

“I’m extremely happy that we’re going to have a formalised understanding between the Joint Research Centre and Cambridge University. I hope very much that European policy will profit from these contacts and from this ocean of knowledge within Cambridge.”

Vladimír Šucha, Director-General of JRC

Feeding the world

How can food supplies and supply chains be made more resilient?

At a glance

The overarching theme of our third topic was ‘risk, resilience and response’ and between October and December 2015, we focused on food water security and supply chain resilience. These three meetings were jointly hosted with the Joint Research Centre (JRC) of the European Commission and formed the core of a pilot activity under a new Memorandum of Understanding between the two institutions to enhance inter-institutional collaboration.

‘Green growth and sustainability’ was chosen as the pilot topic and the Forum worked with JRC and University Strategic Initiatives, including the Cambridge Conservation Initiative and the Global Food Security Initiative, to develop a series of meetings and projects to explore potential areas for future collaboration. The three co-hosted Forum meetings formed the focal point of this programme and each month, expert witnesses and guests from the JRC came to Forum meetings and helped to shape the theme as a whole.

This summary provides an overview of some of the ‘wicked problems’ and questions generated during these discussions. Additional outputs put these questions in a broader context and explore potential future collaborations between the JRC and Cambridge.

Taking a global view

The quality and quantity of data were both recurring themes throughout the discussions. In the first meeting, Professor Alan O’Neill, the founding Director of the NERC National Centre for Earth Observation, highlighted that big data is providing new kinds of datasets and opportunities to measure resilience and risk at a global scale in real-time and at high resolution. However, the volume, complexity and heterogeneity of large-scale datasets also pose challenges for both researchers and policymakers. As a result, there is a need to train more data scientists who are not only technical experts but also familiar the underlying environmental, social and economic issues.

This will enable them to know both what questions to ask and how the data can be used to answer them. Although innovation and developing new techniques is important, solving some of these problems may not necessarily involve more advanced technology. Dr Matt Smith, an ecologist who works in the Computational Science Lab and Microsoft Research, suggested that some of the data challenges we face are quite basic and technical solutions already exist, perhaps in other fields. Finding ways to apply existing technology to solve problems is therefore as important as developing new technologies.

In addition, Thierry Nègre, the Head of the Food Security (FOODSEC) Group at JRC, suggested that, despite the recent advances in data collection, there is an issue with the scarcity and quality of data in areas such as food security or food production. This was, particularly in developing contexts because of issues such as the lack of resources or funding and institutional barriers rather than due to any particular technological limitations. This compromises the ability to develop accurate models in key areas. The limitations posed by institutional barriers with regard to both data collection and effective use of data was mentioned frequently throughout the meetings.

Turning data into information

A related problem was that of turning data into useful information and then communicating that information in a meaningful way to end-users. Currently, there is a disconnect between the amount of data, the information gleaned from these data and people’s ability to turn theory into practical solutions. For example, satellite programmes such as the new Copernicus ‘family’ of satellites are generating vast amounts of high resolution data which will enable us to see global environmental changes in a way never before possible. Being able to process and analyze data on such a massive scale is a huge challenge in itself. Turning those data into information people can use to make decisions adds another layer of complexity. Craig Mills, the CEO of Vizzulaity, described the work his company does to visualise complex scientific datasets to create clear,

Key questions

Through our discussions, we identified four key areas where more research is needed:

- **How can we move from tracking historical trends in food and water supplies to identifying emerging risks and create future projections and scenarios?**
- **Decisions are taken at multiple scales from local to international. What place does satellite data have in decision-making at all of these scales and is it feasible to use it to make local scale decisions?**
- **Given the pace of change, how do we collect and analyse data in a way that feeds into policy processes in time to be most effective?**
- **What role can citizen science play a role in this ‘new world’ of open, big data?**

Catalyzing collaboration

To help facilitate the collaboration between JRC and Cambridge, an EPSRC Institutional Sponsorship Grant was given to a joint project between the Forum and the Global Security and Crisis Management Unit at JRC. This four-month project employed a Cambridge-based research assistant, Adrià Descals Ferrando, to start to explore questions which could be answered by overlaying two of JRC's remote-sensing datasets:

Global Surface Water Explorer, which measures changes in the location and persistence of surface water globally, by region or for a specific area.

Global Human Settlement Layer, which provides information about where people live, how big settlements are, how they have changed over time and the density of built up areas.

Both of these have unprecedented levels of spatial detail for global data (30m resolution) and span the last 30 years. The project explored ways in which combining data from both of these could provide information to inform policy, such as tracking progress towards the Sustainable Development Goals, and enable faster responses to environmental extremes and acute threats.

communicable messages that people can interact with and understand. He and his team often have to work closely with researchers to ensure that the messages from the data are clear and simple while still maintaining its scientific integrity. Presenting complex information is a real challenge and both technological solutions and way the results are communicated needs to be adapted to suit the target audience. More research into how data affects decision makers was also recommended, as there can be external factors that override the influence of scientific advice on policy decisions.

