

DECISION MAKING UNDER RISK & UNCERTAINTY WORKSHOP

170 QUEEN'S GATE, 10-11th FEBRUARY 2016

Workshop Summary Report

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1. Background

On 10th and 11th February a workshop was held at Imperial College, London to discuss decision making under risk and uncertainty. The workshop attracted a broad set of audiences ranging from defence, the police, water, energy, engineering sector to academia - see Annex 2.

This document represents a summary of discussions between participants and will form the basis of other outputs from the event.

The workshop was developed off the back of a short Game Theory workshop held on the afternoon of 12th May 2015 which involved industry, policy makers and academic participants. At this workshop the following was found:

- There was a strong appetite for decision making tools to address uncertainty across industry, academia and policy makers;
- There is likely to be a need for capacity to be developed to address complexity and uncertainty in "multi-actor" systems, situations where there is a lack of information, the need for trade-offs and conflicting objectives;
- Academics and regulators have developed a number of tools which are proliferating;
- The work undertaken in the decision making under risk and uncertainty arena has been fragmented, had limited applications with no real sharing of best practice; and
- The added value and insights from these tools is not understood by senior management.

With this in mind it was decided to hold another workshop to develop a better understanding of the state of decision making tools employment across sectors.

2. Workshop Details

The workshops intent and proposed outputs are summarised below.

2.1 Workshop Intent

- Provide an opportunity to discuss challenges faced by sector leaders in addressing decision making under risk and uncertainty;
- Identify key barriers and effective solutions for overcoming them;
- Identify gaps, be they in capacity or resources, and opportunities for addressing these gaps; and
- Build multi-sector collaboration on complex decision making challenges.

2.2 Workshop Outcomes

- Develop information sharing, networking, and cross-sectoral collaboration opportunities; and
- Identify new capacity to support organisational decision-making needs across industry and policy.

A workshop agenda is available in Annex 1. The workshop can be broken up into the following seven sessions:

- Four 'Pop-Up Talk' Sessions involving 4 or 5 x 5 minute talks from participants discussing: (1) the problems that they have in their organisations; (2) what tools that they use to address risk and uncertainty; and (3) how they implement the outputs into strategy.

This was followed by a 20 minute Q&A session between the Pop-up Talkers and the delegates as well as a 15 + 10 minute talk by a specialist who had been invited to assist in benchmarking the employment of tools to assist in decision making under uncertainty - see Section 3.

- A pair of break-out sessions which sought to collate the extent to which companies / organisations: (1) need tools for making decisions with risk and in uncertainty; (2) the tools that they use and the challenges that they face in employing those tools within their organisations; (3) benchmarking best practice; (4) identifying gaps in capacity to fill company / organisational needs; and (5) how this capacity may be addressed. See Section 4.
- A communicating uncertainty and risk session was also held - see Section 5.
- A panel session comprised of specialists in decision making under risk and uncertainty answering questions from the delegates - see Section 6

Finally, a feedback session was held between the workshop organisers and delegates to capture how to take the agenda forwards in the UK decision making under risk and uncertainty arena - see section 7.

With an integral intention of the workshop being to benchmark and develop an understanding of best practice five specialists were invited to assist in the landscaping of the work. These included:

- **Dr Catherine Butler**, Advanced Research Fellow, University of Exeter;
- **Dr David Groves**, Professor, Pardee RAND Graduate School;
- **Dr Jan Kwakkel**, Assistant Professor, Delft University of Technology;
- **Dr Patrick Reed**, Professor, Cornell University; and
- **Dr Liz Varga**, Professor, Cranfield University.

They gave talks, engaged in an interactive panel session with delegates, managed break-out session groups and were engaged in the workshop throughout.

Furthermore, at the start of session 2 a short presentation was delivered by Professor John Rees of the Natural Environmental Research Council representing the research councils. He stated that developing the risk and uncertainty theme in the councils has been difficult due to fact it is perceived as unfocused and initiatives are being developed in an independent manner e.g. in Doctoral Training Programmes. Risk and uncertainty is likely to be a cross-cutting theme with the

likely integration of Research Council activity in 2017. With this in mind, two sets of questions that the research councils are keen to have addressed:

- To academic audiences: What are the sort of questions should we be asking?
- To industry and policy maker audiences: How should engagement between the different communities be best facilitated?

3. Pop-Up Talk Sessions I to IV

A summary of the issues covered relevant to workshop objectives for each presentation in the Pop-Up talk sessions by both delegates and the specialists as well as the themes developed in each Q&A session are summarised below.

3.1 Session I: Pop-up Talks

This session was comprised of the following participants:

- (1) **Harvey Beck**, Ofgem - representing risk and uncertainty in electricity security of supply assessments
- (2) **Chris Hankin**, Imperial College London - How do I decide how much to invest in cyber security?
- (3) **Anna Railton**, Smith Institute - Optimal decisions for Large Scale Transport Systems
- (4) **Julian Frost**, JESIP Cabinet Office - Joint Emergency Services Interoperability Principles
- (5) **Mike Colechin**, Energy Technologies Institute - Establishing a multi-£M portfolio of low carbon energy innovation.

Specialist: **Dr Patrick Reed**, Professor, Cornell University - What are the trade-offs? Challenges and the State of the Art for Discovering Tradeoffs and Vulnerabilities in Deep Uncertainty Frameworks.

The pop-up talks given in this session can be found in the following [link](#) and the specialists talk in this [link](#). A summary of the points raised and the themes developed in this session can be found below.

Summary

Electricity security of supply assessments

- Four scenarios are used to embed the multiplicity of relevant factors which need to be considered for security of electricity supply assessments such as: weather, plant closures, plant outages, demand changes, interconnector flows etc.
- The scenarios don't have probabilities assigned to them and salient findings need to be communicated to a range of stakeholders and decision makers of varying levels of expertise.

- It is felt that the scenarios don't capture the issues well enough around the sensitivity of the UK energy system to disruption. Decision makers just want one number but it is more complicated than that.
- Ongoing challenges include: (1) technical communication to non-technical audiences; (2) information overload; (3) Lack of probabilistic assessment; and (4) year-on-year consistency. There is also a need for analysis of technological uncertainties.

Industry Control Systems - Investment in Cyber Security

- There are a number of considerations when addressing cyber defence such as degree of control, amount of damage expected and costs both direct and indirect across. These will vary depending upon the entities involved such as corporation or national institutions. When it comes to cyber investment – any information that is useful to inform decision making is useful.
- Use Game Theory with games being played in nested hierarchy within systems in a hybrid manner to ensure a more efficient solution. Tools have been developed to specify parameters such as budget, risk appetite, and optimal portfolios.
- With policy and decision makers wanting numbers to inform decisions there is a tendency for focus on high probability low impact or low probability high impact problems; this can distort resource allocation for cyber investment.

