`Energy & Water Infrastructure Sector Interdependencies Governance - Planning and Preparing for the Future'

#UKEW

Workshop Report on the event held on 2nd December 2014 at the Royal Academy of Engineering, 3 Carlton House Terrace

Mark Workman, Miriam Mendes and Helen Thomas

The Energy Research Partnership

The Energy Research Partnership is a high-level forum bringing together key stakeholders and funders of energy research, development, demonstration and deployment in Government, industry and academia, plus other interested bodies, to identify and work together towards shared goals.

ERP is co-chaired by Professor John Loughhead, Chief Scientific Advisor at the Department of Energy and Climate Change and Dr Keith MacLean, Independent. A small in-house team provides independent and rigorous analysis to underpin ERP's work.

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Prof John Miles FREng	Director and Professor of Energy Strategy	Arup / Cambridge University
Prof John Perkins FREng	Chief Scientific Advisor	BIS
Rob Saunders	Head of Energy	Technology Strategy Board
Prof Rod Smith FREng	Chief Scientific Advisor	DfT
Philip Sellwood	CEO	Energy Saving Trust
Stephen Trotter	Managing Director, Power Systems UK & Ireland	ABB Limited
Mark Wagner	Chair	Isentropic
Alison Wall	Associate Director, Impact	EPSRC
Nick Winser FREng	Executive Director, Transmission	National Grid

Workshop Partners

The UK Infrastructure Transitions Research Consortium (ITRC) is developing a new generation of infrastructure system simulation models and tools to inform the analysis, planning and design of National Infrastructure (NI). Working with partners in government and industry, our research examines energy, transport, water, waste, and information and communication technologies (ICT) systems at a national scale to:

- Develop new methods for analysing performance, risks and interdependencies
- Provide a virtual environment in which to test strategies for long-term investment
- Understand how alternative strategies perform under constraints such as reliability and security of supply, cost, carbon emissions, and adaptability to demographic and climate change.
- Develop risk analysis models to test NI's ability to withstand extreme weather shock events, and so inform long-term risk assessment and adaptation planning.
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The University of Bristol's Systems Centre is committed to excellence in Systems Thinking and provides a focal point for collaborations in teaching, research and enterprise. We invite you to engage with us through our core activities:

- Working with industry to enhance performance.
- Training future leaders of industry
- Developing Systems Generic Research Programme.
- Working with academics to develop industrial collaboration.

UKWRIP delivers the vision of the UKWRIF - the UK Water Research and Innovation Framework - which was drawn up in 2010 by Living With Environmental Change, the UK Collaborative on Development Sciences and the Government Office for Science in 2010.

The Framework highlights the need to co-ordinate the development and dissemination of new knowledge, technologies and skills so our decisions about how to improve the way we manage and use water are based on robust evidence. This includes having a coherent and coordinated approach to public funding into water security. To achieve this the Framework prioritised the UK's water research and innovation needs and government, research organisations, academia, NGOs, industry and other users of water were brought together as UKWRIP to act on those priorities.

The Science Policy Research Unit at the University of Sussex is internationally recognised as a leading centre of research on science, technology and innovation policy. SPRU was one of the first interdisciplinary research centres in the field of science and technology policy and management. Today, with over 50 faculty members, SPRU remains at the forefront of new ideas, problem-orientated research, inspiring teaching, and creative, high impact engagement with decision makers across government, business and civil society. SPRU's research addresses pressing global policy agendas, including the future of industrial policy, inclusive economic growth, the politics of scientific expertise, energy policy, security issues, entrepreneurship, and pathways to a more sustainable future. We work across a broad range of sectors including food, energy, healthcare, biotechnology and ICT. We are driven by a desire to tackle real-world questions, whilst also contributing to a deeper theoretical understanding of how innovation is shaping today's world.

Acknowledgements:

This workshop report was compiled from a recording made during the talks, question and answer sessions as well as outputs from the world café sessions. The workshop organisers would like to thank Matt Holmes, Ralitsa Hiteva, Faith Culshaw, Iliana Cardenes, Robert Carlsson, Modassar Chaudry, Beate Dirks, Sisi, Franziska Gaupp, Xiawei Liao, and Helen Gavin for their note taking and Nick Eyre, Chris Kilsby, Liz Varga, Richard Dawson, Katy Roelich, Mike Woolgar, Craig Lucas and Neil Edwards for chairing tables in the world café session. The report has been authenticated by attendees and speakers as representative of the discussions.

Contents

High Level Messages

- The workshop represented a milestone in bringing major research and innovation networks (ERP, UKWRIP, ITRC) together with practitioners in government, industry and governance in an open forum to develop a common understanding of the interdependencies between the water and energy sectors.
- High level themes in the water-energy nexus were identified orientated around: (1) opportunities for co-location; (2) Risk and Opportunities; (3) Existing Polies; and (4) Others. Over 300 interdependencies were identified.

- A pressing need was expressed by participants for an ongoing forum to provide a platform for the identification of synergies, the consolidation of, and exchange of knowledge, and concerted action between sectors (including those beyond energy and water). The forum would enable:
  - the cross-sectorial exploration of the benefits of using a systems approach to modelling demand and capacity of interdependent services for the substantial rationalisation of investment, risk limitation and robust infrastructure performance;
  - provide a means to inform implementation of effective policies at a government level;
  - assess the most effective governance mechanisms to address interdependencies including the role of bottom up input with the proliferation of actors involved in the infrastructure sectors; and
  - development of an effective cross-sectorial brokerage service to evolve an understanding of respective sectorial cultures, language used, respective needs and visions of the future for a number of infrastructure systems.
- Next steps include a series of targeted, smaller sessions with specialist participants focused on specific topics within the scope of the high level themes.

Event Summary

The Energy Research Partnership (ERP), UK Water Research and Innovation Partnership (UKWRIP) and The Infrastructure Transition Research Consortium (ITRC) have been undertaking and/or exploring work in the interdependencies/nexus space. They were joined by the University of Bristol Systems Centre which has already undertaken a body of work on Infrastructure Management and Governance[1] issues and is working on elements of the International Centre for Infrastructure Futures iCIF. These organisations, representing a broad stakeholder group, considered that it would be expedient to hold a workshop to assess the state of understanding of interdependency thinking between the energy and water industry sectors, academia and governance sectors.

A recent increased focus on Infrastructure interdependencies management[2] has revealed the need to improve understanding of how private sector actors are accommodating for infrastructure interdependencies in their projects and to identify ways of incentivising the `operationalisation' of

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[1] See for example: **Engineering the Future 2011**, Infrastructure, Engineering and Climate Change Adaptation – Ensuring Services in an Uncertain Future; and **Engineering the Future 2013**, Infrastructure Interdependencies Timelines.

[2] **University of Bristol System Centre and Cabot Institute** 2012, Creating and Managing Integrated Infrastructure. A report on the workshop held at the Systems Centre on 30th April 2012.

interdependency thinking. The appetite for dealing with interdependencies is known to change throughout the project planning cycle[3]. Issues of interdependencies must be raised strategically, beyond the project level to create the right enabling environment for interdependencies to be considered and optimised. With this in mind the workshop brought together energy and water industry practitioners, representatives from governmental and regulatory bodies in order to interact with academics working on research-led tools and models to better understand interdependencies.

The objectives of the workshop were to:

- Identify the state of understanding and the different modalities of framing and interpreting infrastructure interdependencies.
- Identify areas of commonality, divergence, required improvement, further research, knowledge exchange and innovation.
- Agree possible platforms, mechanisms and communities to facilitate closer co-operation and collaboration in order to develop a coherent way of framing and addressing infrastructure interdependencies.

The key findings of the workshop were:

State of understanding of infrastructure interdependencies

The implementations of an ongoing forum represents a major challenge as infrastructure interdependency work in the UK is currently highly fragmented with multiple actors initiating multiple initiatives. This fosters:

- Diffused effort amongst industry and regulatory players resulting in sub-optimal outputs from initiatives; and
- Not allowing the appropriate discussions to be developed between relevant stakeholders.

Identified areas of interest of cross-sector working

The workshop strongly indicated the need to develop a strategic direction for the interdependencies debate. One of the key outputs from the discussions was the need to reform and reconcile the present infrastructure governance mechanisms with the need for bottom up engagement – see Box 1.

Box 1: The analysis of Governance in ITRC

The analysis of the governance of infrastructure interdependencies within the ITRC consortium comprises the following main activities:

- Initial research on the development of policy and regulatory frameworks for UK infrastructure sectors. This focused on some of the significant differences between sectors, for example, with respect to the extent of competition and the roles (and relative importance) of EU, national and local governance.
- Governance case studies that focus on (1) interdependencies between the UK electricity and water sectors (with a particular focus on the deployment of renewable energy by water companies); and (2)

[3] **Edkins, AJ and Zerjav, V., 2014.** Infrastructure Interdependencies and Management of Megaprojects. In: (Proceedings) Engineering Project Organization Conference. Devil's Thumb Ranch, Colorado. July 29-31, 2014. http://www.epossociety.org/EPOC2014/Papers/Edkins_Zerjav.

interdependencies between electricity, private transport and ICT sectors (i.e. with a particular focus on smart grid trials supported by Ofgem's Low Carbon Networks Fund).

- The case studies focus on how the governance arrangements for these sectors have co-evolved, and to what extent these have led to tensions or complementarities.

The case study analysis, together with the more `high level' analysis of regulatory and policy frameworks in each sector, are being used to appraise four cross-sectoral infrastructure strategies for the future. They are also the basis for the development of recommendations for the further development of governance arrangements that take interdependencies into account.

Identified mechanisms to facilitate collaborative working to frame and address infrastructure interdependencies

A pressing need was expressed by participants for an ongoing forum to provide a platform for the identification of synergies, the consolidation of, and exchange of knowledge, and concerted action between sectors. The forum would enable the cross sectorial exploration of the benefits of using a systems approach to modelling demand and capacity of interdependent services for the substantial rationalisation of investment, risk limitation and robust infrastructure performance. It would provide a means to inform implementation of effective policies at a government level; assess the most effective governance mechanisms to address interdependencies including the role of bottom up input with the proliferation of actors involved in the infrastructure sectors; and it would enable the development of an effective cross-sectorial brokerage service:

- to gauge and facilitate the ongoing debate on research priorities through organisations such as ERP and UKWRIP who can act as brokers between practice and research;
- to enable researchers to validate their modelling tools with practitioners; and
- develop an understanding of respective sectorial cultures, language used, respective needs and visions of the future for a number of infrastructure systems

The workshop's key messages validate and reinforce the need for the current engagement of (1) the UK Regulators Network; (2) Infrastructure UK; (3) Infrastructures Operators Adaptation Forum; and (4) Cabinet Office to assess the best way to develop a strategic direction and get themes to coalesce in the appropriate fora.

The framing of the debate by these key players will set the agenda which could be further developed into guidance at Chief Scientific Advisor level and involve the Government Office for Science. From this guidance, a framework for the engagement of industry, academia and governance could be proposed to develop in consultation with stakeholders.

We believe that the workshop brought together key organisations that can catalyse the implementation of such agenda and consultations fora, and that, in time, this workshop will be considered to be pivotal in having set out the groundwork for bringing the UK's national infrastructure successfully into the next century.

Workshop Organisation, Administration and Outputs

The workshop was held on Tuesday 2nd December 2014 at the Royal Academy of Engineering, 3 Carlton House Terrace, London. The attendees for the event can be found in Annex 1 and the agenda in Annex 2.

The workshop was broken into 7 sessions as follows:

- Session 1 - Speaker session on: What infrastructure interdependencies are and why they are important;
- Session 2 - Speaker session on: Interdependencies between the water and energy sectors – models, tools and case studies;
- Session 3 - Speaker session on: Interdependent failure and its consequences: critical hotspots analysis - models, tools and case studies;
- Session 4 - Speaker session on: Governance and regulation - interdependency planning, management framework and case studies;
- Session 5 - World Café Exercise 1: Current state of understanding for interdependencies between energy and water across risks and opportunities, policies and initiatives;
- Session 6 - World Café Exercise 2: Perceived barriers and facilitators to inform the governance of interdependencies; and
- Session 7 - World Café Exercise 3: possible initiatives required to plan and prepare for interdependency issues.

The speaker biographies, presentation key messages and notes from talks in sessions 1 to 4 can be found in Annex 3. The biographies and key messages are from the speakers (where they were provided) and notes for the talks augment these contributions. These have been made from the recordings made of speaking and Q&A sessions themselves. Key message summaries for each session are also extracted below to allow the picking up of key themes.

Links to the individual presentation slides and recordings of the talks are available on the following link: http://erpuk.org/erp-itrc-ukwrip-workshop-energy-water-interdependencies/

Session 1: What is infrastructure interdependence and why it matter - Key Messages

- There is a need to be much more specific in the use of the term of infrastructure interdependence.
- The development of modelling capacity to understand impacts across systems is the key role for academics and the opportunity for industry and academia to work together.

- The individual citizen doesn't really mind how the utility sector is structured and organised, what they care about most is provision of an affordable and reliable service.
- Do we continue with a governance structure designed for the 20th Century as we move forward into the 21st Century or do we seek to put in place different and possibly new business models, governance structures and delivery regimes?

- The UK Regulators Network (UKRN), established in March 2014, is seeking to do new things as regulators and are inviting people to engage with them.

Session 2: Interdependencies between the water and the energy sectors – models, tools & case studies - Key Messages

- Future UK low carbon scenarios will impact the amounts of freshwater that will be required for cooling with the role of CCS being the most significant determinant of the degree of increase.
- There is a need for more evidence on the risks and impacts of drought and low flows on hydrology to assess the effects that this will have on power plants capacity to withdraw water from catchments.

- UK future plant mix and its cooling water impact will evolve and be the result of a great number of individual decisions made by individual companies with very different drivers and very different risk appetites. As a result for any given energy mix scenario the water consumption will vary substantially.

- Outside of the water and power sector, a high proportion of energy and water use in buildings is in the co-production of hot water and in some major industrial sectors, energy is used for process heating, with water primarily for process cooling.
- There are synergistic opportunities for demand reduction in the two sectors, which are neglected in single sector assessments.

- The need for need for collaborative mechanisms to co-ordinate and address infrastructure interdependencies was questioned.
- There are multiple factors which will interact and have an impact on infrastructure type and timing.

Session 3: Interdependent failure & its consequences: critical hotspots analysis – models, tools & case studies - Key Messages

- Unique modelling capability, developed in ITRC, has allowed the impacts of infrastructure interdependences to be assessed both between sectors and at different scales within sectors.
- The applications of this capability are substantial ranging from direct and indirect customer demands, hotspot analysis to flood adaptation measures. Further applications are being sought and developed via collaborations with industry.

- Economic infrastructure is distinct and unique from other forms of capital.
- The most vulnerable infrastructure sectors according to losses in economic output in order of importance are: telecommunications; air transport; electricity supply; railway transport; water supply; land transport; gas distribution; sewerage and waste water; water transport. The most

vulnerable non-economic sectors to infrastructure failure in order of importance are: business services; postal and courier services; coal, gas and mining; electrical equipment and banking and insurance etc.

- As a function of the experiences of the 2007 UK flooding the Energy networks association sub-station resilience to flooding task group was brought together to develop ETR138 to improve flood resilience of substations.
- The ETR 138 project topics assessed impact of flooding on UK electricity supply system, risks to society, improved flood risk information, developed a systematic approach to flood risk assessment, targeted resilience levels for investment including CBA accounting for societal risk and work programmes for implementing sub-station flooding resilience.

Session 4: Governance and Regulation - interdependency planning, management framework & case studies - Key Messages

- Based on projections of climate change impacts on river flows, the impact of differing electricity demands and spatial configurations - maintaining environmental standards based on those of today provides dis-benefit to abstractors.
- The interplay between water and energy is just part of the story, in any catchment the interrelationship between all sectors needs to be considered especially agricultural sector such as impact of increased biomass generation with domestic supply.

- An 'open-systems', cross-sectoral methodological approach to creating value from beneficial infrastructure interdependencies has been developed and tested.
- Recommendations from the research study are: (1) that a stewardship function is established by Government; (2) that an 'Open Systems' approach be used to establish an interdependency planning and management process for the HMT Green Book; (3) that there is a need to embed learning and maturity modelling; and (4) that business models and practices are needed which seek to promote openness and collaboration in the creation and operation of infrastructure.

- The important role of local actors, like local authorities and communities in the governance of interdependencies cannot be understated. They are likely best placed to understand how the means can deliver the ends; how different infrastructure systems interact to deliver economic, environmental and social development.
- The market-based instruments, which currently dominate infrastructure policy actively, constrain local authorities and communities. A new approach to infrastructure governance is needed that reflects the diverse motivations and capabilities of local actors.

- Smarter governance of interdependencies to develop integrated planning and thinking across sectors will require more and new types of cooperation between key stakeholders to explore synergies more effectively.

- Governance approaches such as strategic coordinating groups, multi-stakeholder platforms and collaborative networks can encourage cross-sectoral cooperation, strategic complementarities and potential synergies across sectors.

- There are 3 main rationalities for governing interdependencies: (1) Interdependencies can amplify risks to infrastructures and the provision of services due to cascade effects; (2) Economic efficiency: coordinating infrastructure investment can reduce immediate costs; and (3) Co-ordination and innovation: to meet broader sustainability goals (e.g. carbon emissions reduction).
- A case study on the governance of the water and energy sector demonstrates that it has not been well undertaken in the recent past. The key issue is how do you marry up the top down and bottom up needs?

In order to stimulate debate as quickly as possible the organisers of the #UKEW workshop requested primers from a number of individuals attending - these include: (1) John Simmons - On Communications / BP; (2) Mike Woolgar - Atkins; (3) Katy Roelich - University of Leeds; and (4) Ronan Palmer - Ofwat / Environment Agency. These primers included issues that the authors considered important when reconciling the governance for interdependency in the energy and water sectors and augment the points made in the speaking sessions 1 to 4. In addition, a blog on infrastructure interdependencies was released on the online media site `The Conversation' prepared by Ralitsa Hiteva and Jim Watson[4] on the day of the workshop. All these articles can be found in Annex 4.