Using big data effectively and ethically was another recurring theme. Stephen Peedell, a specialist in geospatial information technology from the Land Resource Management Unit at JRC, argued that remotely sensed data does not replace the need for ground sensors and information, but instead complements it. Remote sensing data will always need to be 'ground-truthed', and aligning it with economic, social and biological data provides both context and cements connections between changes in the environment and the effects on people's lives. Consequently, there also needs to be better links between large-scale datasets and data that are gathered at a more local level.

There were also concerns over the proprietary nature of some datasets, issues regarding data standards and data confidentiality. Publicly funded institutions such as the Joint Research Centre have open data policies and strict guidelines surrounding data standards as well as the infrastructure to provide technical and content updates and support. Other data providers, such as private companies, do not have such obligations and can choose which data they put in the public domain, for how long and the conditions they attach to using it. Privately held data contains a wealth of detail and information and there is a danger that if these datasets are not openly and transparently made available, opportunities to address local and global scale challenges may be lost. Sharing data may raise confidentiality concerns, but these should be weighed against the potential value derived from data being examined from a wide range of perspectives.

Taking a systems approach

The resilience of food chains was examined, and Dr Mukesh Kumar, from the Institute for Manufacturing, identified three principle areas of concern: crop failure, product failure and supply chain failure. This was echoed by Professor Jaideep Prabhu from the Judge Business School who discussed food waste in developing countries stemming from supply chain issues, such as the lack of information for farmers concerning neighbouring areas and consumer requirements as well as the need for a better cold chain.

Throughout the three months the need for a multidisciplinary approach to food security was emphasised, by Dr Francois Kayitakire. He leads a team working on resilience and on food and nutrition security assessment at JRC and he argued that there are a number of interrelated issues that must be considered as part of a system approach. These range from conflicts surrounding resources to the need for income-related social protection to help bolster access to food. Our goals and the means to achieving them should therefore orientate around a problem, rather than a discipline. This general approach was echoed by Dr Drew Purves, an ecologist who now works for Google Deepmind. He emphasised that food must be part of a global system, particularly given the increasing risk posed by climate change. It was also repeatedly stated that a long-term view is needed to build resilience in food and water systems, although short-term interventions are also needed when an immediate impact is required.

The Cambridge Forum for Sustainability and the Environment was established in 2013 in the University of Cambridge. Chaired by Lord Martin Rees, it meets once a month, bringing together thought leaders from the worlds of research, policy and industry to talk about some of the great sustainability challenges the world faces in the future and the research pathways which will help to prepare for and address those challenges.

Secretariat: Prof. Paul Linden (Director); Dr Rosamunde Almond (Executive Secretary) and Simon Patterson (Content Writer and Editor).

Forum members for this topic were drawn from 15 Departments, Centres and Initiatives, including: Prof. Alison Smith (Dept. of Plant Sciences); Prof. Danny Ralph (Centre for Risk Studies); Dr Emily Shuckburgh (British Antarctic Survey); Dr Helen Curry (Dept. of the History and Philosophy of Science); Dr Hildegard Diemberger, (Dept. of Social Anthropology); Prof. Doug Crawford-Brown and Prof. Ian Hodge (Dept. of Land Economy); Prof. Ian Leslie (Computer Laboratory); Dr Jake Reynolds and Polly Courtice (Cambridge Institute for Sustainability Leadership); Dr Julian Huppert (POLIS); Prof. Koen Steemers (Dept. of Architecture); Dr Miles Parker (CSaP); Prof. Paul Dupree (Dept. of Biochemistry); Prof. Peter Guthrie (Dept. of Engineering); Dr Shailaja Fennell (Centre for Development Studies) and Prof. Susan Owens (Dept. of Geography).

Witnesses: Stephen Peedell, Dr Francois Kayitakire and Thierry Nègre (JRC); Dr Mukesh Kumar (Institute for Manufacturing, University of Cambridge); Prof. Alan O'Neill (Cavendish Laboratory, University of Cambridge); (JRC), Dr Matthew Smith (Microsoft Research), Craig Mills (Vizzulaity), (JRC), Prof. Jaideep Prabhu (Judge Business School) and Dr Drew Purves (Google Deepmind).

Internal guests: Dr David Coomes and Dr Will Simonson (Dept. Plant Sciences); Prof. Keith Richards and Therese Rudebeck (Dept. of Geography); Dr Marla Fuchs (Research Strategy Office); Dr Martin Roberts (Cambridge Centre for Sustainability Leadership); Dr Nazia Mintz-Habib (Centre for Development Studies) and Kirsten Van Fossen (IfM).

