customers and Utilities, OFWAT, EA, DWI, CCwater, Waterwise, ESRC and academic routes.

In the near-term, planned expansion of metering should allow for implementation of smart metering techniques enabling identification of time and rate of water use for linking to potential future tariff structures to support demand management.

Delegates proposed moving towards 80 litres per capita domestic water consumption for all new properties and for retrofit solutions to reduce by 30%, current 155 litres per capita norm in the existing UK housing stock. Expected to require smart metering, customer acceptable demand management and customer purchase of future, smart, water efficient appliances with appropriate and secure water reuse systems. This may be integrated with smart home energy management and heat reuse.

Perceived lack of a national strategy, incentive or co-ordination framework for planning, investing and developing strategic, water resources and water transfers across multiple catchments / water utility boundaries and multiple stakeholders. Delegates proposed a stronger framework for UK water resource planning at a national level and improved governance frameworks for strategic national (inter-river basin) resource development and local scale multi-party resource development (eg in conjunction with agriculture water resource storage or local to regional scale aquifer storage and recharge schemes).

Academic research could contribute to improved, strategic decision support models for analysing and predicting future supply demand scenarios, integrating customer demand behaviour, seasonal and climatic water resource impacts and future infrastructure storage and transfer options at national, catchment and local scales.

1.3 Reverse the current trend of increasing energy and chemical consumption required to operate current UK water sector infrastructure (mainly wastewater) to meet increasingly stringent environmental standards. Move towards, net energy and resources from waste, producers

Environmental regulations (WFD) driving contradictory impacts between improving wastewater quality whilst increasing carbon and chemical footprint of the water sector's treatment processes.

Reduce operational energy costs in the shorter-term. Longer-term, reduce carbon footprint over the whole life cycle of constructing and operating infrastructure. Trial sensing,

optimization and control techniques and process retrofit technologies to reduce energy and chemical usage/waste production.

Delegates proposed that longer-term research should step beyond incremental, retrofit optimization, focusing on step change, low carbon, wastewater process solutions to become a net energy producer for wastewater operations.

Enhance recovery of biomass energy and fertiliser nutrients (phosphates and nitrogen compounds) from current UK wastewater treatment process operations and infrastructure. Maximise the potential for production and use of renewable energy from wastewater (methane / other fuels / heat from sludge).

2. Key identified challenges and drivers

Workshop delegates identified 10 near-term and 7 longer-term challenges and drivers for innovation to improve water security, infrastructure resilience and reliable service provision to UK customers. Many of the identified themes had both near and longer-term components. These are presented below (without priority ordering)

2.1 Near-term issues for 2015-2020 output delivery (AMP6 in water utility sector)

2.1.1. Ageing infrastructure; targeting capital investment v shorter term operational fixes. UK water and sewer network infrastructure probably the oldest in the world as the UK was one of the earliest countries to industrialise and implement urban utility services. – key performance indicators include leakage levels, burst frequency and sewer collapse frequency. We need to develop better understanding of the relationships between age, condition, environmental factors and asset performance - to enable moving to risk-based investment programmes.

2.1.2. Understanding and optimizing, condition, performance, efficiency and risks of water and sewer networks in near real-time (ie before negative impact on customers)

2.1.3. Understanding location, condition, serviceability, risks and need for investment in recently inherited private sewer infrastructure.

2.1.4. Achieving security of water resources / supply. Applies mainly to Cornwall to Yorkshire to Kent triangle of UK – key performance indicators include frequency of domestic water restrictions, low flows in rivers and abstraction restrictions on all user sectors, together with risks in terms of environmental impact on aquatic life and any long-term impact on aquifers.

2.1.5. Impact, costs and opportunities from increased metering (case for “Smart versus Dumb Meters”) and the possibilities for working with smart meters for other utilities.

2.1.6. Understanding customer service expectations and behaviours versus their willingness to pay for greater water security and infrastructure service resilience (service disruption and full societal costs of streetworks impact). Does current regulatory framework fully reflect customer priorities? We need to improve customers’ awareness of future water security in the UK including exposure to global supply chain water footprints and risks.