The outputs form World Café Exercises 1, 2 and 3 can be found in Annexes 5, 6 and 7, respectively. The outputs for exercise 1 have been presented in a Wordle format (another version can be seen in Box 2, below) and tabular format according to the categorisations made at the workshop. The second exercise on perceived barriers and facilitators to inform the management of interdependencies is also presented in tabular format in the categories of: (1) Physical, (2) Geographical, (3) Cyber, (4) Organisational and (5) Regulatory. The final exercise on possible initiatives to better understand and address interdependencies are also tabulated in the following categories: (1) Partnerships (between any social segments, government agencies, NGOs, industry representative bodies, advisory committees, new bodies, regulators, academia, etc); (2) Lines of research; (3) Reform (i.e. reformed regulatory arrangements, demand-side measures etc.); (4) Technologies; and (5) Others.

Finally, the social media engagement with the workshop can be found in the #UKEW storyfication of the twitter feed for the event and in annex 8.

Follow up work being considered includes the production of policy notes which will be developed from attempts to develop strategic alignment of UK infrastructure interdependencies work with a

[4] https://theconversation.com/britains-infrastructure-must-be-made-to-work-in-harmony-and-heres-how-34828

view to reconciling the need for regulatory reform and more bottom up engagement and further meetings to develop this space.

Box 2: **Wordle (version 1) from World Café Exercise 1 on assessment the current status of interdependencies between the water and energy sectors. See version 2 in Annex 5.**

Annexes:

1. Attendees
2. Agenda
3. Speaker Biographies, Presentation Key Messages and Notes from Talk Sessions 1 to 4
4. Primers and Blogs
5. World Café Session 1
6. World Café Session 2
7. World Café Session 3
8. Social Media

Annex 1: Attendees

ORGANISATION	FIRST NAME	LAST NAME
ABB	Peter	Jones
Affinity Water	Darren	Hewerdine
Atkins Global	Geoff	Darch
Atkins Global	Helen	Gavin
Bristol University	Ges	Rosenberg
Cambridge University	Zenaida Sobral	Mourao
Cambridge University	Liz	Curmi
Cambridge University	Grant	Kopec
Cambridge University	Dennis	Konadu
Cambridge University	Scott	Kelly
Cambridge University	Tristram	Riley-Smith
Carbon Disclosure Project (CDP)	Sarah	Robertson
Cardiff University	Jianzhong	Wu
Centre for Ecology and Hydrology (CEH)	Graham	Leeks
Committee on Climate Change	Daniel	Johns
Consultant	John	Beckford
Cranfield University	Liz	Varga
DECC	Craig	Lucas
DECC	Mark	Prouse
Defra	Jessica	Baldwin
Defra - infrastructure	Meg	Patel
Drax	Oliver	Baybut
Dwr Cymru (Welsh Water)	Gail	Williams
Economic and Social Research Council (ESRC)	Andy	Gibbs
Energy UK	Andy	Limbrick
Environment Agency	Amanda	Turner
Environment Agency	Kay	Johnstone
EPSRC	John	Holtum
ERP	Helen	Thomas
ERP	Mark	Workman
Exeter University	Dragan	Savic
HMT	Richard	Ploszek
HS2	Arefa	Siddiqi
iBuild	Sean	Wilkinson
Independent Consultant	Jim	Wharfe
Independent Consultant	Steve	Hill
Infrastructure UK – HM Treasury	David	Penhallurick
ITRC / Oxford University	Jim	Hall
ITRC / Oxford University	Miriam	Mendes

Knowledge Transfer Network	Stephen	Lowe
Knowledge Transfer Network	Jonathan	Abra
Leeds University	Katy	Roelich
Ministry of Defence	Jason	Flynn
National Grid	Damien	Culley
NERC	Chris	Franklin
NERC	Weihao	Zhong
NERC PURE	Vera	Hazelwood
Newcastle University	Edward	Byers
Newcastle University	Jaime	Amezaga
Office of Rail Regulation	John	Holmes
Ofgem	Jeff	Hardy
Ofgem	James	Luger
Ofgem	Stephen	Beel
Oxford University	Robert	Carlsson
Oxford University	Scott	Thacker
Oxford University	Nick	Eyre
Oxford University	Modassar	Chaudry
Oxford University	Martino	Tran
Oxford University	Beate	Dirks
Oxford University	Iliana	Cardenes
Oxford University	Xiawei	Liao
Oxford University	Franziska	Gaupp
Oxford University	Xi	Hu
Oxford University	Jae-Young	Lee
Planning Inspectorate	Simone	Wilding
RPS Group	John	Simmons
RWE Generation UK	Neil	Edwards
Shell	Harleen	Sindhu
Southampton University	Adrian	Hickford
Southern Water	Emma	Bennett
SSE	Keith	MacLean
Sussex University - SPRU	Paul	Nightingale
Sussex University - SPRU	Charlotte	Humma
Sussex University - SPRU	Ralitsa	Hiteva
Thames Water	Keith	Colquhoun
UCL	Tom	Dolan
UKCIP	Roger	Street
UKERC / Sussex University - SPRU	Jim	Watson
UKWRIP	Faith	Culshaw
United Utilities	Matt	Holmes
WRc	Mark	Smith
WS Atkins	Mike	Woolgar

Annex 2 Agenda

ITRC-UKWRIP-ERP Energy and Water Interdependencies Workshop #UKEW

Programme

Session 1: What is infrastructure interdependence and why it matters?

09:50 - 10:00 Welcome - *Jim Hall, Workshop Chair*
10:00 - 10:10 Overview of interdependence - *Jim Hall, ITRC-University of Oxford*
10:10 - 10:20 Role of Interdependence - *David Penhallurick, Infrastructure UK-HM Treasury*
10:20 - 10:30 Interdependency – A regulators perspective - *Stephen Beel, Ofgem*
10:30 - 10:40 Q&A

Session 2: Interdependencies between the water and the energy sectors - models, tools & case studies

10:40 - 10:50 Academia: Cooling water use in a low carbon and water-constrained future - *Ed Byers,ITRC- Newcastle University*
10:50 - 11:00 Industry: Water demand for the electricity sector - Key Concerns and Priorities for Action - *Neil Edwards, RWE Generation UK*
11:00 - 11:10 Academia: Interdependence in energy demand and strategic planning - *Nick Eyre ITRC- University of Oxford*
11:10 - 11:20 Industry: Obvious and less obvious interdependencies between water and energy both today and the future - *Keith Colquhoun, Thames Water*
11:20 - 11:30 Q&A

11:30 - 11:50 ***BREAK***

Session 3: Interdependent failure & its consequences: critical hotspots analysis – models, tools & case studies

11:50 - 12:00 Academia: Interdependence in electricity transmission and distribution and Vulnerability Hotspot Analysis - *Scott Thacker, ITRC-Oxford University*
12:00 - 12:10 Academia: The costs of interdependent failure - *Scott Kelly, ITRC-Cambridge University*
12:10 - 12:20 Industry: Development and implementation of ETR138 - *Damien Culley, National Grid*
12:20 - 12:30 Q&A

Session 4: Governance and Regulation - interdependency planning, management framework & case studies

12:30 - 12:40 Regulator: Case for Change and water demand by the energy sector - *Amanda Turner, Environment Agency*
12:40 - 12:50 Academia: A Systems Approach to Creating Value from Engineering Interdependency - *Ges Rosenberg, ICIF- Bristol University*
12:50 - 13:00 Academia: The role of local authorities and communities in governing infrastructure interdependencies - *Katy Roelich, Leeds University*
13:00 - 13:10 Academia: Lessons from alternative governance approaches: looking beyond integrating from the top down - *Rali Hiteva, ITRC-Sussex University*
13:10 - 13:20 Academia: Governing interdependencies between infrastructures - *Jim Watson, ITRC-UKERC*

13:20 - 13:30 Q&A

13:30 - 14:15 ***LUNCH***

Afternoon Session: facilitated discussion chaired by Jim Watson

14.45 ***Part 1*** will assess the current status of interdependencies between the water and energy sectors. Key themes:

- ***Areas of interdependencies***
- ***Impacts of interdependencies – risks and opportunities***
- ***Existing policies addressing interdependencies***
- ***Other initiatives addressing interdependencies***

15.25 ***Part 2*** aims to capture perceived barriers and facilitators to inform the management of interdependencies. The following categories are suggested:

- ***Physical***
- ***Geographical***
- ***Cyber***
- ***Organisational***
- ***Regulatory***

15.50 ***Part 3*** focuses on gathering suggestions for possible initiatives required to plan and prepare for better management of infrastructure interdependencies in the future. Suggested themes:

- ***Partnerships (between any social segments, government agencies, NGOs, industry representative bodies, advisory committees, new bodies, regulators, academia, etc)***
- ***Lines of research***
- ***Reform (i.e. reformed regulatory arrangements, demand-side measures etc.),***
- ***Technologies***
- ***Others***

16.05 ***BREAK***

16.45 ***Part 4*** - Jim Watson will present a summary of the generated output

16.45 ***Close of the day***

Annex 3: Speaker Biographies, Presentation Key Messages and Notes from Talk Sessions 1 to 4

The morning sessions 1 to 4 of the workshop are captured in this annex. Key messages for each session are also made.

The presenters talk title is stated along with a biography. Where the presenter sent their talks key messages, these are included followed by notes from the speakers actual talks which were derived from the recordings of the relevant sessions. Only points not made in the key messages are annotated in the `talk notes' section.

Links to the individual presentation slides and recordings of the talks are available on the following link: http://erpuk.org/erp-itrc-ukwrip-workshop-energy-water-interdependencies/

The individual slides and recordings are hyperlinked in the last paragraph of each section below.

A3.1 Session 1: What is infrastructure interdependence and why it matters?

1. Overview of interdependence by Professor Jim Hall, ITRC-University of Oxford

Biography: Professor Jim Hall is Director of the Environmental Change Institute and Professor of Climate and Environmental Risks in the University of Oxford. A civil engineer by background, Professor Hall has pioneered the use of risk analysis to inform tough decisions about the future of infrastructure systems. He advises governments, agencies and utilities globally on how to adapt their systems and plan for an uncertain future. Jim now leads the UK Infrastructure Transitions Research Consortium, - ITRC, which is funded by a £4.7million Programme Grant for EPSRC and is developing and demonstrating a new generation of system simulation models and tools to inform analysis, planning and design of national infrastructure. Jim is a member of the panel conducting the Institution of Civil Engineer's 2014 State of the Nation's Infrastructure Assessment and also sits on the ICE Public Voice Committee. He is a member of the Engineering Policy Committee of the Royal Academy of Engineering.

Talk Notes:

The talk intended to provide an overview as to what is meant by interdependency and highlight some recent work in the area based mainly from ITRC outputs.

Following the body of work undertaken in the ITRC Professor Hall has concluded that there is a need to be much more specific in the use of the term of infrastructure interdependence or may be abandon the term all together because it inspires vague dread or a promise of untapped opportunities, which if could be exploited, would realise substantial benefits. It would be more constructive to discuss specifically the different versions of interdependence, why they are significant and what we might then do about them.

For the workshop, the organisers have used Rinaldi's (2003) framework as follows:

- Physical interdependence between water and electricity production - for example:

- the modelled correlated demand as a function of long term trends in the future such as the introduction of electric vehicles; or
- in the case of extreme events, unusual spatial loading or downgraded response related to failures such as: common cause failure and/or cascading failure.

Research as to how these are then propagated via economic linkages through supply chains can then be undertaken.

- Geographical Interdependence. There are different versions for example:
  (1) Spatial patterns e.g. natural hazards are inherently spatial therefore spatial patterns of correlation in that loading; and
  (2) Co-location of infrastructure and impact of cascade failure on infrastructure output as per the exercise on `Hotspots' undertaken by the ITRC for IUK.

- Cyber interdependence. The research on the impact of the information and communication infrastructure has developed a mixed picture. It is claimed that there is a high level of redundancy and that safety critical software has been developed but in reality there is a lack of understanding of the nature of cyber interdependencies and their impact due to the lack of sector transparency.

- Human interdependencies. These relate to socio-technical perspective governance or human generated disasters.

The study of interdependencies has the epistemological problem of never being complete, is difficult to prioritise and will always have categorisation problems.

The fact is that system managers know their own infrastructure systems better than any academic but there is a need for a holistic perspective which is where opportunity for industry and academia to work together. As a result of this, the role of modelling is important and has been a focus of the ITRC.

The ITRC System of Systems National Infrastructure Systems Model family are outline below:

- NISMOD LP - Providing the tools to devise and analyse long term strategies for national infrastructure
- NISMOD RP - Analysing infrastructure vulnerabilities and risks, to provide the business case for adaptation planning
- NISMOD RD - Modelling the relationship between infrastructure and economic growth
- NISMOD DB - A national infrastructure database and supporting tools

The development of these models is considered to be a significant first in the generation of capacity to look in a cross-sectoral and long term way at national infrastructure. This will allow the building of long term vision for infrastructure planning, analysis of vulnerabilities, adaptation to risks and to develop strategies to address infrastructure provision. There is now the opportunity to develop partnerships and collaboration to further evolve thinking within ITRC.

The full presentation is available on the following link and an audio recording of the presentation is available here.

2. The Role of Interdependence by David Penhallurick, Infrastructure UK-HM Treasury

Biography: David joined the Information, Change and Technology (ICT) team of Partnerships in 2007 and transferred to the commercial delivery unit of Infrastructure UK (IUK) in 2010. Since 2009, David has been involved in providing support to operational PPP / PFI contracts in the UK including delivering classes on contract management.

David is currently the Strategic Lead - Cross-Sector Delivery, a team that is focused on developing projects that cross more than one infrastructure sector so as to reduce the total cost of delivery and increase the economic benefits.

David is presently a member of the Expert Advisory Group for the ITRC, a research programme looking at infrastructure systems and the changes needed to move to a low carbon economy, a member of the Expert Advisory Group for iBuild, a research programme investigating the new business models that might be needed in an integrated and interdependent infrastructure future world and was a former member of the UK Location Council, and Critical Infrastructure Resilience Programme.

Prior to joining PUK, David worked in various UK Government Departments and Agencies principally in the areas of Finance and Commercials including the management and delivery of outsourced contracts.

David holds qualifications in Information Technology, Systems Thinking and Practice, Management and is a Fellow of the Association of Chartered Certified Accountants.

He lives in Cumbria with his partner, 2 daughters and 2 barn cats and has spent the last 4 years modernising and renovating an old farmhouse.

Talk Notes:

Infrastructure UK (IUK) was set up in 2009 to focus on the long term planning, prioritisation and delivery of infrastructure in the UK with a view to exploiting opportunities that might be brought to bear. For example, the 2013 National Infrastructure Plan identified - £3 B worth of opportunities.

In IUK the opportunities that can be harnessed to inform strategy and policy are grouped into 4 main headings: (1) Academia and Research; (2) Environment; (3) Business; and (4) Economic.

In the business environment harnessing the opportunities of interdependencies: (1) can improve network resilience; (2) allow systemic risk analysis; (3) reducing business risk - e.g. one of the features that drove up costs of delivery was the need for contingency to be set aside for dealing with other people's infrastructure yet through joined up approach this could be avoided reduce business risks; and (4) allowing for different business models to emerge.

Continuity of service is seen as an important aspect of the regulated asset base model and something that in price reviews, the regulators consider very carefully when looking at the network build and replacement plans of regulated utilities. The opportunity of the deployment additional network connections, at low marginal costs, should be made between nodes thereby providing more diversionary pathways if a node fails and as a result limiting or localising the impacts.

In 2010, the sixteen sector resilience plans considered resilience within a sector. In 2012 the sectors were challenged to think about resilience from a cross-sectoral perspective and impacts on their sector from other sector and theirs on others.

For various reasons, over the last couple of decades we have constrained the private sector into single infrastructure delivery organisations. Whilst there are merits in ‘sticking to core’ there are also merits in having a diversified business which can balance revenue streams across a range of products. The sector specific approach is a legacy of the way our predecessors viewed the world, but this doesn’t mean that we can or should continue with them if we can identify different and better structures to serve the needs of society and its citizens.

When you focus attention down to the individual citizen, they don’t really mind how the utility sector is structured and organised, what they care about most is provision of a service at an affordable cost to them and an assurance that they will have security of supply of those services.

So the big question is, do we continue with a governance structure designed for the 20th Century as we move forward into the 21st? Or do we explore, question and re-examine some of our pre-conceptions and seek to put in place different and possibly new business models, governance structures and delivery regimes?

The full presentation is available on the following link and an audio recording of the presentation is available here.

3. Infrastructure Interactions Regulators Network Projects by Stephen Beel, Ofgem

Biography: Steve Beel is Associate Director, Offshore Transmission at Ofgem, the UK energy regulator. His primary responsibilities are the design and delivery of the competitive tendering processes that have so far delivered £250m of new investment into UK offshore transmission networks. Steve also works in a number of other regulatory areas including in relation to wholesale and generation markets.

Prior to joining Ofgem in 2009, Steve worked across multiple infrastructure sectors in different capacities. Most recently he was at Hutchison Port Holdings, one of the world’s leading container port investors, where he undertook a range of commercial and strategic roles in Hong Kong, the Middle East and Africa. Prior to that he worked at PricewaterhouseCoopers, where he worked in an advisory capacity on major infrastructure developments, including in the PFI/PPP space and for the London Olympics. Steve has a Masters in Engineering from Bristol University and an MBA from Oxford.

Talk Notes:

The UK Regulators Network was established in March 2014. A summary of the role of the organisation is as follows:

(1) Who we are (Ofgem, Ofwat, Civil Aviation Authority, Office of Rail Regulation and Ofcom are of relevance to the regulated sectors) and our purpose is to share experiences, deliver efficiencies and ensure optimal outcomes;

(2) Work on infrastructure issues - there are presently 8 different projects ranging from consumer switching, cost of capital to cross-sector infrastructure project;

(3) The role of economic regulators that may be relevant to infrastructure can be found here.