Optimal decisions for Large Scale Transport Systems

- Developed a mathematical framework for optimal decision making involving five components: (1) states; (2) decisions; (3) new information (i.e. a source of uncertainty); (4) means of updating the state variable; and (5) means of quantifying the cost/contribution as the system evolves.
- Application to shortest time routing but can also be applied to rail schedule optimisation, spatial inventory problems, mothballing decisions and the impact of change on a network.

Joint Emergency Services Interoperability Principles

- Development of a joint tri-service doctrine between police, ambulance and fire services to allow interoperability and effectiveness in responding to emergencies across all levels of command.
- Simplicity of solution was key: adopted a joint doctrine based on the police conflict management module due to scalability. This was embedded into tri-service training regime across all services.
- Needed senior level buy in - Home Secretary in this case, framework to ensure communication across services, alignment of policies and procedures. The training of 20,000 key staff has been fundamental in facilitating a change in culture.
- Measurement of development of cultural change around behavioural biases and situational awareness is problematic but sought to be embedded into training regimes.

Establishing a multi-£M portfolio of low carbon energy innovation

- Seeking to understand the optimal portfolio of technologies to fund/develop whilst accommodating risk around technologies, markets and regulations; and uncertainty around the evolution of the energy system.
- Gather information across energy landscape and potential future energy system, engage with stakeholders, whole system analysis and modelling of least cost futures to identify key solution options to deliver those futures. Require board approval to invest in those options.
- Challenges around: data/evidence, timescales, economic climate; communicating decisions; non-linear improvements and least cost optimisation omitting issues.

What are the trade-offs? Challenges and the State of the Art for Discovering Trade-offs and Vulnerabilities in Deep Uncertainty Frameworks.

- Two key points
 - Operational modes and workflows reinforce status quo decision making, institutional change requires an integration of elicitation, computation and multi-objective decision making feedbacks; and
 - Effective multi-objective search can be critical for increasing 'robustness' and understanding of stakeholder 'robustness conflicts' given complex, adaptive decisions.
- These points were laid out in an examples based on Aero-space Corps an organisation which lives by innovation for its satellite technology development and adopts change very fast; and a water utilities case study in North Carolina where risk aversion is key and adopts change more cautiously.
- Challenges included: very mathematical process but some aspects are not quantitative; scoping and unpacking issues in space and time, identifying what was important, who was impacted, the role of institutions and elucidating decision feedbacks.

The following themes were developed in the Q&A session:

- The components involved in decision making ranged from the use of flow charts to mathematical models. The most important aspect in developing an environment for decisions making are: (1) communication and the interfacing that takes place between stakeholders, decision makers and analysts; (2) ensuring the appropriate decision making model; and (3) a reliable evidence base that all stakeholders have faith in.
- There is an increasing desire, in certain sectors and circumstances, to delay decision making and maintain the maximum number of options. It was emphasised that this was very sector specific. For example, in the energy sector option maximisation is desirable; in climate risk analysis the ability to defer decisions is also desired; however, in cyber security and emergency response this was not an option at all – indeed making timely decisions is vital.
- The fact that decision makers like a single metric upon which to base their decision on was raised as well as how this might be possible in an increasingly complex operating environment.

It was emphasised that there was a need to explain the selection of metrics and what they mean. In the energy sector the metrics were well understood by policy makers but less so by the layperson.

3.2 Session II: Pop-up Talks

This session was comprised of the following participants:

- (1) **Dennis Konadu**, University of Cambridge - Foreseer: UK Energy-Land-Water interactions.
- (2) **Ian Temperton**, Ian Temperton Consulting - Observations on investment decision making under uncertainty in clean energy.
- (3) **Alexandra Collins**, Imperial College London - Incorporating Uncertainty into Evidence Syntheses
- (4) **Julien Harou**, University of Manchester - Planning water regional water resources investments in East Anglia

Specialist: **Dr Liz Varga**, Professor, Cranfield University - Decision-Making Under Risk and Uncertainty in Complex Infrastructure Systems.

The pop-up talks given in this session can be found in the following [link](#) and the specialists talk in this [link](#). A summary and the themes developed in this session can be found below.

Summary

Foreseer: UK Energy-Land-Water interactions.

- Looking to identify the resource implications of different energy policies thereby allowing an understanding of the trade-offs that need to be considered for different low carbon trajectories.
- The Foreseer tool (available [online](#)) develops scenarios addressing natural resource supply, transformation and uses of energy-water-land, the way that they interact, and the environmental stresses which might result. The outputs are displayed in the form of a Sankey diagram.
- Key challenges have been understanding what decision and policy makers want in terms of metrics and outputs from the tool.

Observations on investment decision making under uncertainty in clean energy.

- There is a need to understand the nature of decision making for low carbon investment in the investment community: it is unsophisticated. Most investment decisions rely on: Internal Rate of Return analysis with a hurdle rate set above a weighted average a cost of capital. The only time that uncertainty is addressed is sensitivity analysis and even then the most favoured choice is highlighted with a red dotted box.
- Theories of uncertainty more useful to understand corporate behaviour than informing it: (1) Agency theory; (2) Behavioural impacts; and (3) Real options – with an emphasis that when it comes to low carbon projects they are capital intensive with front end loaded investment,

thereby making them exposed to downside / regret and are therefore more likely to be deferred than other investments. With the short-term horizons for corporates they don't generally 'buy options'.

- There is a need to understand the world of the decision maker better: you won't change the world and therefore there is a need for analysts and academics to better understand corporate behaviour in order to address how to impact decision making.

Incorporating Uncertainty into Evidence Syntheses – Evidence gained from the UK Department for Environment, Food and Rural Affairs.

- Based on a review of methods to portray complex evidence, issues and how they are incorporated into policy and decision making which can be found in [Collins et al 2015](#). A key undertaking within the review was how to review evidence whilst reducing uncertainty, how to measure uncertainty and how to communicate it.
- Reviewed: IPCC reports, LWEC report cards, Millennium Ecosystem Assessments, Evidence Statements and Combined Quality Assessments.
- The research is a Work In Progress. However, one of the key insights includes whether uncertainty is better addressed by transparency as a lack of transparency can impact the perceived authority of a piece of work.