2.1.7. Reducing operational energy costs in the shorter term, (longer term reducing carbon footprint over the whole life cycle of constructing and operating infrastructure). Maximise the potential for production and use of renewable energy from wastewater (methane / other fuels from sludge).

2.1.8. Environmental regulations (WFD) driving contradictory impacts between improving wastewater quality whilst increasing carbon and chemical footprint of the water sector's treatment processes.

2.1.9. Understanding impact on infrastructure investment, servicability and service pricing for White Paper proposed increased competition in retailing water to customers

2.1.10. Ageing workforce, linked to increasing levels of 'out-sourcing' and loss of people from the industry – skills retention and training delivery

2.2 Longer-term issues for delivery of solutions 2020-2040 (start with AMP6/7 planning?)

2.2.1. Lack of a national strategy, incentive or co-ordination framework for planning, investing and developing strategic, water resources and water transfers across multiple catchments / water utility boundaries. Serious questions over whether increased commercialisation (eg licences) will help or hinder and whether a national approach is required

2.2.2. Uncertainty in impact, timing and regulatory planning framework for addressing long-term climate change and potentially shorter term increase in extreme weather events.

2.2.3. Includes balancing impact and demands by agriculture and energy sectors, taking account of research in global food security and potential impacts on uk agriculture (total needs, crop types, locations) and potential types and locations of future energy generating plants

2.2.4. Determining longer-term supply / demand balance driven by population growth / movement in UK and per capita water demand / usage patterns / behaviours in response to water efficiency or varying future metered tariff structures

2.2.5. Long term urban planning, impact and service delivery for interactions between multiple utility services and transport corridors with different regulatory frameworks, drivers and time-tables.

2.2.6. External pace of technology change, especially information technology, driving rapid, perhaps unsustainable, changes in infrastructure asset life cycle investment and management. Threat or opportunity? Also customers' reactions / behaviour changes and demands in response to technology developments (eg coverage & type of use of mobile phones) and how this will affect demands from water suppliers and their infrastructure assets

2.2.7. Does the current regulatory funding framework incentivize capex rather than totex (capex + opex) solutions?

3. Near-term (2012-2020) innovation, development and evaluation trials for water sector impact.

A total of 28 ideas for near-term innovation were generated and clustered into 10 output / impact areas. These were (not in priority order):-

a) National UK infrastructure test centre(s).

b) Incentives for innovation / reduce barriers in regulatory / procurement frameworks.

c) Reduce energy and chemical demand to operate existing infrastructure

d) More reliable sewerage and pumping systems including implementing SUDs.

e) Trial smart metering with variable tariffs for demand management.

f) How to future proof infrastructure to meet changing customer service expectations?

g) "No-dig" management of urban networks. "Monitor and fix pipes from the inside".

h) Common data standards for sharing, comparison and modeling + "Sim City" tools.

i) Integrated, multi criteria, approaches to water security decision making

j) Urban planning to optimize resilient utility and transport infrastructure services.

These ideas were discussed, expanded and edited for voting on priorities in 2 subsequent rounds of voting. Each of the 30 workshop delegates was assigned 5 votes for near-term innovation for the first round of voting. In the final priority voting process each workshop delegate was allocated a single vote for **either** near or longer-term innovation / research.

The results of both priority voting methods for near-term innovation were:-

3.1. Establish a UK infrastructure test centre(s) and register of urban sites where field trials of innovative technologies and methodologies may be carried out.

Focus on water / multi-utility, network infrastructure buried under urban transport corridors. Include register of current innovative technology trials for opportunistic evaluation of other supply chain or academic innovation that may also be carried out at least "set-up" cost. Identify, co-ordinate and designate example urban streets for a period of technology trials. Link and develop a wider EU network and urban street infrastructure innovation framework (EU WssTP).

Scored 15 votes in first round voting (2nd near-term priority).

Scored 3 votes in final round voting (assigned 1st near-term final priority).

3.2. Reduce network infrastructure asset failures (leaks, bursts, sewer collapses) and related street-works highway disruption, through improved sensing and "no-dig" techniques for asset location, condition and performance assessment, repair and replacement.