(4) For cross-sector interactions maintain resilience and installing assets to ensure service quality is realised.

From a regulators perspective, the National Infrastructure Plan is about greater visibility on infrastructure spend and demonstrates commitment on infrastructure spend. It has been estimated that there is £100 B being spent on regulated sector infrastructure in next 5 years.

We are trying to do new things as regulators. Though economic regulators have a focused role - set by statute - with powers aimed at supporting their core function with regards infrastructure interdependencies we are looking cross sectors for best practice, lessons and where appropriate, opportunities to co-operate with one another, with industry and with existing initiatives across government. Infrastructure investment and installation is a key focus of economic regulators and, through UKRN, are committed to supporting efficient investment ***and we are inviting people to engage with us.***

The full presentation is available on the following link and an audio recording of the presentation is available here.

Q&A

There were no questions for the opening session of the workshop.

A3.2 Session 2: Interdependencies between the water and the energy sectors – models, tools & case studies

4. Cooling water use in a low carbon and water-constrained future by Edward Byers, EPSRC PhD researcher at Newcastle University

Biography: Edward Byers is a final year EPSRC PhD researcher at Newcastle University working on energy and water infrastructure transitions. His research focuses on hydrological variability, climate impacts and cooling water use of thermal power stations. His work has focussed mainly on the UK and more recently in Turkey. He was lead author of Working Paper 9 (Energy: coal, oil, gas, and nuclear) to the LWEC Climate Risks to Infrastructure Report Card. He is affiliated with ITRC and Tyndall Centre and is Energy Topic Editor of Global Water Forum. He previously trained as a civil engineer and has worked in advisory roles with DECC and Infrastructure UK.

Key Messages: This talk will present an analysis of the UK thermal power stations' dependency on cooling water. Cooling water use by thermoelectric power stations in the UK has been quantified for the current system, alongside several other scenarios to 2050.

- In most cases freshwater use declines due to more coastal-based generation or non-water using technologies (i.e. non-thermal renewables).

- In scenarios with high levels of carbon capture and storage (CCS), freshwater use may increase substantially. Clustering of CCS plants may also intensify water demands.

- Extreme low flows and drought are also shown to potentially impact electricity generation in some regions.

This talk will discuss some of the water risks related to CCS development as well as potential options for avoiding risks to generation capacity.

Key messages:

- Unlike some other countries, the UK is on a sustainable trajectory regarding cooling water use, yet this depends heavily on the level of CCS used;
- The localised clustering of CCS facilities and climate impacts on water resources will complicate this issue in some regions; and
- There are innovative ways to reduce cooling water risks, such as wastewater re-use and combined heat and power, but these bring additional governance complications and interdependency issues.

Talk Notes:

Ninety percent of UK electricity from thermal plant requires cooling using water some freshwater. In terms of the water used by a power plant, a 1 GW coal power station which supplies electricity to 1.5 M homes consumes 1 - 1.5 m^3 of water by evaporation per second.

The Energy Water Nexus is a much studied topic particularly in those countries which have experienced cooling water problems via lack of flow or temperature differential e.g. the US, China, India, France and Germany. This interdependency has not impacted in UK though it almost did in the 2012 drought.

There are multiple opportunities for reducing water use - for example by: (1) Using alternate cooling systems types but expensive and needs to be considered early on in the investment decision; (2) Using alternate cooling sources from waste water or sea water; and (3) reducing demand for cooling e.g. gas is more efficient than coal or more Combined Heat and Power. The solutions to be applied will be highly contextual which may make it more difficult to apply policy/governance solutions.

There is a need for more evidence on the risks and impacts of drought and low flows on hydrology to assess the effects that this will have on power plants capacity to withdraw water from catchments.

The full presentation is available on the following link and an audio recording of the presentation is available here.

5. Water demand for the electricity sector – Key concerns & Priorities for Action by Neil Edwards, RWE Generation UK

Biography: Neil Edwards has more than 30 years experience of modelling, effects analysis and risk assessment of the interaction of thermal power plant and the water environment. He has worked internationally on a wide variety of plant types and project developments including options appraisal, permit applications, plant acquisition risks, and emerging environmental legislation. Representational roles include: (1) Eurelectric - production of Water FD CIS (Guidance on Designation of Mixing Zones and Water Accounts; and (2) General Industry (Thames River Basin District Liaison Panel).

Key Messages:

- Use of water for cooling will remain a key driver in coming decades
- Future sector expected water use is highly uncertain. It will result from: (1) Many individual company decisions on plant investment (company circumstances, commercial drivers and risk appetites differ greatly); and (2) closure when facing an uncertain regulatory and market future.
- Plant goal is water use optimisation not minimisation. Sufficiently reliable access to sufficient water is a pre-requisite for investment in water dependent plant.

Talk Notes:

There are many power plant cooling options - but with minor variations of thermal efficiency having substantial impacts on economics of plant through-out its life - thermal efficiency and resource use efficiency balance will be the key considerations in the selection of cooling technology.

Future actual electricity sector water use at a - National, River Basin District and individual plant level - in a given year will remain highly variable driven by many factors such as electricity market, electricity demand, plant mix, fuel costs, constraints, maintenance schedules, weather etc. Therefore, for any given future energy mix scenario there might be variance in water consumption in 2050 by factor of 10. The predictability or lack of predictability of sector water use in the UK is due to uncertainty individual company choices regarding use and operation of their plant.

Beware of benchmarking plant - each one will have its own water story which needs to be understood.

There have been multiple studies but wary of consistency and context of these studies.

Sufficiently reliable access to sufficient water is a pre-requisite for investment in water-dependent plant.

The full presentation is available on the following link and an audio recording of the presentation is available here.

6. Interdependence in energy demand and strategic planning by Dr. Nick Eyre, ITRC- University of Oxford

Biography: Nick leads the Lower Carbon Futures Programme at the Environmental Change Institute at the University of Oxford, and is a Jackson Senior Research Fellow at Oriel College, Oxford. He teaches on the University of Oxford MSc programme on Environmental Change and Management. He is a co-Director in the UK Energy Research Centre (UKERC) leading it work on decision-making; and a co-investigator in the Infrastructure Transitions Research Consortium (ITRC) leading its work on energy demand.

Nick is a member of Ofgem's Sustainable Development Advisory Group, a Fellow of the Energy Institute and a member of the Energy Policy Panel of the Institution of Engineering and Technology. Previously he worked at the Energy Saving Trust from 1999 to 2007 as Director of Strategy. In 2001, Nick was seconded to the Cabinet Office, Performance and Innovation Unit, where he was a co-author of the UK Government's Review of Energy Policy, leading its work on energy efficiency and energy scenarios.

Nick has worked on energy, environment and climate issues for 30 years and was a lead author on the Fifth Assessment Report of the IPCC. He authored the first report on delivery of the Government's 2010 20% carbon emission reduction target and the European Commission report used as the basis for the UK Government's first estimate of the social cost of carbon.

Key Messages: The Infrastructure Transitions Research Consortium has developed a "system of systems" approach to modelling the UK's infrastructure systems of energy, transport, water and waste. In this presentation we outline the approach taken to modelling energy demand, using a "bottom-up" approach with relatively high levels of disaggregation, by fuel and technology, as well as spatially and temporally, generating diverse scenarios of energy demand.

We identify some of the key energy water/interactions. Some are addressed in other presentations, e.g. water use in thermal power generation (Byers) and energy use in the water sector (Colquhoun). Other important interactions occur at sub-sectoral level. A high proportion of energy and water use in buildings is in the co-production of hot water. And in some major industrial sectors, energy is used for process heating, with water primarily for process cooling. In both cases, this implies that important services and processes are dependent on the reliability of both infrastructures, but also that there are synergistic opportunities for demand reduction in the two sectors, which are neglected in single sector assessments.

Talk Notes:

Key findings:

- Water use in energy production is dominated by cooling water for power generation
- Energy use in water supply and treatment represents a high fraction of water industry costs mainly in water treatment but ~2% of UK electricity and <<1% of total energy.
- Insights into other water energy interactions:

  (1) Co-production of steam and hot water. Energy use to produce hot water in buildings is very much larger than energy use in the water industry and is dependent on gas, water and electricity infrastructure sectors. Saving hot water has benefits in both sectors, but separation of programmes does not allow this to be recognised.

  (2) Interactions in industrial processes. High use sectors are high temperature (<400C steam) little generic lessons as it is an extremely diverse sector. As a generalistion, in high temperature processes industries, energy heats up the materials and water cools them down and therefore new, resource efficient processes could address both sectors.

In both cases, there are implications for infrastructure inter-dependence and efficiency.

The full presentation is available on the following link and an audio recording of the presentation is available here.

7. Obvious and less obvious interdependencies between water and energy both today and the future by Dr Keith Colquhoun MBA, MSB, CBiol, Thames Water

Biography: Keith is the Climate Change and Sustainability Strategy Manager for Thames Water and is responsible for Thames Water's integrated approach for accommodating climate change in its PR14 Business Plan based on risk. He is also responsible for interfacing with Thames Water's innovative delivery vehicle Eight20 for over £2 billion pounds of investment in AMP6 for climate change and sustainability. Keith sits on various industry advisory groups, research steering groups on climate change and is active in positively engaging with stakeholders on climate change and sustainability.

Talk Notes:

The presentation represents Dr Colquhoun's:

- own thoughts of the water industries need to respond to the adaptation reporting power request and interdependencies with other sectors;
- colleagues in water sector; and
- is a water sector perspective of the world - in water sector, in opex terms, energy is the second biggest cost after staff.

Dr Colquhoun agreed with the workshop objectives of the need to identify state of understanding, relationship of interdependencies and need for further research and knowledge exchange. He was not so sure on the need for collaborative mechanisms for coherently addressing infrastructure interdependencies.

All of the following factors will have an impact on infrastructure type and timing.

The obvious interdependencies include: (1) water supply for customers; and (2) energy sector needs. Both are dependent on (3) weather impacts availability of water and demand for energy; (4) Resilience; and (5) Security of Supply also important.

Wider water-energy sector interdependencies include:

(1) The TRIAD market managing the sector which can result in an increase in costs.

(2) Short Term Operating Reserve for which water companies have greater input.

(3) Frequency control is a similar opportunity to smooth out consumption.

(4) Use of standby generation [short-term] in water sector to peak demand needs of energy sector.

(5) Self generation of renewable energy [long-term] 1,500 GWh generation in water sector in FY 2013-14 and has no distribution losses so is more efficient.

(6) other incentives - ROCs and FITs – to assist in development of water sectors energy generation capacity.

(7) Water sector wants to reduce emissions but ~70% GHG emissions from electricity - therefore water sector has vested interest in the energy sector reducing its emissions.

(8) Reducing energy and reducing carbon are not necessarily synergistic; and

(9) Skilled employees.

Developing interdependencies include:

(1) The introduction of the Water Framework Directive will mean that there will be less water available to take from the environment. There will be increased competition for that water which means there is likely to be an increase in the price for that water – at the industrial level water will be more important in the future.

(2) Trading of abstraction capacity between sectors e.g. power sector no longer drawing on abstraction licence and trading it with water sector.

(3) Timing of energy consumption from water sector to reduce costs.

(4) Change of processes to create more renewable energy / fuel from processes in water sector such as sludge for energy.

Looking to the future:

(1) Changes to abstraction licences is going to mean working more closely together.

(2) Jointly developing paid for eco-system services by working with land owners to better manage water catchment areas.

(3) Water for CCS is going to create more demand for water.

Create incentives as to manage the (4) timing of energy consumption.

(5) Co-location of assets e.g. put a water treatment plant next to a power generation plant and locate both on the coast and heat from power plant to generate desalinated water.

(6) Stop generating renewable energy and generate hydrogen in anticipation of the hydrogen economy?

The full presentation is available on the following link and an audio recording of the presentation is available here.

Q&A

Question 1:

Darren Hewerdine - Affinity Water. Nick (Eyre) pointed out that though the water industry only uses 1-2% of UK electricity and that heating water in homes uses substantially more. With the domestic use of water being very concentrated i.e. morning peak and evening peak heating - has consideration been given to demand shifting using water storage for industrial process to avoid pressures being put on the grid during these peaks?

Nick Eyre. In the residential sector there has been no attempt to demand shift as households have a fixed charge for their energy. However, as smart metering is introduced then the ability for hot water to act as an energy store will be considered by suppliers to address peaking in morning and evening. i.e. though the hot water is wanted in the morning and evening - the electricity to provide that hot water does not; there will be a need to store that hot water until it is needed. It is notable that in the UK we are ripping out hot water tanks and replacing them with Combi boilers. Such a trend will need to be reversed if we would like to use hot water storage in the residential sector as an option in the future.

Additional comments submitted subsequent to the workshop by Darren Hewerdine

Improving load management in response to grid pricing pressures:

- Improved future guidance on tariff profiles for investing in peak lopping. The water industry and other industries invest in plant to produce a required volume of product within 24 hours. If there is certainty on medium / long term future requirement of price pressures on the supply grid, this will allow investment in increased plant capacity to operate outside of the peak tariffs. Currently peak rates are slowly increasing, as are TRIAD rates. I have insight into a possible supply grid future stresses and the electrification of fuels, with my involvement with the Energy Institute, however most influential people in the Water Industry only are vaguely aware of existing tariff profiles and TRIADS and not long term requirements.
- Energy Price forecast for electricity and carbon similarly would spur investment in efficient assets. However these are not well publicised and can be perhaps lower than what happens in reality, therefore reducing the investment in long term energy efficient assets.
- Abstraction licence relaxation from the Environment Agency; in a similar issue, we abstract some water from below ground aquifers, however at some sites we will not peak loop, since the abstraction licence for the day is constrained to only allow flat abstraction 24/7.

During Rota Disconnections (rotating planned power supply cuts, due to insufficient national generation capacity);

- Key Water industry sites may have been previously agreed to be on the Distribution Network Operators (DNO's) 'V' list, which exempts them from these power cuts, if technically simple to achieve via the local grid. This is good for Water Industry critical assets. However the water industry's **most** critical assets often have fixed standby generation. Having this generator means the site can not be on the V list and must be subject to power cuts. **Large water supply issues can occur if the generator fails, or the nominal (say 24 hours) diesel storage is insufficient for prolonged use and can not be replenished in such a national emergency.**
- Many areas of the water industry are resilient to a single site power failure, or have a limited reservoir of clean water (say 18 hours). However, during rota disconnections, the site and it's adjacent supply site will often both be off at the same time, so water supply could fail after several days.

Question 2:

Jonathan Abre - the Water theme leader for the KTN. Have any of the scenarios modelled considered the impact of energy storage technology on demand shifting?

Nick Eyre. Not explicitly. Present energy storage technology costs at scale - with the exception of pumped hydro - are higher than alternative ways of meeting big demand. That does not mean that this will always be the case and is certainly one of the areas that we want to look at in greater detail going forwards.

Question 3:

Simone Wilding - the Planning Inspectorate. Questions mainly to Neil (Edwards).

- Are you saying that thermal efficiency is the main factor not replacing water cooling with air cooling?

- Does this hold across all types of generation technology - such as gas and coal? And

- Is there the possibility that alterative technologies might be developed which are more efficient than water cooling?

Neil Edwards. It has been the goal of power operators to improve thermal efficiency for some time and there has been substantial progress. Cooling is integral to the operation of a power plant. It is not a bolt on. You can use any cooling technology in a power plant but the heat that you have to address is the same for any technology. So based on economics you will always find that once through is always better than towers which are better than air.

Has the water cooling technology efficiency plateaued? No, the OEM always state that if you pay a bit more you can get more efficiency.

Question 4:

Sean Wilkinson from Newcastle University. I have a question for Stephen Beel.

Regulations, incentives and timescales: How good are the regulations to ensure utilities make the appropriate investments in the long term rather than on just day-to-day issues? Is that balance right and how do we change it (if it is not)?

Stephen Beel. I wouldn't say that the balance is perfect but I think that there is a need to strike a balance here. For example, at Ofgem the recent round of price controls were extended from 5 to 8 years to create a framework for those longer term investments such as innovation. Specific innovation competitions to address these long term issues were introduced which has attracted investment. Striking the right balance is the challenge for regulators. At the moment the balance is about right but for new technologies that might make a material difference to the system - making sure that the appropriate level of investment is made for those presents a challenge for regulators especially to make sure that they are brought through the `system'.

It would be interesting to know if those networking companies see that the right balance has been struck.

A3.3 Session 3: Interdependent failure & its consequences: critical hotspots analysis – models, tools & case studies

8. Interdependence in electricity transmission & distribution & Vulnerability Hotspot Analysis by Scott Thacker, ITRC-Oxford University

Biography: *Scott is a doctoral student at the Environmental Change Institute (ECI) and is supported by the EPSRC and the engineering consultancy ARUP. His research is affiliated with the ITRC project and focuses* on the modelling of complex interdependent infrastructure networks at national and local scales, in particular, adopting a 'system-of-systems' approach to evaluate the risk of failure posed to interdependent infrastructure networks by extreme climatic events. *http://www.eci.ox.ac.uk/teaching/doctoral/thackerscott.html*

Key Messages: The UK Infrastructure Transitions Research Consortium is developing national models to enable the long term planning and adaptation of infrastructure systems in the face of a changing climate. The ITRC has developed a national model of electricity transmission and distribution, along with gas, trunk road and rail networks. For the first time, this model seeks to represent the effect of interconnectivity between infrastructure networks, which can result in failure at a particular location having disproportionate consequences. We have mapped the telecoms, water and water treatment assets that are dependent on electricity networks. The model also uses data on customer/passenger use of infrastructure and census data on where people live, to understand where large numbers of people are dependent on critical infrastructure. This modelling capability has been used to identify 'infrastructure criticality hotspots", which we define as a geographical location where there is a concentration of critical infrastructure, measured according to number of customers directly or indirectly dependent on the infrastructures in that location

Talk Notes:

The motivation of this work is to develop a better understanding of the role of interdependency in increasing potential disruptions from infrastructure failures and its consequences.