External Guests: Gregoire Dubois and Dr Pamela Kennedy (JRC); Daria Dadam (BTO); Dr Gavin Shelton, (FFI); Dr Graeme Buchanan (RSPB); Prof. Neil Burgess and Tim Wilkinson (UNEP-WCMC) and Simao Belchior (Vizzuality).

“We cannot have different systems of resilience for every new risk or peril that comes down the track. Instead, we have to have a coherent framework for dealing with risk that can actually evolve.”

Rowan Douglas, Willis Research Network

Taking a long term view of cities

How can cities become more resilient and how might big data shape the way we view and plan them in the future?

At a glance

The overarching theme of our third topic was ‘risk, resilience and response’ and between January and March 2016, we focused on cities. These meetings built on some of the questions that framed our discussions during our first topic, sustainable cities. Expert witnesses from the worlds of policy, research and industry helped us to explore the role that technology and big data could play in making cities more resilient to short term shocks and long term changes in the environment

In January and February, we discussed new ways to layer social, economic and environmental datasets in order to assess risk and resilience in cities, and how vulnerable they are. In March, we turned to catalyzing change and ways that cities can become more resilient in practice.

This article provides an overview of key emerging themes and some of the ‘wicked problems’ and questions generated during these discussions. Some of the themes related to big data are explored in more detail in our ‘Cities of the Future’ report’, published on our website: www.cfse.cam.ac.uk.

Understanding risk and resilience

One of the key topics of the three meetings was the level of our current understanding of the nature of risk and resilience. This was encapsulated by Dr Emily Shuckburgh, Deputy Head of the Polar Oceans Team at the British Antarctic Survey, who identified four areas that need improvement so as to support resilience: more data collection and processing, particularly at the local level; metrics for risk, mitigation and adaptation; instruments for considering uncertainty in decision-making; and the interface between various key stakeholders of the scientific, legal and political community, amongst others. The complexity of the topic means that resilience and risk are subjective continuums, which should be reassessed after catastrophes, rather than exact thresholds.

Dr Prathivadi B. Anand, a specialist in environmental economics and public policy from the University of Bradford,

argued that there is a societal need to transparently decide what risk is acceptable and cost effective, as well as how much redundancy or resilience should be built into infrastructure. Mitigating every risk is impracticable. Striking a balance in this area is challenging as overdesigning can have unintended consequences, but is often desirable in buildings which need to function after a disaster. The general population is often not aware of risk, which can lead to complacency with regard to mitigation measures. Likewise, knowledge and experience about risk and resilience also needs to be shared between cities and institutions to increase overall preparedness for disasters.

Professor Danny Ralph, who introduced the work of the Centre for Risk Studies, also stressed this need. In 2016, the Centre examined the economic loss of 300 major world cities resulting from catastrophes, and this process emphasised where there was a lack of knowledge and models that need to be addressed in risk management thinking, such as the difficulty of assessing all systems including the social, commercial and legal sectors. Assessing systems in across different areas, sectors and levels, is also a challenge, as highlighted by Professor James Jackson, Professor of geophysics, geodynamics and tectonics in the Department of Earth Sciences. He argued that there is a disparity in the

Key questions

Through our discussions, we identified three key questions where more research is needed:

- **How can we make urban planning systems more adaptive and how can knowledge about risk and resilience be shared at an urban planning level?**
- **How much redundancy or resilience should be built into urban infrastructure and how do we introduce redundancy into social systems?**
- **How can we model direct and indirect effects of catastrophes on cities if they are outside the original impact centre?**

preparedness of countries exposed to earthquakes on the Pacific Rim and those in Continental Asia. The former are aware of the threat and have the wealth to enact policy. The latter, amongst other problems, struggles with complacency because of the large geographic distribution of earthquakes. In these areas, different approaches to mitigation and adaptation will be needed.

“We should not shy away from trying to talk about all threats to cities and from trying to understand that different systems within those cities have different dimensions.”

Professor Danny Ralph,
Centre for Risk Studies, University of Cambridge

Layers of data

Choosing the best metrics for modelling risk requires on-going work, although the insurance industry perhaps provides a useful exemplar for considering risk. It has adopted catastrophe risk modelling and a consistent regulated framework which enforces consideration of 1 in 200 year risks. Rowan Douglas, the CEO of Capital, Science & Policy Practice at Willis Research Group, argued that sustainability and resilience should be viewed through this prism of risk and creating a coherent set of frameworks, metrics and a common language that links all the various sectors beyond just insurance is crucial. The specific metric of 1 in 200 year risk may not always be suitable as it can overlook large, rare risks. Again, society needs to consider what is an appropriate standard and how this may vary according to the local context. In New Zealand the standard for insurance is now 1 in 1000 years. Imposing minimum requirements on other organisations outside the insurance sector would force organisations to assess and disclose their risks and be fiscally responsible. More broadly, protection from climate risk could be considered a human right and the UN and OECD are starting to move in this direction.