The phrase “monitor and fix pipes from the inside” summarised the desired outcome. This topic also featured highly in the longer-range research ideas board. It includes new sensing, optimization and control techniques to reduce asset and service delivery failure and energy used for pumping water and wastewater through pipe networks. This topic is strongly linked to the proposed UK infrastructure test facility which would support and enable trials and evaluation particularly with regard to sensing and renovation techniques for real, “ageing infrastructure”, urban test sites.

Scored 18 votes in first round voting (1st near-term priority)

Scored 2 votes in final round voting (assigned 2nd near-term, final priority)

3.3. Reverse the current trend of increasing energy and chemical consumption required to operate current UK water sector infrastructure (mainly wastewater) to meet increasingly stringent environmental standards.

Trial sensing, optimization and control techniques and process retrofit technologies to reduce energy and chemical usage/waste production. Enhance recovery of biomass energy and nutrients from current UK wastewater treatment process operations and infrastructure. This topic also featured highly in the longer-range research ideas board.

Scored 14 votes in first round voting (4th near-term priority)

Scored 1 vote in final round voting (assigned 3rd near-term, final priority)

3.4. Develop current regulatory and utility procurement frameworks to incentivize full-scale trials, reducing regulatory risk during innovation trial periods and enabling higher financial benefit from successful innovation risks taken.

Utility delegates proposed development of a special regulatory innovation framework to reduce perceived regulatory compliance barriers to large-scale innovation trials and to incentivise financial risk for longer term, innovative utility investments. Supply chain delegates supported this view, adding that utility and contractor procurement supply agreements should include improved frameworks to evaluate and trial innovative product and service offers. Understanding and determining full life cycle costs and risks of implementing innovation in long-life water sector infrastructure was identified as a key area for improvement by all stakeholders.

Scored 15 votes in first voting round (3rd near-term priority)

Scored 0 votes in final voting round (assigned 4th near-term, final priority)

3.5. Trial smart metering with variable tariffs for demand management.

Delegates were concerned if planned expansion of metering did not allow for implementation of smart metering techniques enabling identification of time and rate of water use for linking to potential future tariff structures to support demand management. Longer term considerations included evaluating specifications for smart energy meter communication for integrating future smart home appliance efficiency and demand management.

Scored 12 votes in first voting round (5th near-term priority)

Scored 0 votes in final voting round (assigned 5th near-term, final priority)

3.6. Urban planning to optimize resilient utility and transport infrastructure services.

Delegates suggested that improved education and knowledge transfer was required, sharing resilience and efficiency challenges and opportunities between urban planners, architects, utility and transport infrastructure and service managers.

Scored 11 votes in first voting round (6th near-term priority)

Scored 0 votes in final voting round (assigned 6th near-term, final priority)

3.7. Common data standards for sharing, comparison and modelling + "Sim City" type tools.

This theme was proposed by academic delegates with significant support from utility infrastructure asset operators and some of the supply chain.

Scored 8 votes in first voting round (7th = near-term priority)

Scored 0 votes in final voting round (assigned 7th = near-term, final priority)

3.8. More reliable sewerage and pumping systems including implementing SUDs.

A mix of ideas from innovative policies and funding frameworks to encourage implementation of sustainable drainage systems (SUDs), to more reliable and efficient pumps and use of sewer capacity to improve the quality of sewer discharges either via CSOs or to conventional wastewater treatment plants.

Scored 8 votes in first voting round (7th = near-term priority)

Scored 0 votes in final voting round (assigned 7th = near-term, final priority)

3.9 How to future proof infrastructure to meet changing customer service expectations?

This theme also appeared in the longer term research priority list and indicates that improved customer communication and social attitude and willingness to pay research is required via the multiple potential routes of Utilities, OFWAT, CCwater, Waterwise and ESRC academic routes.

Scored 4 votes in first voting round (9th near-term priority)

Scored 0 votes in final voting round (assigned 9th near-term, final priority)

3.10. Integrated, multi criteria, approaches to water security decision making

This was an academic lead proposal and the low vote may not have been fully understood by most delegates or considered to already be the status quo. Examples were introducing multiple utilities, agricultural water users, waterways owners, traders and water regulating agencies into future UK water security, decision making. Links to longer-term theme on UK water resource strategy.