Using the ITRC NISMOD-RV System-of-Systems Modelling – the interrelationship for different infrastructure sectors (i.e. ICT, gas, transport, electricity, water and waste) have been modelled. The sectors have also been modelled at different scales to take into account sub-systems within systems. This has involved: (1) Assembling Network Data; (2) Understanding customer demands and network flows; and (3) Incorporating interdependencies

The applications of the work are as follows:

- Understanding Direct and Indirect Customer Demands.
- ITRC Infrastructure Criticality Hotspot Analysis. An infrastructure criticality hotspot is a geographical location where there is a concentration of critical infrastructure, measured according to number of customers directly or indirectly dependent on the infrastructures in that location.
- Regional Criticality Analysis *i.e.* working out which regions are we most dependent and which regions support others.
- Vulnerability to extreme flooding - e.g. the Thames in winter 2014 working out the number of customers that are at different levels of risk for being impacted directly and indirectly.
- Planning Flood Adaptation Measures by estimating customer impacts across different sectors can priorised to adaptation measures.
- National Grid - EPSRC IAA Collaboration to understand the impact of distributed generation and consumption on National Grid Assets.

In summary:

- We have developed a unique modelling capability e.g. NISMOD - RV and Interdependencies.
- We have developed a number of informative collaborations with both government and industry.
- We are interested in further developing this capability via collaborations and case studies.

The full presentation is available on the following link and an audio recording of the presentation is available here.

9. The costs of interdependent failure by Dr. Scott Kelly, Senior Research Associate, University of Cambridge

Biography: Scott is presently a Senior Research Associate at the University of Cambridge. He is a junior research fellow of Darwin College and teaches a variety of subjects across economics, statistics and sustainability. He works in the Cambridge Centre for Climate Change Mitigation Research (4CMR) in the department of Land Economy and in Centre for Risk Studies in the Judge Business School. He has a PhD in Energy and Economics from the University of Cambridge; MPhil in Sustainable development; Masters of Energy; and a Bachelor of Mechanical Engineering. He is an author and reviewer for several academic journals and has written a number of book chapters on a variety of subjects cutting across energy systems; infrastructure; risk analysis and sustainable development.

Key Messages:

- From an economic perspective infrastructure sectors are heterogeneous in their contribution to the UK economy. Not only will it be shown that infrastructure sectors are important for economic output and growth, but different infrastructure sectors contribute in distinctly unique but important ways to overall economic activity.
- Results from the ITRC HotSpot analysis show a potential impact of around £2.1 m/day as a result of infrastructure failure on other sectors of the economy. This can be further broken down as £1.34 m/day (physical direct and indirect impacts) and £0.57 m/day from indirect economic impacts across the economy.
- The most vulnerable infrastructure sectors according to losses in economic output in order of importance are: telecommunications; air transport; electricity supply; railway transport; water supply; land transport; gas distribution; sewerage and waste water; water transport. The most vulnerable non-economic sectors to infrastructure failure in order of importance are: business services; postal and courier services; coal, gas and mining; electrical equipment and banking and insurance etc.

Talk Notes:

The primary method that is used is input output analysis as it is well suited to modeling the economic costs of disasters. It also offers a number of other methods for understanding the relationship between infrastructure and the economy.

Research Questions for this work include:

- What is the relationship and contribution of 'economic infrastructure' to the UK economy?
- What are the economic losses both indirect and direct resulting from infrastructure failure in the United Kingdom?

In answer to the first question:

Infrastructure has several unique characteristics that make it a very different and simply treating infrastructure as 'capital' may overlook the essential role that infrastructure actually plays within society.

It is very difficult to draw any direct causality between infrastructure and economic growth, but it is clear that countries with high levels of infrastructure investment are also wealthy countries.

Infrastructure investment and economic development therefore tend to go hand in hand. But infrastructure provides a number of other services that are quite difficult to capture in pure monetary value. Countries with well-developed infrastructure tend to have more healthy citizens, they have uninterrupted supply of electricity in their homes, they can get around efficiently using transport networks, in sum, citizens in countries with good infrastructure systems generally have a very good quality of life.

Infrastructure has several unique characteristics which were highlighted in the presentation.

With regards the UK, based on Office of National Statistics (ONS) - figures issued in November 2014 state that Infrastructure sectors together contribute just under 8.2% of total gross value added (UK Total Value Add £1.116 Trillion) and that capital represents about 8% of all capital infrastructure. Real-estate which has the largest capital value represents 35% of total capital stock, so taking real-estate out increases the value of capital from infrastructure to around 20% (Total value of capital stock to the UK £3.87 Trillion).

In answer to the second question:

Economic infrastructure is part of a network, and all the nine infrastructure types I am presenting today form part of a physical interconnected network which are interdependent and rely on each other to operate. As the ONS statistics don't disaggregate the data in lines with all sectors some modelling was carried out in order to break out the data for the individual 9 infrastructure sectors. The work mapped linkages, relationships and interactions between infrastructure sectors as well as linkages with other sectors of the economy. The physical and economic disruption impacts were then mapped according to the following lines:

- Direct damage to physical assets leading to a decrease in capital value;
- Direct loss in economic output caused directly by the hazard or event; and
- Indirect loss in economic output indirectly caused by physical and economic disruption to infrastructure.

Conclusions:

- Economic infrastructure is distinct and unique from other forms of capital.
- Economic infrastructure provides a central service to economic output and growth but heterogeneous and district strategies need to be found for each infrastructure services.
- Infrastructure has both 'physical' and 'economic' connections and need to be considered simultaneously.
- ITRC HotSpot analysis has an expected indirect economic loss of £0.86 m/day and total economic losses of £2.3 m/day.

The full presentation is available on the following link and an audio recording of the presentation is available here.

10. Development and implementation of ETR138 by Damien Culley, National Grid

Biography: Damien Culley is Environmental Engineering Manager at National Grid Electricity Transmission. He received his MPhys in Astrophysics from The University of Manchester in 2006 and has worked at National Grid since 2007 in a number of asset management and engineering roles. This included work on High Voltage Direct Current, condition monitoring systems and R&D strategy management. In his current position Damien is responsible for managing a variety of environmental issues including National Grid Electricity Transmission's resilience to natural hazards. He is responsible for leading on the evaluation of natural hazard risks, developing mitigation strategies and sponsoring investments to reduce the susceptibility of energy infrastructure to immediate and long term environmental risks.

Key Messages: ETR138: Resilience to Flooding of Grid and Primary Substations is an ENA document that that was published in October 2009. The report sets the standard for flood resilience of electrical infrastructure. The presentation will cover the background of events that lead to the development of ETR138 and how National Grid have implemented the recommendations. The presentation outlines the benefit of the cross industry approach to achieving stakeholder buy-in and the development of the long term plan to improve National Grid's flood resilience.

Talk Notes:

ETR138 is a document produced with the Energy Networks Association is about flood risk assessment with a view to preventing water egress into important substations. A number of substations were flooded in 2007 including Walham and Neepsend. The impact of these substations failing would be 2M people having no electricity for a period of days to weeks and associated economic damage to the regional economy.

As a function of these experiences and findings of the Pitt Review the Energy networks association sub-station resilience to flooding task group was brought together to develop ETR138 to improve flood resilience of substations. The group reported to Energy Emergency Executive Committee. The Task Group report was delivered in October 2009 in form of Electricity Technical Report ETR 138 and included in its development and acceptance were representatives from DECC, Ofgem, Environment Agency, DNO's and UK transmission companies.

ETR 138 project topics assessed impact of flooding on UK electricity supply system, risks to society, improved flood risk information, developed a systematic approach to flood risk assessment, targeted resilience levels for investment including CBA accounting for societal risk and work programmes for implementing sub-station flooding resilience.

With regards work programmes it was found that of 300 sites:

- 11 were at risk of 1 in 100 year flooding
- 26 at 1 in 200; and
- 65 at 1 in 1000.

These are in the process of being upgraded with a view to all sites being made resilient to 1 in 1000 year events by 2021. Furthermore, National Grid have embedded the principles of flood and natural hazards resilience into our policies and design standards and are emplacing risk resilience measures on high risk sites to 1 in 1000 year events. This investment is on a risk basis is resulting in £140 M being spent in the period between 2008 - 2021.

The effectiveness of resilience measures were tested in the February 2014 flooding where Walham substation was found to have stood up well to flooding due to the imposition of new defences. We are also looking at alternative to walls and barriers by using drainage and natural systems.

The full presentation is available on the following link and an audio recording of the presentation is available here.

Q&A

Question 1: Keith MacLean Co-chair for ERP. Question for Scott Kelly.

Can you explain how the impacts of disruptions were represented and calculated?

Scott Kelly. The economic impact analysis was completed using input-output analysis. Physical disruption estimates were taken from Scott Thackers work on identifying the assets that were disrupted due to infrastructure interdependencies. The total number of customers relying on each type of asset affected from the failure were then used to inform the direct economic impacts measured in £/day. Using these direct economic impacts the vector of final demand was adjusted to determine how the impacts would cascade through the UK economy and impact on other sectors.

Question 2: Dragan Savic, University of Exeter. General question.

In the body of work outlined on the presentations there has been no mention of the analysis of uncertainty. These would be inherent in all the modelling that has been undertaken. How can we look at uncertainty in a very comprehensive way to better quantify the level of uncertainty in the outputs that we are getting from the work.

Jim Hall. Good question. The first point to make is that we are at the start of the modelling journey for national scale infrastructure. This is an ambitious undertaking in itself. The results that we are presenting are a first step. They have developed some useful insights about the power of the methodology but we shouldn't read too much into them considering the complexity of the many modes that infrastructure failure can occur. So that's the health warning.

With regards how one goes about dealing with uncertainties? I would suggest two approaches. The first is sensitivity analysis and the second is around validation of results wherever possible.

With regards sensitivity analysis, we are already testing large numbers of failure scenarios and on top of that we need to layer in what are the possible sources of uncertainties and what are the impacts of those uncertainties on the outputs that we are producing.

On the issue of validation we are using specific events such as the recent flood events experience in the UK.

A3.4 Session 4: Governance and Regulation - interdependency planning, management framework & case studies

11. Case for Change and water demand by the energy sector by Amanda Turner, Environment Agency

Biography: Amanda Turner has worked for the Environment Agency since leaving university in 1996; holding a number of area roles within Water Resources, including drought officer, hydrometric officer, Water Resources planning officer, Catchment Abstraction Management Strategy (CAMS) officer, developing the CAMS for the Lower and Upper Mersey catchments.

In 2003, Amanda moved to head office, as project manager for the review of the Agency's national water abstraction charges scheme to establish a revised charges regime to recover funds to enable the Environment Agency to deliver it's duties under the Habitats Directive. She was also involved in a number of implementation projects following the Water Act 2003.

In October 2008, Amanda took the role as Senior Advisor in the Water Resources Resilience Team, where she led on providing technical advice to Defra on a number of policy areas; including license trading, input to the Floods and Water Management Act (2010), input to Defra's Water White Paper (2011), providing technical support for the Water Act (2014) and working with sectors to explore the implication of climate change, population growth and increasing demand under different future scenarios, published as the Case for Change. More recently, Amanda has been on assignment to the role of Environment and Business Manager, managing the Water Resource Resilience Team, leading the strategic management of the Environment Agency's Water Resources business.

Key Messages: The Case for Change analysis provides a plausible envelope of future supply and demand balances exploring the uncertainty around the impacts of climate change and future water availability, and the uncertainty around differing demand for water from different sectors. This evidence has been shared with Defra to provide a suite of scenarios against which they can test policy options for abstraction reform.

We have found that:

- Already 25% of water bodies in England will only provide water for new consumptive abstraction for less than 30% of the time.
- There's a significant risk of less water being available to people, businesses, agriculture and the environment in the future due to the impacts of a changing climate and population growth.

- Under the Case for Change scenarios roughly half of catchments where large thermal power stations are using freshwater for cooling appear resilient and not sensitive to the impacts of climate change in 2050.
- The remaining catchments appear sensitive to the impacts of climate change and have no water available for further consumptive abstraction. The status of "no water available" for a catchment will affect all sectors equally.
- Future governance and policy needs to be adaptable and flexible and take into account the interdependencies between water policy and energy policy and the uncertainties of the future.

Talk Notes:

The Case for Change work comprises the following work: (1) Case for Change (2011): Current & future water availability; (2) Case for Change Refresh (2013); and (3) Current & future electricity generation in freshwater catchments (2014).

This presentation focuses on the work undertaken specifically dedicated to the electricity sector.

The Case for Change work took four different plausible future socio-economic scenarios against which a set of policies and different approaches to the abstraction licensing system were tested. For each scenario we thought about what the world might look like and the implications e.g. agriculture implications of diet / land use and water demand.

In the 2011 work, the electricity sectors demand was kept static as case for change was focused on freshwater and majority of electricity generation is drawn from seawater.

In the 2013 review and electricity sector was better integrated into the scenarios. Using expert judgement from the sector and academics to assess electricity demand going forwards as well as focusing on 13 catchment areas where freshwater supply is impacted by electricity withdrawals.

In these initial scenarios - electricity demand projections varied from just below 400,000 GWh in 2010 to 650,000 GWh for high demand scenarios (Innovation 2050) to just under 300,000 GWh (Local Resilience 2050). Using assessments of cooling technologies that would be used in each of these scenarios the demand requirement for electricity sector within each scenarios was derived.

Water demand is highest in the Uncontrolled Demand 2050 scenario where nuclear plant is constructed inland and lowest in Sustainable Behaviour 2050 scenario where there is a shift in thermal, nuclear and CCS to the coast and high renewables penetration. Geographical spread of all unmet demand was then mapped in framework of climate change scenarios and the degree of environmental protection required. Climate change scenarios show range of river flow fluctuation from a 20% increase to 80% decrease. A key finding is that maintaining environmental standards based on those of today provides dis-benefit to abstractors.

The majority of the Case for Change work was undertaken at national level with national assumptions. The Department for environment and rural affairs (Defra) wanted to look at specific catchments where electricity generation is taking place. Therefore:

- Looked at 13 freshwater catchments supporting large-scale thermal electricity generation (116 have Catchment Abstraction Management Strategy in total);

- Contributed 25% of total gross electricity produced in England in 2010; and
- Generated 59 million MWh of the total gross electricity in 2010.

Resource status of freshwater catchments involved in thermal electricity generation as a proportion of total gross electricity generated:

- Uncontrolled Demand (2050) (11% increase in electricity generation) resulting in an increase from 34% to 46 % catchments with insufficient water.
- Sustainable Behaviour (2050) (15% increase in electricity generation) resulting in an increase from 34% to 40% but extent of over abstraction being less than present and uncontrolled demand scenario.
- 6 catchments robust in all scenarios.

Case for Change work is now complete but looking forward**:**

- Uncertainty means that the EA's future approaches to regulation and governance need to be flexible and adaptable to deal with a range of futures.
- Flexible and adaptable approaches need to be balanced against providing regulatory certainty for investment.
- The interplay between Water and Energy is just part of the story, in any catchment the interrelationship between all sectors needs to be considered especially agricultural sector such as impact of increased biomass generation with domestic supply.

There is a need to work together to develop regulation and policies in order to make sure that the customers trust the regulators.

The full presentation is available on the following link and an audio recording of the presentation is available here.

12. A Systems Approach to Creating Value from Engineering Interdependency by Dr Ges Rosenberg, Research Manager & Visiting Fellow, University of Bristol Systems Centre

Biography: Dr Ges Rosenberg is Systems Research Fellow and Research Development Manager in the University of Bristol's Systems Centre where he is responsible for building partnerships with industry and researching the application of systems-based approaches to engineering design, including interdependency planning and management, the development of sustainable systems, and approaches to create value and enhance competitive advantage. He has a background in aerospace engineering where he worked for a number of years on the modelling, simulation and analysis of linear and nonlinear dynamic systems, including controls-structures interaction, aircraft gust loads and turbulence modelling. He has held strategic roles in business, including at board-level as Operations & Finance Director for a Stirling Dynamics, and has experience of leading change programmes and managing strategic alliances. He is a member of INCOSE and CQI.

Key Messages: Current planning and project appraisal processes have typically handled infrastructure as discrete, sector-specific assets, and hence have not accounted for important networked, 'system-of-systems' aspects of infrastructure. As a consequence these traditional appraisal and planning approaches have failed to identify and capitalise on potentially valuable interdependencies, as well as running the risk of overlooking significant adverse interdependencies in the form of systemic resilience issues. A major infrastructure challenge for governments, investors and developers is therefore how to identify and realise the opportunities provided by beneficial interdependencies and use these to enhance value-for-money, sustainability and resilience; and consistent with this, how to update project planning and appraisal processes.

This talk summarised an 'open-systems', cross-sectorial approach to creating value from beneficial infrastructure interdependencies. It is the product of a research collaboration between by the University of Bristol's Systems Centre and University College London's Bartlett Faculty of the Built Environment with the support of Infrastructure UK. The resulting Interdependency Planning and Management Framework (IP&MF) has been designed to align with the project appraisal and evaluation process set out in the HM Treasury's Green Book. It comprises a set of systems thinking principles: 'stewardship', 'shared-governance' and 'interdisciplinarity', along with decision-making process and systems toolset. The approach and toolset have been demonstrated successfully on four case studies relating to the UK's National Infrastructure Programme - High Speed 2, the Lower Thames Crossing, the Northern Line Extension, and the Engineering the Future Timelines Project.

The main recommendations from the research study are: 1) that a stewardship function is established by Government with the purpose of overseeing the integration of infrastructure planning, delivery and operation; 2) that an 'Open Systems' approach be used to establish an interdependency planning and management process for the HMT Green Book; 3) that there is a need to embed learning and maturity modelling in order to inform the development of policy and practice in planning and managing infrastructure interdependency; and 4) that business models and practices are needed which seek to promote openness and collaboration in the creation and operation of infrastructure. The full supporting reports have been published by the International Centre for Infrastructure Futures[5].