Planning water regional water resources investments in East Anglia

- The challenge includes: (1) Multi-company strategic water resource planning for East Anglia; (2) addressing the challenge of growth, sustainability reductions and climate change; and (3) assessing future supply options such as: reservoirs, strategic transfers, aquifer storage and recovery, water reuse and desalination.
- A model Water Resource East Anglia regional system simulation model was built to address this. Multi-criteria search under multiple scenarios allows the incorporation of multiple performance criteria and finds designs that are robust considering the uncertainties. Robust decision making allows the characterisation of vulnerabilities of selected plans.
- The UK water sector is heavily regulated, very structured with a prescriptive way that investments are justified - least cost is often the optimum. Tends to be undertaken on a water company spatial jurisdictional basis whereas for sustainable options there may be a need to consider issues beyond spatial jurisdictions and that are not least cost. The analysis sought to do this but introduces difficulty in communicating issues to the regulator due to a differing frame of reference.

Decision-Making Under Risk and Uncertainty in Complex Infrastructure Systems.

- Research undertaken in the energy, transport, water, waste and telecoms sectors which are complex for the following reasons: (1) networked and interacting; (2) multi-scale and emergent; (3) dynamic, adaptive and evolving; and (4) involve people - making issues non-deterministic.

Need to consider key elements of futures such as: population growth, urbanisation/densification, regulation/legislation and technological discontinuities.

- The talk also covered the following: (1) Risk and uncertainty can be conceptualised in a 2 x 2 Risk-Ambiguity-Uncertainty-Ignorance matrix; (2) A typology for uncertainty has been developed; (3) The elements of how risk and uncertainty impact decision making has been documented in the literature - see presentation; and (4) consideration of decision making choices also need to be made as well.
- A continuum for quantified risk and qualified uncertainty was also described along with the role for mixed methods as well as the role of modelling and inter-disciplinary investigations.

The following themes were developed in the Q&A session:

- Investing effort in communicating details is key when getting decision 'buy-in' within organisations. The ease of understanding analysis in Defra is a key component to getting the work used. There is a need to consider the different aspects of communicating risk which will differ from one decision making audience to another.
- A key requirement to address uncertainty is transparency. On the one hand, transparency can result in a cognitive burden due to the amounts of information which might be exhibited and on the other the lack of data provision to audiences will led to concerns regarding its authenticity. It is key that the underlying assumptions and uncertainties are explicitly stated.
- The need to collect and process data more quickly and get the analysis to the relevant audiences is becoming an increasingly important imperative. This is becoming problematic with the increased volumes of data being generated and the need to incorporate feedback loops that take place in the social domain - which can be responsible for the development of emergence in systems.

3.3 Session III: Pop-up Talks

This session was comprised of the following participants:

- (1) **Simon Collander-Brown**, Defence Science Technology Laboratory – How do we plan for the future requirements for defence?
- (2) **Anant Prakash**, BP - Planning Price or Oil Price Assumption
- (3) **Simon Cook**, Southern Water Services - Risk and Uncertainty for Water Resource Planning
- (4) **Rosalind West**, DEFRA - Identifying priority risks in 2nd Climate Change Risk Assessment (2017)

Specialist: **Dr Jan Kwakkel**, Assistant Professor, Delft University of Technology - Supporting Decision Making under Deep Uncertainty.

The pop-up talks given in this session can be found in the following [link](#) and the specialists talk in this [link](#). A summary and the themes developed in this session can be found below.

Summary

How do we plan for the future requirements for defence?

- The complexity of the problem covers the following issues: (1) uncertain context; (2) knowledge of system is incomplete; (3) some systems are inherently uncertain; (4) systems is subject to reflexive change across interactive sets of actors; (5) gaming is inherent; and (6) addressing systems change to gain an advantage results in the system being in perpetual flux.
- Use scenario planning to construct small numbers of plausible futures. Complex analysis is undertaken to address which are the main drivers of outcomes and whether there are any shortfalls in defence capability. The process is designed to involve main decision makers so that they buy-into the process and therefore the results.
- Though scenarios give useful results, concerns with present methods employed are that they are: (1) slow; (2) expensive; and (3) doesn't deal with uncertainty well. Other methods are being considered to address shorter cycles of generation which might be simpler; there is a desire to test hybrid methods.

Planning Price or Oil Price Assumption

- Much of the work undertaken is used to advise the CEO - it is therefore subject to corporate confidentiality. For this reason the presentation is generic.
- The uncertainties which need to be considered in oil price planning are: (1) oil price; (2) risk of sub-economic investments and projects especially with a volatile oil price and (3) the typical O&G investment horizons when positive cashflow is anticipated 8 to 10 years from the initial investment; (4) have plentiful amounts of data generated from multiple methods which results in huge range; and (5) strategic complications of being committed to a regular dividend; being subjected to geopolitics and sector deflation.
- Multiple methods: (1) Bottom up analysis; (2) price and profit calculations for various assets; (3) deterministic calculations, forecasts and sensitivities; and (4) development of scenarios, portfolio analysis, predictions and forward strips.
- These tools are used to allocate capital for projects, the workforce, capital and opex, however, sophistication of analysis is lost when it has to be aggregated and presented to decision makers. Actual decisions are heavily based on the experience of the board. There is a desire for faster analysis and turnaround of analysis with less complexity and the incorporation of a probabilistic dimension.

Risk and Uncertainty for Water Resource Planning

- Obligation for Southern Water to produce a Water Resource Management Plan for a minimum of 25 years accounting for a range of uncertainties including: weather variability and drought,

climate change, impacts of new technology, source behaviour, water quality, demand forecasts, environmental impacts, options and allocation of investment.

- Use multiple tools to compile plans: stochastic approach for rainfall; climate change scenarios; multiple growth scenarios for demand; Monte Carlo approach for supply and demand balance; investment modelling reflecting different states of the world; and Real Options for no regret investment.
- There is a statutory consultation period which involves informal engagement with regulators and stakeholders. The main challenges are around the technical difficulty of the tools and communication of the outputs to different audiences. Regulators lacked acceptance and confidence in new and advanced techniques. Future plans include the extension of the present approach, improving reliability, extending real options and incorporating better environmental forecasting.