Scored 2 votes in first voting round (10th near-term priority)

Scored 0 votes in final voting round (assigned 10th near-term, final priority)

4. Longer-term, strategic step change research for impact on 2020-2040 UK water sector.

A total of 24 ideas for longer-term innovation were generated and clustered into 9 output / impact areas. These were (not in priority order):-

a) Move from a high carbon energy consumer towards being a renewable energy recycler / producer

b) Chemical free water treatment.

c) Intelligent network infrastructure with zero leakage and failures and minimal urban disruption.

d) Improve the UK strategic planning framework for water security at national and local scale

e) Improve water security for the UK through understanding usage and demand management.

f) Understand and implement large-scale, inter-catchment water transfers.

g) Develop low carbon desalination solutions for UK saline water resources including estuaries.

h) How to future proof infrastructure to meet changing customer service expectations?

i) Achieve global recognition and international market growth for "UK Plc" water offers.

These ideas were discussed, expanded and edited for voting on priorities in 2 subsequent rounds of voting. Each of the 30 workshop delegates was assigned 5 votes for longer-term innovation for the first round of voting. In the final priority voting process each workshop delegate was allocated a single vote for **either** near or longer-term innovation / research. The results were:-

4.1 Intelligent network infrastructure with zero leakage / failures and no urban disruption.

Research and innovation required included; low or power harvesting sensors to convert existing "dumb" network infrastructure to smart, self diagnosing condition and performance management with in-pipe or no-dig repair and replacement solutions. Smart, multi-utility, buried infrastructure location, condition and fault location services available to zero urban disruption, 24/7, smart streetworks contractors and service providers. All new infrastructure assets have smart condition assessment and communication ("Internet of Things" concept).

Scored 32 votes in first voting round (1st longer-term, initial priority)

Scored 8 votes in final voting round (assigned 1st longer-term, final priority)

4.2 Improve UK water security through smart demand management.

Delegates proposed moving towards 80 litres per capita domestic water consumption for all new properties and retrofit solutions reduce by 30%, current 155 litres per capita norm in the existing UK housing stock. Expected to require smart metering, customer acceptable demand management and customer purchase of future, smart, water efficient appliances with appropriate and secure water reuse systems. This may be integrated with smart home energy management and heat reuse.

Scored 17 votes in first voting round (2nd longer-term, initial priority)

Scored 5 votes in final voting round (assigned 2nd longer-term, final priority)

4.3 Move from a high energy consumer to being a carbon neutral energy recycler / producer

This topic featured as 3rd priority in the short-term innovation need. Delegates proposed that longer-term research should step beyond incremental, retrofit optimization, focusing on step change low carbon wastewater process solutions to become a net energy producer for wastewater operations.

Scored 11 votes in first voting round (3rd = longer-term, initial priority)

Scored 0 votes in final voting round (assigned 5th longer-term, final priority)

4.4 Achieve global recognition and international market growth for "UK Plc" water offers.

Delegates proposed that the UK should seek to increase its current low global market share of water sector products and services through UK showcasing and implementation of innovative and world leading urban water designs, technology and asset management systems. UK Regulators and water utilities should have a recognized (and incentivized?) role to support international growth learning from current international market support by France, Germany, Netherlands, Singapore & S.Korea.

Scored 11 votes in first voting round (3rd = longer-term, initial priority)

Scored 1 vote in final voting round (assigned 3rd = longer-term, final priority)

4.5 How to future proof infrastructure to meet changing customer service expectations?

This theme also appeared in the shorter-term research priority list and indicates that improved customer communication and social attitude and willingness to pay research is required via the multiple potential routes of Utilities, OFWAT, CC water, Waterwise and ESRC academic routes.