Talk Notes:

Research presented is a product of work undertaken at Bristol's Systems Centre and UCL's OMEGA Centre for the Treasury and IUK. The work has developed an Interdependency Planning and Management Framework (IPMF) for inclusion in the HMT Green Book.

The essence of the framework is described in the presentation and the case study from the Engineering the Future's Timeline Project which can be found here.

[5] http://www.icif.ac.uk/networks/123/portfolio.html#t67

Conclusions from whole study:

- Project sponsors or owners should:
    - Identify interdependencies and engage stakeholder at the inception;
    - Explore further opportunities during design and also during implementation.
- Benefits provided by an open systems and systematic approach comprise:
    - Creativity from broad cross-sector participation;
    - Interdependency planning to identify potential synergies;
    - Opportunities to enhance project through co-benefits as well as manage adverse interdependencies;
    - Opportunity to structure decisions around trade-offs and more balanced judgments;
    - Recognise and meet relevant policy goals.
- Transformative nature of mega-projects means:
    - There is value in flexibility and by provisioning when futures are uncertain.

Recommendations

- That a stewardship function is established by Government with the purpose of overseeing the integration of infrastructure planning, delivery and operation.
- That an open systems approach be used to underpin the Green Book Interdependency Planning and Management Process.
- That there will be a need to embed learning and maturity modelling in order to inform the development of policy and practice.
- That business models and practices are needed which seek to promote openness and collaboration in the creation and operation of infrastructure.

The full presentation is available on the following link and an audio recording of the presentation is available here.

13. The role of local authorities and communities in governing infrastructure interdependencies by Dr Katy Roelich, Senior Research Fellow, Leeds University

Biography: Katy joined Leeds as a Senior Research Fellow in 2011, after spending two years at the Stockholm Environment Institute, where she was co-leader of the Rethinking Development theme. Prior to moving to research Katy worked in environmental and engineering consulting in the UK and overseas for nine years. She worked with the private sector, government agencies and utility companies in a wide range of sectors including, water, energy, rail, road and housing. Her current research activities centre around the governance of sustainable transitions and in particular transitions in infrastructure (predominantly energy and water) and consumption.

Key Messages: When considering infrastructure interdependence we tend to focus on the role of national actors, like utility companies and national government in managing risk and exploiting opportunities. This presentation introduces the important role of local actors, like local authorities and communities in the governance of interdependencies. It could be argued that these actors are best placed to understand how the means can deliver the ends; how different infrastructure systems interact to deliver economic, environmental and social development. However, the market-based instruments, which currently dominate infrastructure policy actively, constrain local authorities and communities. A new approach to infrastructure governance is needed that reflects the diverse motivations and capabilities of local actors.

Talk Notes:

Lots of focus so far has been on the national scale but there is a need to raise the profile of local interdependencies and local governance of those interdependencies. See also Annex 4 for Dr Roelich's blog.

There has been a local upsurge in engaging in energy and infrastructure as they are recognising importance of infrastructure to their function in economic development and social welfare. The same can be said for communities, at least 5000 community energy groups are active in the UK with ~60MW of generation capacity which is expected to grow to up to 0.5 to 3 GW by 2020. There is less activity in water provision because it's so highly regulated but some role in flood alleviation has taken place due to its importance.

The motivation of local authorities and community groups for engaging in infrastructure is highly varied. They are not interested in the infrastructure itself but the service that the infrastructure provides with many requiring more than one infrastructure system to be achieved to fulfil services that they want. For example, when attracting new business to a city to deliver local growth and jobs requires that the local authorities enable connection to reliable heat and electricity systems that might be specific to business, access to reliable water and wastewater services, and that they aren't likely to suffer damage from floods or extreme weather. Therefore efficient, well-connected infrastructure services development is essential. However, there is a need for an area-related strategy rather than an infrastructure-related one. As a result of this local authorities want control over the governance of infrastructure themselves with direct operation or facilitation of a more integrated approach by other actors.

This, however, is not straightforward:

- Local Authorities haven't had a role in infrastructure for over half a century so they are locked in to legacy issues and lack the confidence and capacity to engage with the sector.
- There are also substantial transaction costs as they have to interact with multiple sectors, actors and regulatory areas that work in very different ways.
- The policy environment is built around large, private actors so civic actors face a series of challenges. The present regulation is good at correcting market failures for the present actors or where there is little diversity. It is poor for civic actors because they have diverse (non-monetary) motivations and different ways of working.

Therefore, the need for different ways of governing but what might these alternative forms of governance be?

- Firstly, stop trying to treat local actors like small versions of private actors.
- Funding and incentive criteria need to recognise broad range of motivations and value created. And targeted support is more effective than market-based instruments.
- Standardisation is no good to address diversity of ways of working. Learn from self-governance of natural resources and create design principles which guide the development of locally relevant institutions
- And make sure different types of governance at different scales can work together and add up to the sum of what you're trying to achieve. Polycentricity not in parallel but integral.

The full presentation is available on the following link and an audio recording of the presentation is available here.

14. Lessons from alternative governance approaches: looking beyond integrating from the top down By Dr. Ralitsa Hiteva, Research Fellow at the Science and Technology Policy Research Unit (SPRU) at the University of Sussex

Biography: Dr. Hiteva has been a Research Fellow at the Science and Technology Policy Research Unit (SPRU) at the University of Sussex since 2013. She is a member of the Sussex Energy Group and is part of the UK Infrastructure Transitions Research Consortium (ITRC). She is interested in energy and environment governance, low carbon infrastructure, and the energy-water- environment nexus. Her current research focuses on the governance of infrastructure interdependencies in the UK for the energy, water, transport, waste and ICT sectors. More specifically, Dr. Hiteva is analysing the governance interactions between the electricity, ICT and private vehicles regimes in the UK since 1950, and the barriers to low carbon network innovation (smart grid development).

Key messages: This talk will explore what lessons can be learned from alternative approaches to governing infrastructure interdependencies. The next step to smarter governance of interdependencies is integrated planning and thinking across sectors, which would require more and new types of cooperation between key stakeholders to explore synergies more effectively. Governance approaches such as strategic coordinating groups, multi-stakeholder platforms and collaborative networks can encourage cross-sectoral cooperation, strategic complementarities and potential synergies across sectors. These governance approaches can also act as enabling platforms for developing a common understanding between stakeholders and across sectors, and for negotiating competing priorities and trade-offs between them.

Talk Notes:

Governance interdependencies case studies in ITRC work focused on energy-water and energy-ICT-transport. The research found that the differences in approaches and priorities between sectors represented some of the biggest barriers to more integrated planning for interdependencies. There is a need for more co-ordination to address these barriers and bring together concepts.

Governance occurs at different scales, for example: cities, groups and companies. The challenge is co-ordinated approach for future planning. How is this best addressed? Strategic co-ordination groups, multi-stakeholder platforms and collaborative networks have been put forwards as key mechanisms for collaboration to take place. These mechanisms have more bottom-up input and could build on existing platforms such as from Local Resilience Forums which in turn could bring together infrastructure providers and public sector groups to identify risks to services. The Local Resilience Forums remit could be extended to comment on national and international obligations which conflict with local needs.

Strategic co-ordination groups co-ordinating local crisis beyond the capacity of a single organisation that needs multi-agency teams working across boundaries to implement the governments resilience policy. Strategic co-ordination groups agree to work as collaborative networks moving away from top down hierarchical structure towards horizontal networks with shared leadership. Decisions are based on expertise rather than positions i.e. work as enabling platforms to work out common understanding between agencies and across sectors and for negotiating priorities and trade-offs. Their operation is not without problems but capacity to function to negotiate competing priorities between stakeholders and sectors has substantial benefits. Information sharing, willingness to collaborate and shared values are key to effective networks as they facilitate trust between participants: Common vision and common goals.

The presentation gives detailed examples of the function of the Smart Grid Forums and the Crown Estate.

The work highlights the fact that intermediaries can play an important role in shaping infrastructure governance and discusses their role as intermediaries between different stakeholders and sets of interests.

- They translate knowledge and interests between stakeholders.
- But they don't just facilitate. They have own interests.
- They reorder and prioritise certain interests over others.
- They are as capable of complementing government policy, as well as competing with it.

With this in mind, there are two underlying questions: (1) how can interactions between stakeholders be enhanced to move to better cross-sectoral co-ordination; and (2) how to ensure that they meet societal policy goals.

The full presentation is available on the following link and an audio recording of the presentation is available here.

15. Governing interdependencies between infrastructures by Professor Jim Watson, Director of the UK Energy Research Centre and Professor of Energy Policy at the University of Sussex

Biography: Jim Watson is Research Director of the UK Energy Research Centre and Professor of Energy Policy at the University of Sussex. He was previously Director of the Sussex Energy Group. He has 20 years of research experience on climate change, energy and innovation policies. He frequently advises governments in the UK and abroad, and has been a specialist adviser to three UK Parliamentary select committees. His international experience includes ten years of collaborative research on energy in China. He is a Council Member of the British Institute for Energy Economics and a member of the DECC and Defra social science expert panel.

Talk Notes

There are three main things to highlight in the governance of interdependencies between infrastructures: (1) what is the definition of governance; (2) where governance of interdependencies didn't work in the UK context; and (3) what to do that is different from now?

(1) With regards `What is governance? '

It is not just government. The shift to governance is due partly to:

- the '*hollowing out'* of the State during the shift created by liberalisation and increasing globalization as well as the upward move of the decision making processes to EU;

- Transfer of responsibility outwards to Regulators; as well as

- downwards with devolution.

This has made governance more complex.

Governance means decision-making by multiple actors, including government(s), private sector and civil society. There is no 'one size fits all' model.

These different actors don't all agree where infrastructure should go e.g. for the energy sector though we broadly agree on the trajectory of the energy sector but the details as to the technologies to deploy and in in what combination is fraught with uncertainty - therefore it is natural that we should have a contested discussion about the future.

There are 3 main rationalities for governing interdependencies:

- Interdependencies can amplify risks to infrastructures and the provision of services due to cascade effects;
- Economic efficiency: coordinating infrastructure investment can reduce immediate costs; and
- Co-ordination and innovation: to meet broader sustainability goals (e.g. carbon emissions reduction).

(2) Where governance of interdependencies didn't work in the UK context: Water and Electricity Case Study

- Strong national and EU environmental agendas: improve water quality and reduce emissions.
- But competing policy priorities: water quality vs energy demand / emissions reduction.
- Some renewable energy investment by water companies to try to meet both objectives.
- But investment stalled; discouraged by water regulator and climate policies.

(3) What to do that is different from now?

Is there a need for an integrated infrastructure regulator? Therefore all decisions can be made under one roof. But actually:

- may then only internalize the tension;

- increase complexity e.g. what would the guidance that an integrated regulator be given, what would its objectives be? Address customer needs, sustainability issues, water quality etc.; and

- would be very top down which would not address multi-scale issues highlighted by Katy's talks earlier.

So how do you marry up the top down and bottom up needs?

The full presentation is available on the following link and an audio recording of the presentation is available here.

Annex 4: Primers and Blogs

#UKEW: Thoughts on UK electricity / energy and water sector governance.

A4.1 Preface

In order to stimulate debate as quickly as possible the organisers of the #UKEW workshop requested primers from a number of individuals attending; these included:

- John Simmons (On Communications / BP).
- Mike Woolgar (Atkins);
- Katy Roelich (Leeds); and
- Ronan Palmer (Ofwat / Environment Agency).

These are included below. In addition, a blog on infrastructure interdependencies will be released on the online media site `The Conversation' prepared by Ralitsa Hiteva and Jim Watson – this can also be found below.

A4.2. Lessons learned when writing and illustrating a book on Water in the Energy Industry By John Simmons, ON Communication Director and RPS Energy Communications Group Principal Advisor.

Context

In 2013, I was involved in the writing and production of a book, *Water in the Energy Industry - An introduction* for BP's Chief Scientist, Professor Ellen Williams. The thoughts below are personal reflections on lessons learned from this project.

The water lexicon

At the beginning of the project, I believed strongly that the language chosen, in general, to describe water use was misleading. The press and other media regularly offer statements such as the following from the National Geographic website: '*On average, a vegan indirectly consumes nearly 600 gallons of water per day **less** than a person who eats the average American diet'* and '*A gallon of gasoline takes nearly 13 gallons of water to produce'.* This type of statement is woven into many of the debates about water and, combining 'statistics' with the misuse of verbs such as 'to consume' and 'to take', results in chronic misinformation, which negatively influences the development of onshore oil and gas and other energy projects. Therefore, the book offers suggestions to counter this negative trend and includes definitions of terms, including 'withdrawal', 'discharge', 'disposal' and 'consumption'. We exhort readers to base examination of water in their own industry on these definitions.

Another requirement for examination of the impact of the energy industry on water resources is to compare volumes of water to the amount of energy produced - water intensity -, in a consistent manner. The book uses M^3/TJ throughout, so facilitating direct comparisons across energy sources and processes. It might be helpful to prepare and distribute to the media, a resumé of the *Water in the Energy Industry* book.

Scarce data

Although my team was not involved in the research that underpins the book, we were intimately involved in gathering the data from a wide range of researchers from selected universities. It became apparent, early on, that unlike, for instance, mineral or energy statistics from the USGS and the IEA respectively, we could not find a central repository of reliable water statistics.

Also, from personal experience of researching, scripting and filming case studies about water in a variety of energy industry settings, often the only incentive for the companies involved to gather data was financial. The old adage: 'you can't manage what you can't measure', was a constant theme.

Given that the sustainability of an industry depends on recognising risk, facts are essential; up-to-date facts, gathered from methodical research, set in a logical context and tested for their veracity and relevance to real world settings.

Energy industry versus the rest of the world

The present day total withdrawal of freshwater is estimated at around 4,000 cubic kilometers ($km^{3)}$ per annum, some 10% of the total renewable fresh water available. Agriculture accounts for 70%, some 2,700km^3 of this extraction, compared with the energy industry's 470km^3 or 12% of the annual total. Most of the energy industry withdrawal is for cooling and is, ultimately, evaporated or returned to the hydrological cycle as warmer water. The rest is exposed to variable levels of contaminants, treated post-use and either returned to the environment or disposed of as waste.

Understanding how freshwater is used in the energy industry is the first step in reducing both withdrawal and consumption. Reduction can benefit the industry in many ways. Every litre costs money to obtain and treat pre- and post-use. Energy companies have to compete for water in many areas with agriculture, other industries and municipal needs. Public perception that energy production requires vast amounts of water constrains activities. Furthermore, concerns that energy companies pollute water systems can, as is the case in the nascent European shale gas sector, literally be a showstopper.

Four Rs for progress

Pressure is growing from all sides to reduce water intensity for energy production. It makes sound economic sense, increases the likelihood of continued licences to operate and improves environmental performance. Reduction, as summarised by Ellen Williams in her introduction to the book relies on the four Rs:

- **Replacement:** the use of non-freshwater sources such as seawater, brackish water, produced water and wastewater in place of freshwater.
- **Reuse:** using the same water multiple times in an industrial process.

- **Recycling:** treating wastewater to make it a usable replacement for freshwater in another application.
- **Regional responsibility:** adapting practices to suit the local availability and demands on renewable freshwater.

Directing action towards any of those requires understanding of where and how water is used in the energy industry and reliable data

The *Water in the Energy Industry – an Introduction* book is available free, online:

http://www.bp.com/en/global/corporate/sustainability/the-energy-future/meeting-the-energy-challenge/energy-sustainability-challenge.html

A4.3. How governance of the UK electricity / energy and water sector could be structured and regulated By Mike Woolgar, Managing Director of Water and Environment, Atkins Ltd.

Without sustainable energy and water supplies our wellbeing and current economic models cannot be maintained or enhanced. All economic activities including family life and leisure as well as business and industry rely at root on water and energy. Consider a "world-wide water web" where one can trace for any activity the presence of water in the execution of that activity: similarly one can trace energy in most if not all activity chains.

Currently there does not appear to be a coherent energy policy nor a water policy. The water sector is de facto divided into: water utilities for supply, regulated economically by Ofwat; the Environment Agency for water resource management, water quality management and flood management and for environment regulation; DWI for drinking water quality standards and regulation; and customer representative bodies. Energy appears slightly different as there are only generation, generation mix and transmission/distribution and customer supply aspects which are regulated economically.

It is a truism that policy is "how we want it" and regulation is "how we achieve it". In the water sector, where I have most experience, we have fairly well developed policy around water utility management which essentially boils down to "ensure that appropriate water services are supplied at the most economically attractive price for consumers and ensure that the utilities remain financeable". Regulation in support of these policies is fairly detailed and in a continuous state of development.

There is no overarching policy visible for water management which relates directly to macro-economic outcomes:

why is water so much more expensive for consumers in the West Country than in London? In essence this is a result of history (how much necessary capital work had been done before privatisation and how was the asset base valued by the investment community at privatisation?), geography (how much vulnerable environment needs protection?), demographics (how many people who can contribute revenues, noting that larger denser populations come with economies of scale) and costs of finance. It has been an objective (not sure if explicit or not) that although it is OK to cross subsidise consumer costs within utility areas of control, it is not OK to cross subsidise between companies so expensive water in less well-off areas can remain more expensive than for better off areas.

why are there unexposed price differentials for water for food, water for industry, water for energy, water for drinking? (Clearly these different uses have different economic added values although little attempt is ever made to assess such economic values, usually relying on financial gain or rents if the assessment is made.) Again this is history (deemed licences, who got there first?) and there have been some attempts to re-negotiate abstraction licenses and to encourage competition in an effort to reduce impacts on water short areas. Would subsidies to water, benefits, industry, etc. as social instruments achieve this more effectively or does the market have perfect long term vision? Does this make it harder for individuals to be successful just due to post code bias?

There may be some benefits in creating a vertically disaggregated system with a resource manager creating explicitly cross subsidised or market tested resources for the various demands on the system – with responsibility to forecast need in the face of climate effects, population etc. It would also reduce the economic price of supply variability due to weather variability. It also has the potential to keep the cost of capital down given that it would be a quasi –government entity.