Identifying priority risks in the 2nd Climate Change Risk Assessment (2017)

- Defra published the first Climate Change Risk Assessment (CCRA) in January 2012. It identified over 700 risks to the UK from a changing climate and focused on around 100 of them to determine their severity and likelihood in the short, medium and long term. The analysis used the 2009 UK Climate Projections (UKCP09).
- For CCRA 2, Defra has commissioned the Adaptation Sub-Committee of the Committee on Climate Change (ASC) to produce the underpinning Evidence Report. This is due to be published in July 2016 and will then be laid in Parliament along with the CCRA 2 Government Report in January 2017. The Evidence Report will identify policy areas with barriers to adoption and/or where adaptation is most urgent in period 2017-2022. The report will attempt to consider: (1) how climate interacts with socio-economic factors in risk; (2) how the effects of adaptation actions are/could alter risks; and (3) how climate change overseas could affect the UK.
- A fundamental challenge for the ASC's CCRA 2 Evidence Report is how to identify the most urgent risks from climate change that will require additional government action in the next five years. Major uncertainties arise at every step in the method, which involves: (1) assessing current and future level of risk; (2) estimating the effect of planned and autonomous adaptation on residual risk; and (3) assessing the benefits of additional action in the next 5 years. The priority risks identified through this process will ultimately inform the national adaptation plans of the UK government and the devolved administrations.
- As part of CCRA 2, the ASC has also published four research projects¹, including new plausible high end (H++) scenarios² for a range of climate hazards (heat waves, cold snaps, low and high rainfall, droughts, floods and windstorms). These low likelihood, high impact climate scenarios can be used to test the limits of adaptation and inform future adaptation

¹ <https://www.theccc.org.uk/tackling-climate-change/preparing-for-climate-change/climate-change-risk-assessment-2017/>

² <https://www.theccc.org.uk/publication/met-office-for-the-asc-developing-h-climate-change-scenarios/>

planning. They are intended to be used alongside estimates of the more likely range of future outcomes, to enable the full range of risk to be considered.

Supporting Decision Making under deep uncertainty some experiences in The Netherlands.

- The Netherlands has a long history of flooding. A common theme of flooding is the tendency to respond after a failure event. This is less acceptable in the Netherlands now that such a large proportion of the population live below sea level. There is now a shift from the predictive use of models to an exploratory use. The essence being to allow flexibility for decision makers rather than being locked into a specific anticipated future.
- This has resulted in a shift from the use of scenarios to adaptation tipping points along an adaptation pathway which provokes a relevant set of actions. This allows the anticipation of uncertain futures whilst addressing them proactively which in turn requires the use of new methods for problem analysis, policy analysis, planning and decision support.
- Adaptation pathways are constructed through qualitative approaches - harvesting expert opinions and participatory processes and quantitative approaches such as multi-objective Robust Decision Making and multi-objective Robust Optimisation or hybrid approaches which accommodate both sets of methods.
- These techniques have now been enshrined in law in the Netherlands for delta management and has been adopted in other countries such as: Bangladesh, Vietnam, Indonesia, Australia, New Zealand and the UK (Thames Estuary 2100). These techniques are also being applied to other problems other than flood risk such as climate and land use change.

The following themes were developed in the Q&A session:

- Scenarios generated, often by brain storming, can drastically under-estimated reality. This impacts on the preparedness of organisations for certain events such as the recent oil price drop. It is suggested that organisations are better at anticipating small micro-scale events but are relatively poor at macro-scale, impactful events - the difficulty is compounded by the scrutiny of the finance sector which question aspects of corporate behaviour. In climate change risk assessments there is a desire to address this by generating High++ events which are considered beyond plausibility but generated to test strategies and policy frameworks. These do stop short of completely implausible scenarios.
- The ability to anticipate other actors decisions could be important in shaping your own corporate decisions. However, these cannot be anticipated. The best strategy to address this is to be prepared to respond as effectively as possible.
- In order to address the increasingly multi-disciplinary nature of the processes and tools employed by organisations is there a drive to recruit more multi-disciplinary staff? In the defence sector this has definitely been the case and in the water sector there is often high quality multi-disciplinary activity taking place within the organisations – it is a case of identifying it.

- In Holland there is a good understanding of the issues surrounding flood risk as most Dutch people have grown up in a state of awareness. This in turn allow consensus and the political space for far reaching policies (transcending political terms) to be enacted. Can those lessons be translated to the UK? It is still not easy in Holland and issues are still subject to political interference. The key was to identify politically trusted actors who could act as knowledge brokers between the different stakeholders.

3.4 Session IV: Pop-up Talks

This session was comprised of the following participants:

- (1) **Adam Whitmore**, Adam Whitmore Consulting - The nature of decision making in commercial organisations.
- (2) **Bessma Maroud**, Skoll Global Threats Fund – Decision making under risk and uncertainty for a not for profit organisation.
- (3) **Steve Moncaster**, Anglian Water - Decision making under risk and uncertainty for a water utility company.
- (4) **Mike Steel**, Environment Agency - Long-term investment scenarios for flood and coastal risk management.

Specialist: **Dr David Groves**, Professor, Pardee RAND Graduate School – Preparing for an Uncertain Future: Developing Robust Climate Adaptation Plans in the Water sector.

The pop-up talks given in this session can be found in the following [link](#) and the specialists talk in this [link](#). A summary and the themes developed in this session can be found below.

Summary

The nature of decision making in commercial organisations

- Decisions are always subject to constraints of circumstance. Analytical techniques need to work in these contexts if they are to have any impact.
- Key areas to consider include: (1) cognitive biases among decision makers e.g. confirmation bias; (2) Discontinuities and internal barriers such as imperfect information assessment and transmission, cognitive load, target thresholds which may imperfectly reflect actual risks; (3) internal dynamics such as different interests, preference for the familiar, well understood, standardised approaches; and (4) Political influences in the energy and resources sector. The latter are often the major source of risks and uncertainty especially given the long lead times.
- If the analytical community is going to make a difference in decision making the ability to account for the politics of an organisation is vital.

Decision making under risk and uncertainty for a not for profit organisation.

- The Skoll Global Threats Foundation seeks to assess how and when local water and climate shocks have regional or global impact? And how can we be better prepared, as a society, to minimise and respond to these challenges?
- The risks and uncertainties to consider include: (1) climate variability subject to an increasingly large level of uncertainty; (2) more interconnections and interdependencies; (3) the overexposure of the poor to the risk from these shocks. Need to consider how people respond to these shocks and what decisions are made? And which events or combination of events may trigger cascading impacts?
- Use data and information intensive methods and novel analysis which get fed into security gaming and scenario planning. These often involve facilitated role play to better integrate human behaviour and seek to assess networked risks.
- Need for better data / information on water and machine learning has been considered to pick up patterns or signals. Methods are a positive way to engage with participants but with the limited numbers of individuals involved it can be difficult to assess the utilisation of the outputs in policy.