Scored 6 votes in first voting round (6th longer-term, initial priority)

Scored 1 vote in final voting round (assigned 3rd = longer-term, final priority)

4.6 Improve the UK strategic planning framework for water resource security at national and local scale

This theme was also identified in the shorter term prioritization under 6.10 multiple critieria decision making for national water security. Delegates proposed a stronger framework for UK water resource planning at a national level and governance frameworks for strategic national (inter-river basin) resource development and local scale multi-party resource development (eg in conjunction with agriculture water resource storage or local to regional scale aquifer storage and recharge schemes)

Scored 7 votes in first voting round (5th longer-term, initial priority)

Scored 0 votes in final voting round (assigned 5th = longer-term, final priority)

4.7 Develop low carbon desalination solutions for UK saline water resources including estuaries

The majority of UK large urban areas are within economic pipeline range of partially saline estuaries or seawater sources. These could provide a significant proportion of future sustainable and reliable water resources, affordable for most UK urban domestic and industrial applications if the energy consumption and carbon footprint of current desalination technology is significantly reduced. International research is indicating this may be possible with nano-engineered novel membranes and materials and novel processes. The UK has a strong research capability in nanomaterials and should consider a stronger role in this global market opportunity to develop next-generation, low energy desalination processes.

Scored 5 votes in first voting round (7th longer-term, initial priority)

Scored 0 votes in final voting round (assigned 7th longer-term, final priority)

4.8 Understand and implement large-scale, inter-catchment water transfers.

This theme had close links with shorter-term theme 6.10 and longer-term theme 7.6 and will be consolidated in the summary report.

Scored 4 votes in first voting round (8th longer-term, initial priority)

Scored 0 votes in final voting round (assigned 8th longer-term, final priority)

4.9 Chemical free water treatment

This proposal attracted only 1 vote but has some synergy with the shorter-term theme of reduced chemical wastewater treatment (6.3) and waste resource recovery

Scored 1 vote in first voting round (9th longer-term, initial priority)

Scored 0 votes in final voting round (assigned 9th longer-term, final priority

Appendix 5 Extract from reference (1) on water infrastructure

5.1 Water infrastructure R&D& innovation needs extract

The resilience of UK water infrastructure requires better understanding

A changing climate and growing population will bring significant challenges to UK and global water infrastructure. The capacity, quality and resilience of UK infrastructure directly impacts growth and competitiveness in the global economy. Ageing infrastructure in the UK is a growing risk. Development of a resilient UK water infrastructure requires better understanding of societal behaviours (and their potential for change) and customer acceptable and affordable service levels.

Recommendations included:-

- Academia and providers of innovation should recognise that improving knowledge and management of existing and ageing infrastructure will have far greater impact in the UK over the next 30 years than investment in completely new infrastructure. There is a need for new technologies that can be retrofitted to existing assets to improve resilience, efficiency and capability to cope with increasing demands from population growth, increasing consumption and potential impacts of climate change.

- Infrastructure planning, including community scale solutions, requires better understanding of changing societal behaviours and service levels acceptable and affordable to customers.

- Investigate new ways to plan, design and maintain infrastructure and enable innovative solutions underpinned by integrated, multi-utility and urban planning. Leakage, bursts and sewer collapses from ageing, buried, urban water and sewerage networks may reflect a need to improve asset planning and that current investment levels may be insufficient to prevent deterioration of the UK pipe network asset base and future service delivery.

- Need for new technologies and “smarter assets” together with improvements in understanding and modelling for determining accurate location, condition, performance and deterioration rates of buried urban infrastructure. This includes multi-utility, traffic and natural environment interactions. There is a linked need for smarter technologies to access repair and install buried infrastructure with minimal disruption to busy city streets. There are complex interdependences in these infrastructures, which could be improved using probabilistic scenario modelling and addressing priority vulnerabilities.

- Affordable, innovative solutions are required to address the potentially huge investment challenges of providing flood protection, sustainable drainage, combined sewer overflows and appropriate separation of rainfall and sewerage

- Need “ultra-low powered or self powered sensors and ultra-low maintenance, long life cycle (10+ years) sensors for measurement and control particularly for buried assets and whole river basins.

- Need for reduction in the carbon footprint of both constructing and operating water and wastewater infrastructure. Energy positive wastewater treatment and low carbon desalination should be longer-range, infrastructure research objectives.

5.2 Resilient infrastructure

Figure 7 Innovation activity map to achieve water security: Resilient infrastructure

There are clear risks in respect of UK water infrastructure, in terms of resilience and ability to adapt to changing demands and environment. Longer-term investment horizons linked to policy on energy, agriculture and urban planning are required. Infrastructure planning, including community scale solutions, requires understanding of changing societal behaviours and service levels acceptable to customers.