Utilities would then be able to compete on service effectiveness and/or price depending on the method of pricing water, and or the cost associated with timing of water availability. Using the customer as the "regulator" is the intent of Ofwat in the long run but the current embedded price differentials mean that competition is a bit one-dimensional and if price competition is used through cross subsidy into cheaper areas then there is a risk of de-averaging and "cherry picking" leaving the harder to serve customers with higher prices.

Difficult job for the resource manager unless there are good demand signals (e.g. metering?)

A4.4. Localising infrastructure governance By Katy Roelich, Senior Research Fellow, Institute of Resilient Infrastructure and Sustainability Research Institute University of Leeds

When thinking about the governance of infrastructure interdependencies, it's tempting to think big; of national grids, international companies, gigawatt power stations, gigalitre wastewater treatment plants. And effective regulation of large infrastructure assets and organisations is essential. But we shouldn't forget that infrastructure can be small too - for example, council-operated district heating or community electricity provision.

Civic actors like local authorities and communities are often best-placed to understand how the interactions between people, infrastructure and the economy can be organised to exploit or manage infrastructure interdependencies. Unlike the profit-driven private sector, they are also motivated by such outcomes as poverty alleviation, local prosperity and environmental improvement[6]. These

[6] Roelich, K., and Bale, C. S. E, (2014) Municipal energy companies in the UK; Motivations and barriers. *International Symposium of Next Generation Infrastructure*, Vienna, October 2014

characteristics make them better suited than the private-sector actors that dominate our energy and water systems to the task of connecting the means of infrastructure operation to the ends of economic and social development.

The current system of governance, which was built around large, private-sector organisations, constrains civic actors and limits their potential contribution[6]. The economic instruments which are prevalent in energy and water policy are effective only if stocks and flows of goods are predictable, if the number of users or producers who are regulated is low and if regulated users or producers are homogenous[7]. These conditions obviously do not hold for civic infrastructure provision, so market-based regulation is not effective[8].

We need new governance mechanisms that recognise the differences between private and civic actors and reduce barriers to civic infrastructure provision. Civic actors should not be regulated as smaller versions of private actors. Appropriate governance at the local scale should be supported by, and sit parallel to, the national system of energy and water regulation. National government should enable civic actors to develop locally relevant ways of managing the production and distribution of not only financial but also social and environmental value.

This is by no means straightforward. The diversity in capability and motivation of civic actors means that ways of working vary dramatically and there are potentially thousands of producers to be governed (compared to the six energy and twelve water companies that dominate the UK market). But it could be most effectively addressed by self-governance, rather than through highly centralized governmental institutions.

Research on the management of natural common pool resources, such as irrigation, fisheries and forests, has identified a series of principles for effective self-governance. These principles support the development of operational rules that enable diverse ways of working and ensure fair distribution of economic, environmental and social value[9]. Using similar principles that reflect the specific challenges of water and energy provision could result in institutions better able to address the crucial issues of diversity and change in civic infrastructure governance[10].

However, self-governance cannot happen in isolation from governance at other scales; it must form part of a polycentric system that combines scales and types of governance mechanisms. Regulation of the national systems with which civic actors must interact (such as transmission and distribution systems and energy markets) should enable, not over-ride, civic governance. Conversely, civic infrastructure provision contributes to national goals and affects the efficiency of national infrastructure. Self-governance mechanisms must therefore be held accountable for their contribution to wider system goals.

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[7] N. Dolsak, thesis, Indiana University, Bloomington, IN (2000)

[8] Ostrom, E., 2010. Polycentric systems for coping with collective action and global environmental change. *Global Environmental Change*, 20(4), pp.550-557.

[9] Ostrom, E. (1990) Governing the Commons – the evolution of institutions for collective action

[10] Roelich, K., Knoeri, C. (2014) Community energy provision: why is it constrained by liberalised markets and how can cities help to overcome these constraints? *International Workshop on Sustainable Heating Provisions and Cities*

Not all infrastructure will be big, nor will it all be small. A new approach to infrastructure governance must enable integration across scales and reflect the diverse motivations of actors. One size does not fit all when it comes to infrastructure regulation; civic actors are not simply smaller versions of the private sector. Polycentric governance is essential in supporting different motivations, at different scales, using different ways of working.

A4.5. How governance of the UK electricity / energy and water sector could be structured and regulated By Ronan Palmer, Director Ofwat

Interdependency is trust. And trust must be at the heart of the governance of interdependency, especially for vital public services like water and electricity. Trust is critical because of the ever-greater (inter-)dependence of our lives on these services and those services on each other. Let me unpack what I mean by trust, and (inter-)dependence.

Customers and society must trust the services, and trust how they are delivered. Trust must run all along the supply chain, from resource extraction to waste disposal, production to delivery, billing to debt collection.

There must also be trust across the services. That is to say, the electricity and water systems must be able to support each other technically; and the way they are run must support each other institutionally. Just as a failure in electricity supply may mean a pumping station cannot pump; or a dried up river means no cooling water for a generator; so a whiff of unfair play in one public service may call into question behaviour in others. Equally, strength in one sector can come to the aid of another, both technically and institutionally.

Our public services are increasingly critical to the successful operation of society and economy. Technology means the can be managed more efficiently, taking more stress, but possibly also carrying risks. They are increasingly dependent on a constrained environment, for example water availability. Increasingly interdependent technically, they are also more open to public scrutiny, both in terms of expectations of service quality, and expectations of acting in the broad public interest.

What does this mean in practice? Results, and relationships.

Results, in that the service must deliver, and not fail. Once, piped water and reliable electricity may have been novelties, luxuries, rarities. No more. The lights going out, even for a few minutes, or the tap running dry, even once every few years, are not expected, and ever less acceptable.

Just as the services are themselves complex, interdependent networks, they are embedded in a web of relationships. The relationship between service provider and customer is vital - see Ofwat's PR14 methodology. There are relationships along the supply chain, with the community, with other services, involving regulators, local and national governments. Community and supplier relationships can overlap, as in the catchment schemes involving water companies, farmers and eNGOs.

Results and relationships also enable responsibilities to be exhibited. Responsibilities matter in that it's not enough to deliver, but delivery has to be in the right way - treating the environment correctly, treating people fairly, remembering the long-term. Service providers have responsibilities to both owners and customers, if the flow of money from the investor (into the service for the customer) is to continue. There are also responsibilities the other way of course - for owners to be good owners, and customers to be good customers, to pay, to challenge their providers to be better, to manage their own use of water, energy, etc.

Finally governance must thread through all of this. A central planner would be challenged in this world, and magic wand fixes likely to be hard to come by. Surely, therefore, governance needs to evolve along with the complex matrix it governs, based on watchwords rather than prescription:

- transparency - is as much information being shared as clearly as possible, as widely as possible?
- engagement - do all the actors with a voice have the chance to engage - and who is looking after those without a voice?
- openness - to innovation, to opportunity, and to the risks of not getting this right - so that we are never complacent.

And the institutions can follow in the wake of experience and performance.

A4.6. The Conversation: Britain's infrastructure must be made to work in harmony and here's how

By Jim Watson, Research Director at UK Energy Research Centre and Rali Hiteva, Research Fellow at University of Sussex

Every time we turn on a tap, switch on a light or drive to the shops we are relying on the infrastructures that make our modern economy work. These infrastructures are being developed to meet new challenges we face, such as climate change. However, the constituent parts are not always moving ahead together or with sufficient urgency.

The UK's National Infrastructure Plan, **which has been updated this week**, is an illustration that government now takes this agenda seriously. Last year's iteration of the plan recognised that infrastructures are interdependent – for example, the uninterrupted supply of good-quality water requires energy for pumping and treatment as well as control systems reliant on information and telecommunications technologies.

However, the UK is still a long way from the plan's aspiration for a cross-cutting and strategic approach to infrastructure planning, funding, financing and delivery.

The latest version will need to be complemented by more ambitious and concrete mechanisms for getting a governance system which support a more joined-up approach. It is also worth acknowledging that sustainability is not yet embedded fully in the commissioning of key projects. The 2013 edition of the plan did include a number of high-profile, low-carbon electricity projects, but it also prioritised road schemes and airports – which at best have ambiguous implications for **targets to reduce greenhouse gas emissions**.

Three rationales

There are at least three different rationales for delivering a more co-ordinated approach which takes seriously the links between infrastructures.

First, co-ordination can provide immediate economic benefits by combining activities, perhaps upgrading urban areas such as the West End in London while building and maintaining large new office buildings.

Second, interdependencies have led to new risks to services. The pervasiveness of new technologies means that more attention needs to be paid to cybersecurity within other infrastructure sectors such as electricity.

Third, and perhaps most challenging, there is a need to reduce the incidence of conflicting demands on infrastructure providers by government or regulators. Our research for the **UK Infrastructure Transitions Research Consortium (ITRC)** on the water and electricity sectors has highlighted the problems that water companies have faced in meeting higher water quality standards while reducing the carbon emissions associated with their operations. For example, some water companies invested in renewable energy but were not always permitted to pass on the cost of these investments to consumers or use them towards carbon-reduction obligations.

This year has seen the creation of **UK Regulators Network (UKRN)** which has been addressing co-ordination issues across infrastructure sectors. Other government bodies have been actively addressing the second area of cross-sectoral risks. For example, the **Centre for Critical National Infrastructure** provides advice to infrastructure providers about risks to security, including cross-sectoral risks. However, more will be required to achieve a genuinely cross-cutting approach.

A top-down solution?

To do this, it is tempting to think that the solution may be simply to break down governance barriers between sectors. There could be mergers between regulators so that water, energy and transport sectors are managed in an integrated way. Alternatively, the UK Regulators Network and the Treasury could have significantly enhanced powers to co-ordinate and direct sector regulators to address interdependencies where they arise.

But there are problems and risks associated with these kinds of top-down solutions. Merging regulatory bodies could mean a loss of transparency and would increase the potential impacts of poor regulatory decisions. It could also mean a loss of focus on the particular characteristics and policy goals for each sector.

They operate in very different ways and have different mixes of competition and regulation, different technological and investment challenges, different environmental impacts and different degrees of decentralisation. Furthermore, such mergers would not deal with the tensions that can arise when policies from more than one government department affect the same sector.

A more plural approach?

By contrast, efforts to promote co-ordination should start by recognising that infrastructure governance involves a large number of interests. Governance has moved outwards from government departments into economic and environmental regulators. Some powers have also moved upwards to international bodies, particularly the European Commission. In some cases, the role of local authorities is also strong – for example in governing road networks and waste management – and some are looking to broaden their role to include the development of energy infrastructures.

This spread of governance responsibility suggests that a plural approach to infrastructure co-ordination may be required. This would focus on understanding the specific nature of the interdependencies themselves while strengthening institutions which can bring together regulators and government departments to identify and resolve significant problems.

This kind of bottom-up co-ordination could build on existing initiatives **such as Local Resilience Forums**. Examples include Lincolnshire's Critical Infrastructure and Essential Services Group. These forums already bring together infrastructure providers and public sector agencies to identify risks to services. Their remit could be extended to include joint investment and identifying where policies impose conflicting obligations.

We would see stronger top-down incentives for better co-ordination, combined with bottom-up processes that build on local synergies between infrastructure sectors and institutions. That might give us a chance to take on the challenge of moving towards more sustainable infrastructure sectors, where significant incentives are required for the innovation, demonstration and deployment of new technologies and business models.

This will be an essential change which can cut across traditional sector boundaries. An example of this in action can be seen in the projects across electricity, telecommunications and transport taking place through the **Ofgem Low Carbon Networks Fund**. And as our colleague **Mariana Mazzucato has pointed out**, there is significant scope for government to take a more entrepreneurial approach to economic development and to innovation. If it is successful, the state can then share any benefits and reinvest them. The need to get infrastructure provision right has never been more pressing.

The article can be found here: http://theconversation.com/britains-infrastructure-must-be-made-to-work-in-harmony-and-heres-how-34828

Annex 5: Session 5 - World Café Exercise 1

This exercise sought to assess interdependencies between the water and energy sectors that may presently be overlooked in the research sector. Attendees were requested to brainstorm existing interdependencies, existing policies, risks and opportunities and any other aspects of interdependencies along the following key themes:

- Areas of interdependencies
- Impacts of interdependencies - risks and opportunities
- Existing policies addressing interdependencies
- Other initiatives addressing interdependencies

The interdependencies were then arbitrarily clustered according to theme areas designated by the workshop organisers as per the tables below. A wordle was also compiled based on the sum of all the notes made by attendees for this session - see Figure A5.1, below. Some attendee notes have yet to be clustered - these are in the final table.

Figure A5.1: Wordle of session 1 (version 2) from World Café Session on assessment the current status of interdependencies between the water and energy sectors.

A5.1 Areas of interdependencies

Energy and Water
Opportunities for co-location • Plants - Wastewater, water and power • Pipes • Future Provision
- Geographic co-location of water and energy assets – risk or opportunity - Opportunities to co-locate systems. - Co-location of knowledge and expertise particularly given the cyclical nature of regulatory cycles. - Infrastructure construction and redevelopment – co-location (positive or negative). - Impact of technology on co-location - Gender imbalance area of work and engagement. - Wider Sector analysis on water-energy interdependencies - Rivers (Common Carrier) societal resource. - Innovation competitions -> new sewerage / waste to energy technologies - Transport to Sites - Greater shipping of buds / demands on energy systems if negotiation permitted - Power generation at waste water sites - Use of sludge - Waste to Energy / Uses of Wastes in other sectors - Heat recovery in wastewater - Less water intensive energy options to contribute to energy mix - Reusage of waste water stream (water differentiation) to find enhanced water value chains and reduce demand for water. - Water: (1) Use; (2) Service; (3) Water Framework Directive - Waste Water: (1)Energy Use; (2) Energy Generation; (3)Source of Fuel – biogas and sludge. - Income : (1) ROCs; (2) FITS - Cost: TRICAPS - Domestic / Commercial Cooling using water - Areas of interest – Cooling water resource - Water industry use of waste heat for sludge drying - Desalination with Power generation - Gulf Mover - Heat Recovery via water e.g. from sewers; industry and from data centres. - Energy from water and Water from Energy - Energy Efficiency initiatives address water and energy sector. - Sewerage for electricity - Energy use for water treatment e.g. Water Framework Directive - Hot water for Process Industry - Waste Water Treatment Works Energy Production – Energy Use of Waste Water Treatment Works construction. - Limited Available Grid Connection allowing water company renewable generation to connect. - Use of gas from sludge treatment for fuelling vehicles (which deliver the sludge to site). - Hydro-power generation (water + energy) potentially causes aquatic environmental issues. - Energy for Waste-water treatment - Power generation requires water to generate. - Impact on water and then energy - Highway development - More secondments of water / energy people

- Efficiency as a coolant - Novel energy storage at grid scale to make better use of renewables, reduce coal, gas dependency -> reduce water use. - Areas of interdependencies: (1) Reliability of assets / infrastructure; (2) Water use for cooling in Power Stations; (3) Electricity use for Pump Stations - Large Water Efficiency programmes will also reduce (peak) energy demand. But this extra benefit is not valued / funded. -
Food connection
- Biogas generation - UK Bioenergy Strategy 2012 - Biofuels / Crops and Biomass - Land-use – potential conflicts (and synergies) between energy and water - Nexus with Food - Energy-Food-Water nexus - Food – carbon or ecosystem services
Demand Management (both, interdependence)
- Customer Engagement (SIM in Ofwat) - Customer / Consumer affordability (to meet investment funding) - Impacts: demand response can and does help system stability. - Existing: demand response market driven not fully co-ordinated - Areas of interdependence: Demand reduction. - Demand Response. - Customer interactive: crowd data generation for infrastructure demand planning. - Peak lopping – demand shift in water sector for reduced load on power stations. - Location of Demand - Consumer Advice Programmes - Concurrent demand for emergency response resources e.g. high volume pumps, all terrain vehicles. - Consumer willingness to pay and affordability for utilities coupled with economic regulation. - Linked demand in economic cycle. - PR14 customer challenge groups.
Energy in water supply and wastewater treatment • Construction • Pumping • Treatment • Dedicated Generation e.g. for Desalination
- Energy and water embedded in materials - Pumping water costs - pumping for distribution - Freshwater pumping - Water Treatment and Movement requires consistent power (i.e. avoid brown-out) - Pumped storage - Pressure in pump system - Heat pumps water source. - In water sector – greater separation between energy and emissions reporting - Pumping consume electricity and keep mobility of water networks. - Opportunity for both water and energy – work together on resource management / supply of

water.
- EU Water Framework Directive – Impact on energy requirement for waste water treatment

Energy Generation

- Biogas/Wastewater
- Cooling water
- Energy Efficiency
- Unconventionals and new technology – fracking, renewables, geothermal

- CCS implementation
- Fracking – High water use
- Micro / smart fluids hat need innovative energy storage and heat management (water tanks).
- On Shale exploration include in shale development and impact on water resources in fracking.
- Fracking legislation needs
- Fracking + water provision and waste management.
- Water use for fracking.
- Hydro-power generation including micor-hydro.
- Cooling energy / water
- Power station cooling water
- Hot water and energy storage domestically.
- Impacts: opportunities provision of renewable energy for national targets.
- Opportunity for water sector – promote own generation.
- Areas: renewable energy supply.
- Promoting community hydro.
- Hybrid solar PV / water heating technologies
- Low carbon renewables, nuclear and CCS.
- Heat pumps – aquifer heating
- Growth in shale gas / oil developments to pit increased pressures on water resources.
- Geothermal energy for heat.
- More heat recovery from waste water using heat exchanges.
- Changing energy mix over provision of Gas and LNG infrastructure.
- Treatment aeration process quality v's energy vs chemicals.

Water

- Water Efficiency
- Customer Engagement
- Response to changing demand

- Waste Water
- Cooling Water
- Hot water production
- Embedded water
- Energy efficiency / recovery in the water industry – could do more.
- Hot water as energy storage.