Decision making under risk and uncertainty for a water utility company.

- As a water company, have to deal with many regional risks such as droughts and floods. There is a need to balance the needs of customers with a reliable supply at an acceptable price as well as prevent risks such as flooding. Attempt to balance the needs of the customer, business and the environment.
- Use Robust Decision Making. Working with multiple actors in value chain and other water companies in a Regional Planning Initiative. The challenge is to get new informatics and data analytics with the appropriate level of detail so as to allow decision makers to act especially on investment issues.
- There are multiple constraints to deal with due to the heavily regulated nature of the industry in the UK with institutional risk being a key consideration. The outputs of the Regional Planning Initiative will be available in a year's time.

Long-term investment scenarios for flood and coastal risk management.

- The problem is centred around seeking to develop a baseline of different economic, development and climate change factors whilst addressing a 10% decrease in cost of building and maintaining defences between 2015 and 2021 - whilst reducing the overall flood and coastal erosion risk.
- Uncertainties include climate change costs, changing future costs, degree of flood plain development with substantial residual risk. Use of scenarios relative to the baseline.
- Social expectations and human implications is constantly brought into the decisions for addressing flood risks. Political trends such as degree of investment in the short to medium term also impacts the ability to make decisions.

Preparing for an Uncertain Future: Developing Robust Climate Adaptation Plans in the Water sector.

- A number of uncertainties and risks need to be addressed when planning in the water sector. These include: (1) How might the climate change? (2) How might other uncertain drivers interact with climatic changes to impact society? (3) How can we evaluate many potential futures objectively?; (4) How do we balance across many objectives; and (5) How do we support public dialogue over choices.
- Planners require technical analysis that support deliberations fusing innovative methods with data driven participatory planning. Methodologies, used at different stages of planning, include: Exploratory Analysis, Robust Decision Making (RDM), Decision Scaling; Multi-objective Robust Decision Making; and Dynamic Adaptation Pathways.
- Concepts underlying decision making under uncertainty methods include: (1) Evaluation of a multitude of futures; (2) Define candidate Strategies; (3) Identify key vulnerabilities of candidate strategies; (4) Develop robust strategies that adapt over time as the future unfolds; and (5) Highlight key trade-offs and support deliberations. A detailed rundown of the RDM process is available in the presentation.
- Approach has been applied internationally in many different settings such as for: (1) Water Resources Planning; (2) Community Resilience; (3) Coastal Resilience; and (4) Flood Risk Management. A case study of the application for RDM for water management for Lima-Callao, Peru was given and is available in the slide pack.

The following themes were developed in the Q&A session:

- The challenges of treating the non-linear risk such as flooding and with a linear implementation strategy requires the incorporation of simplified decision making schemes to deal with the risks. In Anglian water there has been an attempt to incorporate customer opinion into decision making to augment traditional cost analysis methods in order to get better consensus on decision making. This has involved multi-criteria decision making and has been fairly successful. The release of data to the public by the Skoll Foundation has also allowed collaborations to be developed.
- In order to manage risk better within organisations at a senior decision making level there is a need to incorporate technical sides of the organisation to communicate with decision makers so as to provide reassurance and better decision making.

4. Break-Out Session Synthesis

Break-out sessions were used to landscape the use of tools, barriers to their deployment and implementation into strategy across industry, policy and academia. The following is a summary of the findings from these sessions.

4.1. What tools do organisations use?

Tools span a wide range, varying by organisation, need, and scale: from mathematical modelling and optimization, through qualitative analysis or evidence and argumentative analysis, to participatory modelling and stakeholder engagement tools. Techniques vary broadly by the organisation's sector (e.g. public, regulated, private) and industry; by reactive and proactive responses to risk; and by the organisational unit (e.g. engineering and operations or business and strategy). *More detail will follow in the Grantham Policy Note.*

General approaches to risk management include risk transfers (e.g. by contracts and insurance), direct risk mitigation, or avoiding the risk by adjusting strategy (e.g. by inclusion in company hurdle rate). Risk-specific expertise can either come from within the organisation or can be hired externally. Complexity occurs when risks are developed endogenously to the organisation – they can combine with external risks to form compound risks. Not all risks can be hedged or transferred - the requisite financial products may not exist or may be outside the reasonable expectation for management (e.g. investors would have found an ex-ante decision by management to hedge against the financial crisis or the oil price collapse inappropriate). Further, decision-maker bandwidth and expertise is limited.

4.2. What are the challenges organisation face in employing risk and uncertainty tools?

Advocates most regularly encounter barriers in organisation culture and industry norms which need to be overcome in order to adopt better practices (e.g. industry preference for IRR-based decision making and risk inclusion in the hurdle rate). Human and behavioural factors dominate organisational decision making, including instinct and experience. There is a need to adapt existing decision-making frameworks slowly, beginning with what DMs are familiar with and slowly incorporating new tools.

Additional challenges come from managing compound risk (i.e. risk complicated by both endogenous and exogenous factors) and strategic uncertainty (where the organisation's actions will influence the responses of others which create the risk). Delegates reported insufficient feedback and measurement processes, and a failure to connect ex-post impacts with ex-ante analysis.

Ownership of risks depends on the organisation. For private businesses, it might be the Board of Directors. For public organisations, it might be the public and politicians. This difference drives the response of decision makers to risk and uncertainty (e.g. a CEO's legacy is based on the risks they took, and they express visionary leadership with confidence in their decisions despite uncertainty. A politician might recognise the uncertainty in their decision making and politically hedge or delay their choices). Organisations with more strict hierarchy have an easier time identifying who owns risks, however they may have difficulty ensuring free-flowing information. For large organisations, decision making or risk management may be centralised far away from 'on the ground' conditions. All organisations suffer from agency problems – planning horizons are multiple decades but the career or responsibility of organisational agents may only be a few years.

Decision makers are often overwhelmed by data. What DMs need is actionable information. Organisations of all types have challenges mixing qualitative and quantitative data and information (e.g. a reputational risk on a potential merger might make the deal a 'no go', but this is very difficult to capture with any qualitative data, let alone reconcile with the other quantitative analysis concerning the merger). Organisations may find it easier to put resources into event response rather than prevention, despite prevention being a far more efficient use of resource. Decision makers sometimes must also choose whether they are seeking the optimal solution or the least-bad solution. This will also vary by organisation and the interest and influence of stakeholders.