- Innovation is needed to provide technology, modelling and "smarter assets" to improve accurate location, condition and performance assessment and deterioration rates of buried infrastructure. This should include understanding and managing multi-utility, traffic and natural environment interactions and provide smarter technologies to access, repair and install buried infrastructure with minimal urban disruption.

- There is a need for reduction in the carbon footprint of both constructing and operating water and wastewater infrastructure. Energy positive wastewater treatment and low carbon desalination should be longer-range research objectives.

- It is proposed that a multi-partner framework is established to provide leadership and direction of water infrastructure research, development and innovation.

- Researchers should recognise that improving knowledge and management of existing infrastructure will have far greater impact in the UK over the next 30 years than investment in completely new infrastructure. New infrastructure has a greater potential

impact and market opportunity where first time urbanisation is growing rapidly e.g. China.

5.3 Hazard risk management

- Develop integrated land use planning and flood risk infrastructure, together with better predictive modelling capabilities and improved engineering and infrastructure options
- Affordable, innovative solutions are required to address the potentially huge investment challenges of providing flood protection and sustainable drainage.
- It is proposed that a multi-partner framework is established to provide leadership and direction of high impact water hazard risk management research and development of affordable adaptive infrastructure investment and response planning to UK and international extreme events.

5.4 Growing UK water economy

Figure 8 Innovation activity map to achieve water security: Growing UK water economy

There is a need for innovation in the UK for development of smarter infrastructure, metering technologies, energy positive wastewater treatment and smart approaches to reduce flooding and water demand. Demand for new water resources in global markets requires new water reuse and low carbon desalination solutions.

- The UK water industry averages £4Bn capital and £4Bn operational expenditure per year, but the UK has fewer innovations in water per capita than Australia, Germany or

USA. Overseas water markets are estimated to be at least $500bn per annum providing growth opportunities for UK consultants, contractors and suppliers.

Extract from subsequent UKWIR Internal review of infrastructure research and innovation needs 2011.

The UKWIR Innovation Mapping Study stimulated further analysis by UKWIR members on significant gaps and challenges for innovative infrastructure solutions summarised in a 2012 presentation by UKWIR CEO Hans Jensen as (unprioritised order):-

- Existing infrastructure asset condition, performance and risk assessment, including predictive technical, risk and cost modelling techniques applicable over the whole life-cycle of assets in a changing environment. Balance the need for asset renewal against acceptable functionality, resilience and cost.

- 3D Underground asset mapping and modelling technologies to minimise 3rd party damage and disruption associated with interventions and upgrades

- Smarter assets for self diagnosing failure risks on pumps and pipes, embedding real-time control, quality monitoring and asset condition

- New self repairing pipe materials and in situ live repair technologies and smart retrofit options

- Modelling effect of extreme weather events on infrastructure resilience (pipe networks, coastal and flood plain assets, sewerage works capacity, dams)

- Real Time Control technologies to maximise utilisation of existing sewerage asset capacities

- greed and improved modelling approaches to both rural and urban diffuse pollution challenges, and extreme tail event modelling tools for urban environments to assist Sustainable Urban Drainage challenges

- How to link Ecosystem Service improvements to security of supply and security of quality outcomes (new modelling tools) including urban water quality modelling (micronutrients and e.coli) for predicting WFD and Bathing Water Directive diffuse pollution impacts

- Low energy, CO2 and self sustaining infrastructure solutions including energy generating assets; anaerobic digestion, hydro turbines and gas plant

- Resource recovery and low energy and chemical usage technologies including resilient and reliable grey water re-use treatment technologies

- New ways to plan, design and maintain integrated often multi-utility infrastructure

- Improve assessment and adoption processes for smart and innovative technologies

Appendix 6 Figure 9 Example of 25 year vision and programme

Example 25 year research, development and innovation vision and programme of work related to one aspect of water infrastructure

Mapping the Underworld is researching a multi-sensor scanner to look beneath the streets – the targets are buried utility pipelines

This is part of a 25 year initiative to make streetworks more sustainable Source: Prof Chris Rogers