- Catchments
- Future Catchment Policies
- Abstractions

- Abstraction licenses
- Uncertainty over future water licenses for abstraction
- Water abstraction regulation
- Abstraction licenses for cooling.

- Catchment management - Catchment management v's capital infrastructure. - Water resource generation v's drinking - Opportunity for water companies to improve statutory adaptation reporting looking at interdependencies - Opportunity for sharing of resources e.g. National Grid example of flood barrier sharing - Opportunity – catchment scale interventions to reduce flood risks (e.g. substations) while simultaneously benefiting water quality reduced treatment need. - Water abstraction - Abstraction reform - Water abstraction license affecting location of investments
• Dependence on ICT
- Rail electrification - Risk of ICT impacts – is it properly understood - Increasing reliance on ICT / Technology - Security Risks through ICT / Cyber attack e.g. Stuxnet - Jane projects leading to `hot spots' - ICT shared dependency - Smart metering efficiency for interconnected services.

Biodiversity and Environment Impacts • Natural Capital • Conflicting requirements • Ecosystem Services
- High Chemical Usage - Biodiversity and Pressure on `in-stream' flow of water resources - Conflict on Environmental Outputs - Risks – Biodiversity land use and water abstraction not well understood. - Ecosystem Services Management - Current Policy / Opportunity: carbon reduction drives innovation in all infrastructure sectors - Should environmental compete with users for scarce resources - Risks to miss interdependencies other than water to energy – more players must be included. - Ecosystems (good and services) impacts - Impacts of interdependencies – catastrophic failure triggers policy action which can cut across sectors e.g. Pitt Review - Natural Capital – Better costing of natural assets e.g. water - Risk Cascades - Risk supply chains up to a global scale – incompletely understood - Regulatory recognition of flood risk / resilience

A5.2 Impacts of interdependencies - risks and opportunities

Risk
• Uncertainty • Resilience Planning • Climate • Flooding • Trends vs. Impacts

• Space Weather
- Drought = suspended / disrupted energy supply - Modelling cascading failures between water an energy (man-made risks and weather?) - Adaptation and resilience solutions to address changes including hazards. - Risk of overuse of water i.e. water stress - Areas of interdependence – an extreme weather event affecting several utilities (e.g. water-energy) at the same time. - A cascade of extreme events e.g. wind storm and flooding creating correlated damages (usually modelled independently. - Natural hazards other than flooding - Space weather impacts - Existing policies: space weather -> simultaneous shut down of many infrastructure objects. - Extreme weather events = drought / flood / snow storm. - National security strategy addresses some interdependent risks to infrastructure operations and services. - Trend v's catastrophic risks - Water availability shared resource - Contingency plans for crisis management of power generation (48 hours or more). - Critical water supply sites are being protected against flooding by Water Companies, however the upstream 11 KV transformers are unlikely to be protected. The local Distribution Network Operators (DNO's) are only protecting 33kV transformers and are not aware which 11kV transformers feed critical water infrastructure assets. - Flood protection and resilience and climate change adaptation. - Climate Change Risk Assessments.
• Social Risk • Skills shortage • Public Perceptions
- Educational awareness raising of the public to accept implications of integration and reduced resource use e.g. re-used water. - Public engagement - Consumer perspective - Public Perceptions of government and industry - Public Perception issues e.g. waste water reuse issues. - Public perception general dislike of change and development. - Fiscal governance and public persceptions. - Risk and opportunity for ICT impacting interdependency (technical) - System Failure and risk to services - Impacts risk – lack of power system resilience with lack of cooling water. - Impacts – increased uncertainty around risks - Increasing international interdependence = globalisation. - Shared risks between actors with different objectives. - Impact of interdependencies (1) failure of assets in one sector on another; (2) Impact on costs; and (3) impact on energy and water demand being unmet. - Risk assessments needs to be careful not to overstate risks e.g. by omitting storage in networks and latency in the impacts of dependencies. - Risk analysis - Methods to determine uncertainty. - Impacts: wealth - Impact on water Risks Power loss

- Impacts – Health - Impacts – Welfare (inequality). - Silo's decision making – risk of locking in more harmful pathways / lost opportunities. - Impacts from exogenous economic fluctuations e.g. Coal v's Gas - Risk on water – Road Transport – chemical supply - Impacts – Risks Skills Shortage in engineering.

Problems • Data • Conflicting Targets across infrastructure Sectors
- Data Repositories' - Clearer mapping of water-energy interdependencies comparing long term and lows v's critical / extreme events. - Explore power of self-organised effects for creating optimal solutions - Risks of not learning lessons from overseas or other sectors. - Impact of interdependencies – conflicting targets (water and energy) - Completing outcomes not complementary – energy generation v's carbon reduction. - Innovation and market opportunities -Legacy Issues and risk aversion. - Opportunities – cascading - Skills - Issue – availability and cost of data, especially historical data to get baseline datasets. - Balance of drivers - Ineffective regulation across sectors - Sub-optimal resulting allocation of scarce resource. - Areas of uncertainties of forecasts are poorly understood. - Hard solutions v's soft solutions: reservoirs v's demand management | increased abstraction v's water efficiency optimisation. - Lack of governance flexibility. - Is there wool for corporate social responsibility and voluntary sector.

A5.3 Existing policies addressing interdependencies

Policy • Lots of options • Carbon • Connected up Policy • Better Reporting • Market Reform
- Quality of water - Drinking water energy use - Water company statutory duties and control of storage – unwilling to let other actor access. - Low size hydro-assessment - desalination - COE water mandate - Water Action Hub - Convergent infrastructure service provision to housesholders - Smart / Sustainable Cities initiatives that consider holistic interactive infrastructure planning. - Carbon pricing EUETS

- Carbon neutral water production with biogas generation heat recovery / renewable energy - UK Carbon commitments for CO_2 / GHG reduction efficiency and effective delivery. - Who or how are incentives set? How do rewards flow between sectors. - possible questions / foci: (1) Is large scale facilitation valid / feasible?; (2) what type of institutions can? - Can top down planning possible deal with complexity? => abstract simulations. - Role of capital - Competing for capital (or subsidy) - Existing polices non on skills OPEM succession. - Generate the needed type of informative processing and decision making - Innovation – new business models - UK electricity network joining EU grid. - Joint regulation - Risk: investors make decisions on the risk based on a lack of information. - Promotion of low grade water network - Electricity Market Reform. - More integration of Water – Energy departments – across government-academia and industry. - Policies new guidance in Green Book allows for connecting benefits to other information systems. - Impacts of Interdependencies: Opportunity to change governance structure to create better resilience. - Why are existing infrastructure companies not responsive enough to their customers? - Policies Water can be included in energy audits (EU energy efficiency directive). - MUSCOS - Policy Energy and Climate => decarbonisation influencing interdependency? - Policy impacts on interdependency e.g. electrification - Desire for sectors to work together by government but sectors operate in free market economy. - Modelling - Develop abstract governing principles and justification. - Decentralisation risks and opportunities on interdependency - organisational or regulatory. - Technology incubators / catapults to address interdependencies - Carbon reduction taxation on water company renewable energy generation (CRC) - Centralisation v's localised - Silo'ed policy making – inherent risk - Adaptation across government - Opportunity create a new overarching facilitating / co-ordination network.

A5.4 Other initiatives addressing interdependencies

Existing Initiatives
- UKWIR locating at interdependencies including Energy - Scottish Adaptation Programme - National Infrastructure Planning Process - UKRN Process Work plan and Cross Sector Work Programme - Research: (1) iCIF; (2) ITRC; and (3)iBuild. - ARRC Network - National Joint Utilities Group (on delivery issues) - National Adaptation Programme - Update to HMT Green Book – Valuing Infrastructure Spend - Climate Change Act 2008.

- Government resilience reviews will consider interdependencies across sectors. - Adaptation reporting power asks reporters to identify, assess and outline action taken on interdependencies . - Existing Policy – is there one between sectors? - Infrastructure Operators Adaptation Forum (IOAF) – focus on weather and climate - Existing – Renewable Energy Provision Market Driven. - National Infrastructure Plan - Sector Resilience Plans
Future
- Economic Regulation - Technology Disruption. - Provides opportunities for addressing risks across two sectors – adaptation resilience solutions. - National adaptation programme in 2018. - Planned behaviour v's catastrophic impact - Cabinet office – sectoral resilience plans - Other initiatives – next climate change risk assessment will consider cascade / concurrent risk in 2017. - Building regulations Carbon and Water neutral Housing. - Societal Interdependencies: Behavioural v's technology solutions. - Technology Compatibility - Knowledge Exploitation - Mapping interdependencies - Skills interdependencies.

Non-allocated Notes
- Value for consumers if utilities could share customer service platforms. - Other initiatives addressing interdependencies: (1) co-ordination networks; (2) interdisciplinary research consortia. - EIA's and consenting processes - Waste water is (I think) more dependent on power but lower impact and more difficult to model -Opportunity: regulator(s) to rethink their approaches and allow addressing interdependencies. - Road access for staff to reach work e.g. trains are delayed in bad weather because staff cannot drive to work. - Access to and cost of investment financing and market regulated rate of return. - Area: lack of clarity re: role of water companies in the generation of electricity from sludge (AD, supercritical oxidation) co-digestion – Business models. - Areas: At the end user: (1) gas and water for hot water; (2) ICT and Energy for communication. - Impact: opportunity – resource efficiency e.g. less energy and water to deliver cleanliness. - Areas of interdependencies: Cities connected infrastructure needed to enable economic growth and societal wellbeing. - Impacts: Opportunities for new business models. - The need for several sectors to help meet common policy goals (e.g. emissions reductions). - Smart electricity network demonstrations cut across several sectors (energy / transport / ICT). - Area of interdependency: infrastructure finance and insurance: Financers and insurers are worried about risks they don't understand. - Area of interdependency /Current policy: infrastructure investment is seen by government as a

`good thing' across sectors. But different sectors provide economic goods in different ways. - Opportunity for Water Companies: Utilise Corporate Risk Assessment to fully cover interdependencies. - Opportunity: relationship between research bodies e.g. NERC, UKERC and industry bodies to co-ordinate. - Business decisions are based on the same thinking as economics. - Competition in water sector may lead to more economic valuation of water and peak pricing which individuals may not be inclined to compete for. - Water Framework Directive: governs catchment water characteristics which may be affected by abstraction modifications. - Fresh water impact volume + temperature (due to cooling demand). - No obvious policy re interdependency at government level. - Residential hot water - Cooling water - Sewer overload - Where: (1) Areas of interdependence; (2) Impacts of interdependency; (3) Existing policies addressing interdependencies; (4) Other initiatives addressing interdependencies. - No coherent policies on interdependencies. - Existing regulatory designations have unintended consequences e.g. labelling resource as a waste. - Water companies looking to deliver outcomes not outputs provides flexibility to develop new ideas to deliver `long-term benefits'. - Need to think about where we need to be and work backwards.

Annex 6: Session 6 - World Café Exercise 2

This exercise aimed to capture the perceived facilitators and barriers to inform the better planning and management of interdependencies.

The organisers requested the attendees classify the barriers and facilitators based on Rinaldi (2003):

- Physical
- Geographical
- Regulatory
- Organisational
- Cyber

The attendees contributions are collated in the tables below according to these categories as per the annotated rows with the facilitators and barriers within each category in the columns.

The following was noted by attendees during the exercise:

- Cultural and human behaviour issues should be a separate category;
- That the categories were somewhat arbitrary with issues tending to cover many of them; and
- That the impact of markets and legacy issues were pervasive.

Facilitators and Barriers in Planning and Managing Infrastructure interdependencies

Physical Facilitators • Site Sharing • Renewable Energy Production by water companies on site • Smart infrastructures / cities • More binding concepts and spaces which might require legislative / regulatory amendments • Co-digestion –Waste Water – Energy e.g. World Bank Grey Water Cleaning Project. • Water differentiation • Energy differentiation • Waste water energy technologies transfer • Data / Assessment sharing	**Physical Barriers** • Legacy Infrastructure • Differing rates of innovation in different sectors and the absence of technologies for industrial waste water treatment. • Perverse incentives form smart meters. • Access / Availability to Water • Limited access to more pumped storage capacity • National Grid for water for transfer • Constrained Land Availability / Ownership / Legislation • Security of physical assets • Flood Risk to Sub-stations – alternative approaches to concrete walls e.g. Catchment management SCAMP improves water quality (for abstraction and environment) and can reduce flood risk but question of who pays? • Terrorist attack • Differing Scales of Networks - see below • Lack of acceptability of public to infrastructure.
Geographical Facilitators • Multi-use corridors • Distributed generation • Short distance / local services. • Utility Master Planning • E.g. Bicester and Ebbsfleet village • Community level planning • Create conditions for bottom up delivery, local groups know what they need. • Social media as a platform to ask the market what it needs – the	**Geographical Barriers** • Uncertain climate futures as a barrier to planning • Differing Administrative Boundaries • Availability of resources and there competitive access e.g. power plants on the coast. • Water demand is not co-located with supply. • Transmission losses for water transfer also for co-located assets (siting of power stations away from centres of population. • Security Issues • Physical

evolution of technology to allow users to have an impact on planning. • Scale issue might be mitigated by the greater proportions of distributed / localised energy generation e.g. CHP and Solar. This might increase efficiency and resilience.	• Cost of water for use in energy production. • Bounds of uncertainty are so large that it is not possible to plan large infrastructure taking into account all the issues. • Complexities of infrastructure projects. • Miss-match of different scales that energy and water sectors operate. • Water utility can only be reduced to a regional scale so energy sector may reduce in scale from national to local but water will only stay at regional scale. • Energy system might have to think one scale up e.g. global outlook and the greater interconnection e.g. solar energy from Sahara.
Regulatory Facilitators • Multi-level regulations • ISO standards • Incentivising demand reduction • Green Deal • Integrated regulatory body e.g. UKRN though what is their ambition? Disruptive change or incremental? • Holistic regulation and cross-sectoral affordability – recognition of knock on effects. • De-politesse regulation and infrastructure planning • Abolish regulation all together or change remit to not just be limited to economic drivers • EU Directives – INSPIRE Programme (buildings etc). • Flexibility in financial accounting (for water companies)[?] • Cross-learning and collaboration between sectors. E.g. Ofwat drive for stakeholder engagement for PR14 lead to STW taking to WPD which led them to identify interdependencies: • WPD could justify requirements to Ofgem • STW could justify requirements to Ofwat • i.e. went beyond regulatory requirement.	**Regulatory Barriers** • International Regulations = Constraints • EU Directives such as the Water Framework Directive; Renewables Directive. • Impact of entrenched EU member state positions • Regulatory (and Political) cycles miss-aligned. • Short termism of political terms makes long term investment planning difficult. • Fuel and water poverty • Make MUSCOS less attractive • Need to get a return on investment in water sector of <5 years. • Long lead times for infrastructure development v's short term outlook • The evolution of regulation in the water and energy sectors is progressing behind the needs of both sectors. • Siloed mentality of regulation. • Environment Agency / Scottish Environmental Protection Agency is not part of the UK Regulators Network. • Water sector has 5 year lock in for planning cycle. • The Water Sector is the only sector thinking 25 years ahead. • Multiple levels / fragmentation of regulation (and a lack of co-operation)

	• Separate regulators pursuing narrow perspectives • Too many regulatory bodies in water sector. • There is not energy regulation just electricity regulation. • Ofgem is good at assessing interdependencies but others are not as good. • The UK is missing a whole middle level of planning and policy development between national level and local authorities. • Variable costs for water from region to region (a legacy of privatisation in different geographical areas. • Current bias on built physical assets / capex bias rather than ecosystem services e.g. from planting of trees • Lack of code of practice / audit / enforcement of energy efficiency and water use (+emissions reductions?) • Market based regulations • Myth that markets can regulate. • Legacy pricing and a lack of incentives. • Difference between energy and water sectors in that water sector has to continue to supply clients even if bills are not paid whereas electricity sector can cut off the client. • Legacy pricing reflecting historical issues and assets • Access to technology subsidises e.g. onsite energy production, management of trade, low carbon fund, allow for innovation in regulatory framework. • Regulatory framework not penalising joint funding of projects between sectors • Carbon-Carbon storage (£1B) funded by Government. • Environment Agency won't allow for `pilot schemes'if don't meet standards so does not encourage innovation. • Academic flow of ideas and lessons from research and reports and how fed into sectors.

Organisational Facilitators	**Organisational Barriers**
• Enabling platforms / organisations • National Joint Utilities Group (private sector on improving efficiency) • National underground (sharing information for all sectors). Dial before you dig service – already exists. • Highways (HUAG) • City governance systems are sensitive to risk therefore driving Enterprise Risk Management and horizon scanning for risks such as interdependencies. • Local governance and NGO community action groups to assist with lobbying. • Natural Resources Wales takes an integrated role across the environment. • Public / private / research – ITRC; iBuild; iCIF; ARCC • Willingness to discuss issues • Innovation programmes e.g. NERC • Multi-disciplinary centre RISK doctoral training • MOU's Environment Agency • Consultancies JBA, Arup, Atkins • Increasing engineering training in systems of system thinking • Professional Institutions e.g. IMechE, ICE, EI etc • Educational, awareness building / data sharing • RCUK • EU Horizon 2020 funding • UKWIR Smart Cities • City blueprint (Data ~50 cities in water management in EU. • Carbon Disclosure Project • Infrastructure UK • Civil Contingency Secretariat • Trade Press could be more joined up/hold companies to account	• Lack of awareness between sectors • Lack of shared terminology, standards and datasets e.g. accounting for emissions reduction metrics • No central co-ordination? • Split location of water company operations and head offices • Commercial confidentiality • Silo-mentality and institutional lock in • Different departments have different missions and frame the issues differently e.g. DECC Energy Security, affordability and carbon and Defra water resources management. • Difference between interest of large internationals in the UK energy sector to invest where least risk and cheapest v's the UK need for more strategic generation facilities (where at which time the energy facilities are coming online) in the UK. • No obligation of energy companies to build their capacities in the UK. • Role of education e.g. in schools and wider population and availability of information to direct commonality in understanding. • Less reliance on Return on Investment thinking by financial officers and the development of capacity to understand more holistic thinking. • Infrastructure dealt with as assets rather than service provision. • Different valuation of the same infrastructure by different sectors. • Lack of champions or central co-ordinator for good practice • End of pipe treatment hard to contemplate; don't understand the system. • Markets • Disaggregated market for energy sector • Monopoly for water sector • Private v's Public Ownership • Need to satisfy shareholders for private sector organisations. • Organisations have different positions.