4.3. How do these outputs impact strategy development?

Internal risk is often managed through internal processes, policies, strategies and codes. External risks are often assessed using frameworks that are more scientifically rigorous, i.e. more probabilistic.

Organisations recognise that the past does not predict the future, but the past is all they have to base their modelling on. As a behavioural issue, the recent past is particularly over-weighted. Limitations to the length of record-keeping limit the precision of modelling (e.g. flood planners must make projections for over 100 years based on 50 years of records).

Approaches to long-term and 'deep' uncertainties are fundamentally different between the public, regulated, and private sectors. The planning horizons of organisations range from several decades for private organisations to almost a century for public organisations. All organisations, but especially private ones, struggle to capture the social implications and interactions of their decisions. Other constraints, like environmental and macroeconomic conditions, are difficult for organisations to conceptualise and capture, driving decision-making into the more tangible short term. These externalities eventually have an impact on the organisation, even if this impact is only relative to a preferable counter-factual case.

4.4. What is missing in these processes?

As much as the information being provided to DMs must improve, so too must the DMs' abilities to interpret and use that information. DMs are enthralled to the decision-making processes of long-dead economists. Critical questions must be asked of the role of the DM. Are they paid to manage risks? Or to make experiential judgements? Visionary leadership might be incompatible with technocratic data-driven decision-making. Perhaps the value of DMs should be their knowledge of the shortcomings of the models and the behavioural traps and biases inherent in the development of the models, which are imperfect by definition.

Even if they are able to overcome 'single number' preference, DMs are faced with a series of challenges and their own behavioural biases which prevent more sophisticated decision making. They may be beholden to external stakeholders (e.g. investors and traders) who demand substantial executive-level bandwidth or who do not appreciate more sophisticated decision-making methods. DMs may even seek to limit their own access to information to provide

themselves with built-in deniability in case benefits fail to materialize. Perhaps the best way to influence DMs is to influence their close advisors, both internal and external to their organisations.

More measurement and validation in organisations will improve the overall quality of decision-making processes. Data monitoring and sensing and trigger thresholds and events, both qualitative and quantitative, can lead to more structured decision making processes and reviews. DMs and their advisors must be held to account for the quality of their decisions and recommendations. Proper connection of ex-ante analysis to ex-post impacts of decisions made will allow the separation of the good forecasters from the lucky ones. Ex-post analysis must also identify the gap between the intention of a decision and its implementation.

A wider conversation needs to be had about the management of systematic risks (e.g. can or should organisations manage systemic risks like the financial crisis?). However the boundary of where risks become systemic varies for different risks (e.g. social, environmental, economic, financial) in different industries. Delegates expressed that scenario development often develops along too narrow a band of foreseeable futures. Even having a long-term plan has costs, and decision making needs to balance nearer-term 'no regrets' actions with long term strategic positioning.

4.5. What should be done about it?

Multiple-criteria and robust decision making methods need to be put in to practise. Many methodologies exist, however convergence is needed to develop optimal tools informed by successful practise. One avenue to enhance the use of these tools is to work with fund-granting organisations. If the fund granters use more advanced risk and uncertainty tools, it may drive culture change in grantee public organisations. Likewise better understanding of tools by investors may drive performance in private organisations.

The study of risk and uncertainty needs to move from science to practise. Application is currently siloed by industry – substantial public value can be created by better information sharing. However the form of this information is very important. The strength of consultants is to identify forms of information which help experts communicate most effectively with decision makers. Decision makers can start by asking the right questions of their advisors (e.g. how do we ensure the lights don't go off more than 3 hours per year?). Better visual aids, more consistent cross-sector vocabularies, and widely applicable case studies are needed to build cross-sectoral capacity.

There is a need to map the research space, the availability of resources, and the public organisations who are interested in the development of these tools. Research should prioritize how to include more socio-economic and qualitative interests in decision-making tools and how to bridge research into private organisations. *See forthcoming Grantham Policy Note for more details.*

5. Special Session: Communicating Risk and Uncertainty

Led by **Dr Catherine Butler**, Advanced Research Fellow, University of Exeter

The talk given in this session can be found in the following [link](#). A summary and the themes developed in this session can be found below.

Summary

- Communicating risk and uncertainty is a messy process.
- There are three key debates in communicating risk and uncertainty. These three areas were then expanded upon with examples:
 - (1) Interpretation of risk and uncertainty - is a social process with multiple interactions, forms of experience, values, and views influencing decisions and how information is processed; and not a purely rational and calculative process, it involves emotional and political elements which serve diverse interests.
 - (2) Public participation, engagement and uncertainty. Conventional approaches to decision making are often poorly adapted to account for the challenges in complex dynamic systems where indeterminacy can be inherent. Indeed frameworks that allow for decision-making to be responsive and more robust in light of the inevitability of shocks, which have multiple pathways, are seen as more acceptable.

Central to creating an alternative approach is an understanding of the ways that different people and groups value different aspects of systems and goals or outcomes, and frame the issues in fundamentally different ways. The narrowing of framing results in narrow range of options being considered (e.g. risk and control, singular tech responses) and reduces the ability for responses to account for inevitable changes and surprises over time.

- (3) Communication beyond 'formal' modes covers issues such as: (1) Beyond participation as a means to solve problems of deficits in information, legitimacy, trust, or acceptability; (2) Engage with plurality, open-up, reflexivity; (3) Institutional body language; and (4) Emergent publics and generative events.

The themes developed in the Q&A session were as follows:

- Agency of the public - who represents the public, how does one measure the risk tolerance of the public, how to be transparent and communicate what the issues that are at stake and how to live with the consequences of the decision especially if they are impacted negatively e.g. if more dredging of rivers were to take place around the Somerset levels would the next public outcry from flooding be as strong as it has been in 2014?
- Different aspects of evidence to create trust - what represents an evidence base and the truth-who should have access to it and be responsible for framing it? What legitimacy do different actors have in being experts? How do you know you are answering the right question and bounding it right e.g. the dancing of the risk thermostats in that seatbelt legislation resulted in less car born casualties but more casualties for other transport modes.

- How to institutionalise plurality into present regimens? Can the government abrogate responsibility following large disasters? Can you decentralise all decision making in increasingly complex systems operating over multiple, coupled scales? Does the public have the capacity to comprehend the issues and trade-offs that need to be considered? It was also noted that in developing nations water programmes don't get any traction without engagement and the use of participatory methods.

6. Specialist Panel

An open panel session was held with the specialists in an open question format and moderated by Kaveh Madani.