• Asset Management • Replacement of old infrastructure is an opportunity for integration. • Change in business models. • Water companies should sell a service (e.g. hot water) rather than water provision by volume. • Flextricity which is a company aggregating and shifting demand. • Climate Change adaptation power taken as an opportunity to reconcile opportunities by those that took it seriously.	• Collaboration does not always follow all the way through a process • Who owns water • Who licenses abstraction (surface and ground water).
Cyber Facilitators • Results in more efficient interdependency management (though may increase interdependencies and greater chance of cascade failure). • Integrated spatial data systems to facilitate investigations and management i.e. multiple agency platform enablers which might be catchment based. • Learning from ICT (Software and Hardware) used in different sectors. • Development of ICT e.g. 5G and opportunities for much smarter technology. • National Underground Assets Group • 3D map of subterranean services • Smart water meters to enable block tariffs and / or integration of water and energy issues. • Big data and demand shift. • Culture, education and consumer behaviour • Need to ensure systems are secure. • Case Studies e.g. www.linesearch.org Lack of incentives to co-ordinate street works.	**Cyber Barriers** • Data availability / sharing • Commercial value • Competitiveness • Information security • Lack of water data as not all water is metered (political issue). • Smart meter (also facilitator) • Impact of increasing use of ICT on power demand and knock on impact on water demand. • Technology limitations • Bandwidth constraints may limit smart technology • Don't know how to develop demand side technology in water sector. • SCADA systems are a barrier because when integrating energy and water there could only be one ICT system. Though still possibilities to integrate into SCADA [?] • Separate systems = resilience • Combined systems = vulnerable • Keep critical infrastructure off public systems • The use of a lot of wind for generating electricity.

Annex 7: Session 7 - World Café Exercise 3

This exercise sought to developing insights as to how to plan and prepare for better management of infrastructure interdependencies in the future. Attendees were requested to brainstorm issues along the following themes:

- Partnerships (between any social segments, government agencies, NGOs, industry representative bodies, advisory committees, new bodies, regulators, academia, etc)
- Lines of research
- Reform (i.e. reformed regulatory arrangements, demand-side measures etc.),
- Technologies
- Others

These are summarised according to these categories in the tables, below.

Partnerships (between any social segments, government agencies, NGOs, industry representative bodies, advisory committees, new bodies, regulators, academia, etc)
• Multi-Agency Platform Enablers (Catchment based – multiple benefits: flooding, water quality) and the development of incentives to realise these. • In the UK tendency to look internally for solutions. In reality people across the world are facing similar problems. Need to fund people to learn from international experience. • Society objectives – reconciling different competing objectives for constrained resources. • Partnerships forces people together but bottom up is more innovative. Say \`do this' to encourage conversations. • Too many overlapping organisations but ned innovation from new actors to assist in development of conversations. • Shareholders and low risk utilities. • Possible initiatives: UKWRIP / cross-council co-operation • UKERC for UK infrastructure? • Skills training: ICE is doing some training. Royal Society technician training and Doctorial Training. • Different business models /partnerships/approaches/cooperatives – social community • Need for community involvement • Holistic approach – circular economy – of waste to identify opportunities i.e. where there's muck there's brass.
Lines of research
• How useful is academic research in policy making? • Cross-economy understanding of costs / benefits across different sectors • Intergenerational across time and need for longevity in planning. • Water efficiency and how that reduces energy use • Correlation of ITRC critical hotspots with private sector data • Sharing of data to create commercial benefits • Incorporation of more social science into modelling. • Unifying Defra, National Grid and Environmental Agency inputs.

• Aligning the outcomes of energy, environment and water (evidence based) policy. • Shared innovation funding – IUK / Innovate UK: Mapping of funding streams within and cross sectors. • Multiple grades of heat in district heating and how to maximise this energy. • Aligning research in areas that are common across water and electricity and other infrastructure sectors. • Research on price of water (value?) • Insurance applications • Land value • Demand side measures • Conservation programmes on water and energy simultaneously. • Social research feed into engineering research e.g. behavioural research) e.g. US rewards the best neighbourhood for water; small scale alternatives e.g. solar energy. • Academic work on regulatory issues is a recent development. • Use of information and data • How to measure `load factors' • Better understanding of trade-offs. • Case studies – Demonstration Pilot Studies • Industrial Ecology • Core City Examples e.g. Leeds, Glasgow and Bristol • Models which enable uncertainties to be better understood in order to take action. • Demand reduction / value return to customers> • Transformation options = capacity how to build? How to change? • Marginal cost analysis • Life Cycle Assessment: Risk and Opportunities • Business models => stakeholder instead of industry • Water: Utilities as goods • Cross-council co-operation • Social: • Consumer expectations • Behaviours • Technology control and labelling. • Develop an integrated electricity-gas-heat grid like that developed in Maemo in Sweden. • Low grade heat recovery e.g. North Sea oil and gas generate more hot water than oil and gas need => need to recover this.
Reform (i.e. reformed regulatory arrangements, demand-side measures etc.),
• Frameworks which provide regulatory certainty. • Standards for consistency (to make interdependencies easier to manage): • Risk management • Business continuity • Re-launch the Green Deal • Nationalisation of Infrastructure Assets (Social Ownership) • Reform Regulatory Bodies • Water regulatory body that includes economic and environmental consideration • Deregulation in the Water Sector. • More joined up regulators • More mainstream payment for ecosystem services • Longer-term regulatory framework

• Change the rules so generators on sites are allowed (DNO's) • Developing a long term energy policy • Including more inputs of consumers – facilitate engagement with eth publics direct participation (i.e. e-democracy and e-governance) • Benign dictatorship. • Better compensation for people whose land us being used for the development of infrastructure. • Build public consensus for long-term infrastructure planning. • More pluralistic and inclusive approach to planning • Regulators to provide incentives for water and energy efficiency. • Creating a proper market for energy and water services rather than a monopoly. • Regulatory mechanisms to incentivise / realise the benefits of collaboration (as the end of the day they are all financially driven). • Opportunity to work more with local governments and partnerships. Water companies are often absent. Climate UK can be a facilitator. • Reform water market to act more like energy market. • Urban planning (good example in Hague) • Use of local resources • District heating in London (sign of politics) • UK reserved to role of local authority • Insist on local plans that have zoning. • Meters to let people know how much they are using and better price true cost / price of water and energy • Combined regulatory system (some don't agree but why are some regulators so powerful? • Lessons from other countries • Competition size matters for creating market • No model says `this works' • The transfer of research into action (not more research) e.g. National Grid `hot spot' from ITRC. • Master-Holistic Plan for integrating everything together at Cabinet level. Broader development of policy in government to get away from silos. Relationship between civil service and political masters. • Low carbon network fund RIIO • Regulatory Reform => regulate by stakeholder instead of sector • Cost of capital stops innovation. • UKRN to administer cross-sectoral equivalence of LCNF. • Need for regulation of heat => need for heat grid (note uncertainty in markets). • Need to improve skill set in construction industry for energy efficiency and regulate these issues (Trading standards) as otherwise skills will not be lost. Furthermore, re-accreditation every so often to retain staff for new techniques.
Technologies
• Integrated spatial data systems. • Smart Meters – integration of water and energy • Large scale energy storage • Smart metering - water accounting data to be included on smart meters. • Use hot water as energy storage • Micro-hydro-electricity technology • Develop technologies that allows selling of water and energy services to neighbours rather than grid,

- Supercritical boilers are more efficient / but only suitable for new build plants.
- Allow combinationational technologies.
- Multi-use assets (Combined Heat Power -> desalination plants?)
- Public acceptance of technologies v's socially excluded.
- More densely populated cities increase impact of interdependencies.
- W-E nexus: not use water and waste movement has implications in energy requirements
- Use of waste products to generate electricity:
- Sewerage
- Fats, Oil and Greece
- Food Waste.
- Home duel fuel / fuel cell – research and development into this.

Others

- Behavioural change – People need to be incentivised to change their patters /life style -> get over it.
- Perceptive changes to move to an acceptability e.g. recent scandal over waste heat from crematorium being used to heat water in next door swimming pool.

Annex 8: Social Media

The link to the storify page can be found here: https://storify.com/SPRU/how-to-govern-the-complex-links-between-energy-and

How to govern the complex links between energy and water sectors in infrastructure delivery?

A one day workshop organised by ITRC (Infrastructure Transitions Research Consortium) - UK Water Research and Innovation Partnership (UKWRIP) - University of Bristol's System Centre (UoBSC) - and Energy Research Partnership's (ERP).

Ralitsa Hiteva @RalitsaHiteva Follow
TODAY: #UKEW What can we learn from approaches to governing infrastructure interdependencies beyond a centralised top down approach? @SPRU
6:39 AM - 2 Dec 2014
3 RETWEETS

Dragan Savic @H2ODraganSavic Follow
On my way to the Workshop on governance of water & energy interdependencies with live twitter feed &Q&A session: #UKEW @SPRU @RAEngNews
7:57 AM - 2 Dec 2014
1 RETWEET 1 FAVORITE

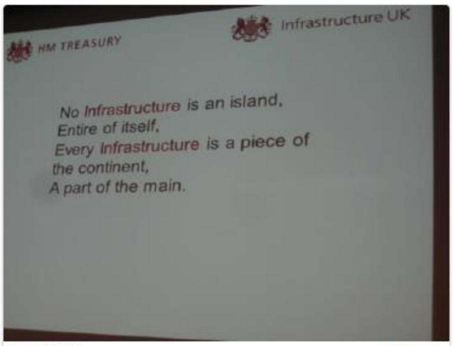
Session 1: What is infrastructure interdependence and why it matters?

SPRU @SPRU Follow
Jim Hall @UKITRC launches with breakdown of 'interdependencies' - physical,geographical, cyber & human #UKEW
10:09 AM - 2 Dec 2014
6 RETWEETS 1 FAVORITE

Scott Kelly @scottknz Follow
Jim Hall: we require a new definition for what we mean by interdependence #UKEW
10:06 AM - 2 Dec 2014

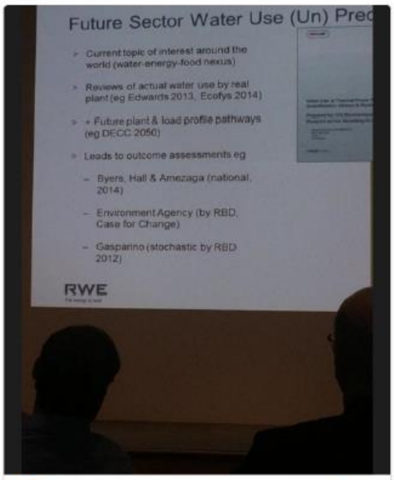
1

Keith MacLean @macleank Follow
#ukew workshop on energy and water interdependence. 20% of fresh water abstraction is for power stations and provides 40% of cooling needs
10:02 AM - 2 Dec 2014
5 RETWEETS 1 FAVORITE



SPRU @SPRU Follow
David Penhallurick @INFRA_UK @hmtreasury quotes Donne #UKEW
10:20 AM - 2 Dec 2014
4 RETWEETS

Session 2: Interdependencies between the water and the energy sectors - models, tools & case studies



ES KTN @esktn Follow
France, Germany, USA, China all have experienced generation constraints due to water. Not (yet) in UK. Lucky? #ukew
10:59 AM - 2 Dec 2014
2 RETWEETS

2

Ralitsa Hiteva @RalitsaHiteva

@EdwardByers Clustearing of CCS facilities in the UK to save on cost of pipeline infrastructure will pose threats to water management #UKEW

10:52 AM - 2 Dec 2014

3 RETWEETS

Keith MacLean @macleank

#ukew variability in DECC future power scenarios means that water use could triple or reduce to a third - planning on this basis is hard!

11:03 AM - 2 Dec 2014

6 RETWEETS

SPRU @SPRU

High % of energy &water used to produce hot water in buildings says Dr Nick Eyre @UKITRC . Saving hot water crucial 4 sustainability #UKEW

11:13 AM - 2 Dec 2014

2 RETWEETS 1 FAVORITE

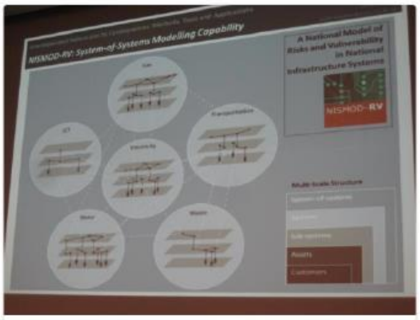
Session 3: Interdependent failure & its consequences: critical hotspots analysis – models, tools & case studies

Keith MacLean @macleank

#ukew Water Framework Directive will reduce availability and increase competion for, and cost of water for all users.

11:27 AM - 2 Dec 2014

4 RETWEETS



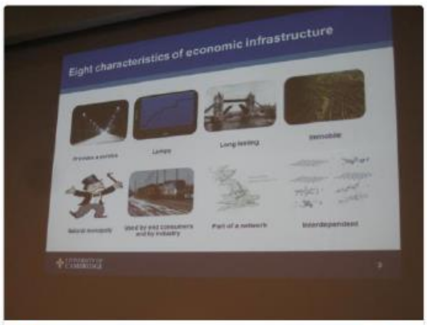
SPRU @SPRU

Mapping interdependencies by @UKITRC for l-term planning & adaptation for climate change identifies hotspots #UKEW

12:11 PM - 2 Dec 2014

4 RETWEETS 1 FAVORITE

3



SPRU @SPRU

Economic infrastructure - components explained #UKEW

12:19 PM - 2 Dec 2014

1 RETWEET 3 FAVORITES

Session 4: Governance and Regulation - interdependency planning, management framework & case studies

mike simpson @mike_simpson_82

Scott Thacker and @scottknz presenting quantifications of uk infrastructure interdependency - great contributions and not easy work #ukew

12:37 PM - 2 Dec 2014

2 RETWEETS

SPRU @SPRU

Amanda Turner @EnvAgency identifies less water will be available by 2050 due to impact of climate change & pop growth #UKEW

12:51 PM - 2 Dec 2014

4 RETWEETS

SPRU @SPRU

Ges Rosenberg @SystemsCentre recommends stewardship & open systems approach to governing interdependencies #UKEW

1:02 PM - 2 Dec 2014

1 RETWEET

SPRU @SPRU

Important role for local actors in infrastructure. EG there are currently 5000 active community energy projects in the UK @KatyRoelich #UKEW

1:05 PM - 2 Dec 2014

3 RETWEETS 1 FAVORITE

4

SPRU @SPRU
Local resilience forums enable common understanding betwn different stakeholders & sectors says @RalitsaHiteva #UKEW
1:17 PM - 2 Dec 2014
2 RETWEETS 2 FAVORITES

Katy Roelich @KatyRoelich
We don't all agree on where we're heading so governance needs to capture the fact that the future is contested @watsonjim2 #ukew
1:32 PM - 2 Dec 2014
11 RETWEETS 2 FAVORITES

PaCCS Research @PaCCSResearch
UK National Infrastructure Plan 2014 out today: bit.ly/1FJhy5r. Includes concepts of systemic resilience & passive provision. #UKEW
10:55 AM - 2 Dec 2014
2 RETWEETS

Afternoon Session
Part 1 will assess the current status of interdependencies between the water and energy sectors.
Part 2 aims to capture perceived barriers and facilitators to inform the management of interdependencies.
Part 3 focuses on gathering suggestions for possible initiatives required to plan and prepare for better management of infrastructure interdependencies in the future.

SPRU @SPRU
Share your thoughts - What are the areas of infrastructure interdependencies & impact? #UKEW
2:36 PM - 2 Dec 2014
1 RETWEET

5

SPRU @SPRU
What are the perceived barriers & facilitators in planning & managing infrastructure interdependencies? #UKEW
3:23 PM - 2 Dec 2014

SPRU @SPRU
Barriers & drivers by @watsonjim2: uncertain futures and climate impacts; water availability & access #UKEW
4:22 PM - 2 Dec 2014

SPRU @SPRU
facilitators to #water & #energy interdependencies: site sharing, sewage sludge generation, data sharing, community level planning #UKEW
4:23 PM - 2 Dec 2014

SPRU @SPRU
Cyber issues present a risk and a potential driver to developing collaboration bwtn water & energy sectors #UKEW
4:26 PM - 2 Dec 2014

Edward Byers @EdwardByers
World cafe session over. 388+ #ukew post-it notes and 80 hours of ideas...
4:20 PM - 2 Dec 2014

SPRU @SPRU
Policy cycles need to be aligned to facilitate more collaboration for #water & #energy &necessary education & skills #UKEW
4:25 PM - 2 Dec 2014
2 RETWEETS

SPRU @SPRU
Governing interdependencies amplifies risk, improves economic effieciency & helps to meet broader sustainability goals - @watsonjim2 #UKEW
1:31 PM - 2 Dec 2014
4 RETWEETS 1 FAVORITE

6

SPRU
@SPRU

Towards a more coordinated approach for delivery of national #infrastructure by @RalitsaHiteva & @watsonjim2 goo.gl/T9ffuk #UKEW

4:09 PM - 2 Dec 2014

Britain's infrastructure must be made to work in harmony and here's...

Every time we turn on a tap, switch on a light or drive to the shops we are relying on the infrastructures that make our modern economy work. These infrastructures are being developed to meet new...

The Conversation @ConversationUK

2 RETWEETS 1 FAVORITE

mark smith
@marks_wrc

Attended interesting event on water energy interdependencies yesterday - guess what? There are lots of interdependencies! #ukew #ukwrip

10:05 AM - 3 Dec 2014