A summary and the themes developed in this session can be found below.

Summary

- Decision making under uncertainty is a maturing field but it is growing with more events taking place every year and more case studies becoming more available. It was observed that the majority of the work undertaken in Deep Uncertainty has been undertaken in the water sector though it is expanding into other domains. The degree of proliferation of these tools beyond the US and Europe is less well understood. Furthermore, the role of cultural pre-dispositions and socio-cultural impacts of utilising the tools and embedding them into strategy and decision making systems beyond the US and Europe is understudied.
- There is a need for greater understanding of what the different tools can do and how they can address problems. The outcomes of the tools need to be tailored to the different audiences within decision making hierarchies. The trend from the use of tools for exploratory purposes rather than deterministic ones was also noted which means that there is no one single answer to the problems posed. Furthermore, there is a lot of complexity that audiences simply don't understand.
- Related to the above was the comparability of the different tools. The application of the tool is predicated to the nature of the problem though different tools can be applied in a complementary fashion to gain further insights. However, the transaction costs of having two methods being run alongside each other in a 'bake-off' manner is problematic: it would involve having two sets of expert teams running computations alongside each other producing different outputs. The relationship between processes and tools was also aired: the nature of the tools selected tends to dictate the process of engagement with decision makers - though where necessary the process of engaging decision makers should be undertaken when deemed appropriate as that is where fundamental change can occur. Where possible there is a need to integrate and iterate.

- On advice for communicating with decision makers the following was aired: It is not down to the decision making under uncertainty community to inform decision makers which decisions to make. There is a need for explicit communication of the boundaries, transparency, provenance and inclusivity on the part of the analyst community. When communicating the issues to decision makers they like information condensed into process-able packets: (1) maps, graphs and other visuals; (2) context of options and decisions is important; (3) relate the experiences and outputs to their experiences; and (4) having a menu of options at their disposal.
- Accounting for the lack of information was discussed, which contrasted with the fact that in one of the talks concern was expressed at the volume of data available and the need to be able to assimilate the information in a timely manner was an important imperative in order to allow timely decision making. Data protection laws, commercial sensitivity and over specificity of some agencies limits access and the usefulness of data. The trend for open access, Freedom of Information Act and funding agencies stipulating more open access to modelling that is undertaken and institutional awareness of the need for data availability are assisting in making information more available.
- The decision making paradigm considered so far has tended to focus on an authoritarian model whereby a single individual / entity is empowered to make a set of decisions. Are there other models of decision making that can be considered to address some of the problems identified to which decision makers are subjected when engaging with the analyst community to make decisions under risk and uncertainty? The example of Citizen Juries or Jury by Peers were aired but these don't necessarily address the problems of scoping, framing, bounding and early consensus development amongst audiences.

7. Wrap-Up and Concluding Remarks

A short wrap up session was given by Mark Workman to summarise some of the salient issues raised by the workshop. They were categorised along the following themes of: (1) tools; (2) Decision makers; and (3) Communication to different audiences.

These are outlined below:

(1) Tools

- There are a variety of a wide variety of tools being used across sectors.
- There has been a shift to the exploratory use of models rather than for predictive use as a function of this decision makers have to understand that there is more than one answer - it is a process.
- There is a shift to making small decisions that avoid lock in and keep options open for later.

- A critical area to address is around problem conceptualisation and inherent embedded biases of institutions - there is a need to ask are we answering the right question? And therefore the role of appropriate framing.
- There was a feeling that socio-economic impacts of decisions are ignored.
- There is a need for transparency, provenance and inclusivity on the part of the analyst community when undertaking work and engaging with decision makers.

(2) Decision Makers

- It is hard, it is complicated. It is not as simple as it was in the past.
- There is a need to understand the world of the decision maker better: you won't change the world and therefore there is a need for analysts and academics to better understand it.
- Policy makers don't buy options they would rather defer a decision.
- Sophistication of analysis is lost when it has to be aggregated and presented to the decision makers: A 'single number outcome' is preferred.
- The weak link is the transfer of information between analysts and decision makers:
 - Decision makers bandwidth is already overwhelmed.
 - Do we need to integrate the decision makers into the analytical process? How do you do this without influencing the decision that is made?
 - Assumption that decision makers know how to make decisions in the modern era? Is there a need to educate / profile decision makers?

(3) Communication

- Language and ease of understanding:
 - length of briefing scripts for audiences v's bandwidth that audiences have the assimilate the information;
 - deciding on the metrics selected; and
 - cultural differences (sectoral and national) – need for socio-cultural analysis.
- How to convey information to different audiences and those that are impacted?
- Difficult to get the vulnerabilities communicated - people don't like bad news.
- Getting society to understand the issues more - there is an appetite: But who represents society and which fora to use to communicate issues?
- There will always be some level of ignorance.

Next Steps

The workshop planning team are trying to capture things that we do not know or that have not been identified as of yet to develop: (1) traction; and (2) meaningful interventions in the decision making under uncertainty sector. Under the following categories the following points were raised:

(1) Have we covered the right stuff?

- It was useful to not just talk about the tools and cover their applications and aspects.
- Sectorial diversity was extremely useful and it was interesting that many of the problems were similar and it allowed a good cross-sectoral learning opportunity.
- Having the analysts at a number of levels within different organisations present their problems was very useful as they don't always get the opportunity to do so in such fora.

(2) What should we do more of?

- It would be useful to have a lay persons guide to the different tools available and how they might be applied to different problems.
- There is a greater interest in deep uncertainty and epistemic uncertainty rather than risk and the activity should focus on these aspects of uncertainty rather than risk.
- Invite psychologists, behaviour and communication specialists, the finance and insurance sector.
- Allow a session to engage with decision makers to better understand the needs of different communities. Some of the outputs from this workshop were similar to the outputs of a Heads of Analysis in Government – there might be the opportunity to link up the two communities.

(3) What should we do going forwards?

- Link with the RAND annual conference on Deep Uncertainty. See also www.deepuncertainty.org
- In line with the need for have a better understanding of what the different tools can do and how they can be applied there might be the possibility of having a practitioner summer school over a number of days.

It was felt that there was an appetite for the following:

- A Decision Making under Risk and Uncertainty Community which would involve an interaction between academia- industry and policy makers to develop thinking in this area. This community might: (1) Have regular webcasts, share problems and solutions; (2) Respond to events; and (3) Develop thinking as to how issues might be best addressed as the agenda evolves; and
- For a regular annual meeting which would evolve from the present format / scope as the sector matures.

The organisers would like feedback from attendees and any other relevant stakeholders to assess how to shape the community and the evolution of the next workshop. Please get hold of either Lucas Kruitwagen on Lucas.kruitwagen14@imperial.ac.uk and/or Mark Workman on: mark.workman07@imperial.ac.uk to register your views.

Annex 1: Workshop Schedule

WEDNESDAY 10 FEBRUARY 2016

9:00 – 10:00	Refreshments and Registration
10:00 – 10:30	Welcome and Introduction Welcome from Joanna Haigh, Grantham Institute Introduction by Kaveh Madani, Centre for Environmental Policy
10:30 – 11:45	Session I: Pop-up Talks 1) Harvey Beck , OFGEM 2) Chris Hankin , Imperial College London 3) Anna Railton , Smith Institute 4) Julian Frost , JESIP Cabinet Office 5) Mike Colechin , Energy Technologies Institute Specialist: Patrick Reed
11:45 – 12:15	Break
12:15 – 13:30	Session II: Pop-up Talks 1) Dennis Konadu , University of Cambridge 2) Ian Temperton , Ian Temperton Consulting 3) Alexandra Collins , Imperial College London 4) Julien Harou , University of Manchester Specialist: Liz Varga
13:30 – 14:30	Lunch
14:30 – 15:30	Break-out Session I Assessment of the use of different tools by organisations to account for risk and uncertainty in decision making - challenges and what to do about them (session I).
15:30 – 16:00	Break
16:00 – 17:00	Special Session: Communicating Risk and Uncertainty Led by Catherine Butler, University of Exeter
17:00 – 18:00	Specialist Panel Moderator: Kaveh Madani, Centre for Environmental Policy
18:00	Dinner

THURSDAY 11 FEBRUARY 2016**8:00 – 9:00 Refreshments and Light Breakfast****9:00 – 10:15 Session III: Pop-up Talks**

- 1) **Simon Collander-Brown**, DSTL
 - 2) **Anant Prakash**, BP
 - 3) **Simon Cook**, Southern Water Services
 - 4) **Rosalind West**, DEFRA
- Specialist: **Jan Kwakkel**

10:15 – 10:30 Break**10:30 – 11:20 Break-out Session II**

Assessment of the use of different tools by organisations to account for risk and uncertainty in decision making - challenges and what to do about them (session II).

11:20 – 11:45 Break**11:45 – 13:00 Session IV: Pop-up Talks**

- 1) **Adam Whitmore**, Adam Whitmore Consulting
 - 2) **Bessma Maroud**, Skoll Global Threats Fund
 - 3) **Steve Moncaster**, Anglian Water
 - 4) **Mike Steel**, Environment Agency
- Specialist: **David Groves**

13:00 – 13:30 Wrap-Up and Concluding Remarks**13:30 Lunch and Close**

Annex 2: Attendees

Susana Almeida , Postdoctoral Research Assistant	University of Bristol
Harvey Beck , Environmental Economist	OFGEM
Michael Burgass , PhD Student	Imperial College London
James Bussell , Principal Adviser	Natural England
Catherine Butler , Advanced Research Fellow	University of Exeter
Karla Cervantes , PhD Student	University College London
Mike Colechin , Partnership Manager	Energy Technologies Institute
Simon Collander-Brown , Principal Analyst	DSTL
Alexandra Collins , Research & Knowledge Exchange Fellow	DEFRA
Simon Cook , Water Resource Planner	Southern Water Services
Geoff Darch , Head of Climate Change	Atkins
Paul Dodds , Lecturer	University College London
Kim Dowsett , Climate Change Advisor	Environment Agency
Tohid Erfani , Lecturer in Water Engineering	University College London
Clemence Finaz , Programme Officer	International Alert
Julian Frost , JESIP Police Senior User	JESIP Cabinet Office
Helen Greenhough , PhD Student	Imperial College London
Alastair Gregory , PhD Student	Imperial College London
David Groves , Professor	Pardee RAND Graduate School
Chris Hankin , Director	Imperial College London
Julien Harou , Professor	University of Manchester
Daniel Hdidouan , PhD Student	Imperial College London
Edward Hgarth , Finance Manager	Rolls-Royce
David Holland-Smith , Fellow	DSTL
Candice Howarth , Senior Research Fellow	Global Sustainability Institute
John G Rees , Professor	NERC
Matthew Ives , Senior Researcher	University Of Oxford
Ceris Jones , Climate Change Adviser	NFU
Gary Kass , Deputy Chief Scientist	Natural England
Dennis Konadu , Research Associate	University of Cambridge
Grant Kopec , Managing Director	Foreseer Ltd.
Ariella Kristal , Associate Advisor	Behavioural Insights Team
Lucas Kruitwagen , Visiting Researcher	Imperial College London
Jan Kwakkel , Assistant Professor	Delft University of Technology
David Lenaghan , Innovation Lead	National Grid
Kaveh Madani , Senior Lecturer	Imperial College London
Jim Maltby , Strategic Analyst	DSTL
Steve Moncaster , Supply & Demand Strategy Manager	Anglian Water
Bessma Mourad , Program Officer, Water	Skoll Global Threats Fund
Fernando Parra , Commercial Analyst	SSE
Edward Pope , Senior Applied Scientist	Met Office
Anant Prakash , Strategy Advisor	BP

Meysam Qadrdan , Lecturer	Cardiff University
Raul Quinceno , Senior CO ₂ Analyst	Shell
Anna Railton , Consulting Mathematician	Smith Institute
Patrick Reed , Professor	Cornell University
John Rees , Risk Research Coordinator	RCUK
Michael Reynolds , Director of Propositions & Solutions	SSE
Andrew Richards , Severe Risk and Resilience Analyst	National Grid
Bora Ristic , PhD Student	Imperial College London
Henry Ross , Development Manager	SSE
Amiera Sawas , Researcher	Imperial College London
Amber Sharick , Industry Network Manager	UKERC
Mike Simpson , Post Doctoral Research Assistant	University of Oxford
Sophie Smith , Project Manager	Imperial College London
Mike Steel , Expert Advisor	Environment Agency
Ian Temperton , Director	Ian Temperton Consulting
Owen Turpin , Senior Advisor Water Resources	Environment Agency
Liz Varga , Professor	Cranfield University
Janani Vivekananda , Head of Climate Change & Security Programme	International Alert
Rosalind West , Climate Science Advisor	DEFRA
Adam Whitmore , Director	Adam Whitmore Consulting
Mark Workman , Analyst	Energy Research Partnership