There were numerous other challenges considered with regards to metrics. The interactions between different and successive catastrophes need more analysis, as do the direct and indirect effects of catastrophes outside the original impact centre. Events which have a wider impact, such as the eruption of the Icelandic volcano, Eyjafjallajökull, introduce more complexity and uncertainty into models and methods of incorporating such events need to be developed. A number of other uncertainties with regards to risk and resilience were also raised: How can new events that have no past analogue be modeled? How are abstract and less quantifiable challenges, such as threats to biodiversity of mental health issues in society, assessed and costed?

Sérgio Freire, a geographer working in the Global Security and Crisis Management Unit of the European Commission's Joint Research Center (JRC), discussed the manner in which big data can be useful to answer some surprisingly fundamental questions about the state of global development that are necessary for understanding our current exposure to risk: what is a city, how many and where are they and what are their sizes and shapes? Professor Michael Batty, Bartlett the Professor of Planning at UCL, explored another use of big data as an emerging tool in the context of transport planning. For example, data from London's public transport could be compared to a synthetic baseline to assess the resilience of the system in real time.

Planning future cities

The use of big data is not without its difficulties. Incorporating risk metrics and dynamic big data into planning systems is another challenge that was emphasised by Dr Elisabete Silva, a Senior Lecturer in Planning in the Department of Land Economy. She argued that current planning systems are static and there needs to be flexibility in policy and decision-making to allow for changing scenarios and quick responses to dynamic data.

Big data and planning systems also need to adapt to the dynamic expectations of individual residents. For risk and resilience concepts to be successfully adopted there has to be communication and trust between communities and policymakers. The public has to understand, and help decide, where certain areas can or cannot be sensibly protected from disaster because of a lack of finance or resources. This relationship between the various stakeholders, ranging from the government to the individual, including industry, law and finance was consistently mentioned, and it was agreed that an institution like Cambridge University could help bridge these levels.

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We would like to thank everyone who took part in Forum meetings related to this topic, especially the expert witnesses and guests who joined us from across and outside Cambridge:

Witnesses: Prof. James Jackson (Dept. of Earth Sciences, University of Cambridge); Prof. Danny Ralph (Judge Business School); Dr Elisabete A Silva (Dept. of Land Economy, University of Cambridge); Rowan Douglas (Willis Research Network, Willis Group); Dr Emily Shuckburgh (British Antarctic Survey); Dr Prathivadi B Anand (University of Bradford); Prof. Michael Batty (University College London); and Sérgio Freire (Global Security and Crisis Management Unit, EC Joint Research Centre).

University guests: Prof. Andy Hopper (Computer Laboratory); Prof. Ash Amin (Dept. of Geography); Dr Bonnie Wintle and Dr Shahar Avin (Centre for the Study of Existential Risk); Dr Marla Fuchs (Research Strategy Office); Prof. Peter Tyler (Dept. of Land Economy) and Dr Tom Herbstein, (Cambridge Institute for Sustainability Leadership) and early career researchers, including Gerry Casey, Hannah Baker and Kristin MacAskill (Dept. of Engineering and Mingfei Ma (Dept. of Architecture)

Guests from outside Cambridge: Dr Alejandro Palermo (Royal Society of Chemistry); Prof. Charlie Kennel (CSaP) and Emily Miles (Defra).

“If we were to develop new technologies and new improvements on growing materials, there is a likelihood that demand will increase and this is a dilemma that will need not just technical solutions, but political and societal solutions as well.”

Edgar Blanco, Andigestion Ltd

Building resilient energy supplies

How could photosynthesis-based technologies can provide a sustainable and rapidly-deployable energy source for rural communities?

At a glance

For our final three meetings centred on ‘risk, resilience and response’, we focused on energy resilience. Between April and June 2016, expert witnesses helped us to explore ways in which photosynthesis-based technologies can provide a sustainable and rapidly-deployable energy source for rural communities.

In April, we focused on off-grid situations and to explore existing approaches and possible challenges while using local resources. In May and June, we turned to ways in which existing bio-energy technologies linked to photosynthesis can provide sustainable and rapidly-deployable energy and the role of policy in applying the principles of the circular economy to bioenergy provision.

This article provides an overview of key emerging themes and some of the ‘wicked problems’ and questions generated during these discussions. This theme was carried out in partnership with the Energy@Cambridge Strategic Initiative and the CamPlants Hub.

Living off the grid

One of the main points of discussion concerned the appropriateness of different technologies for providing energy solutions to developing areas. Professor Sir Brian Heap, Scientific Advisor of the ‘Smart Villages Initiative’, discussed biomass as a rapidly deployable off-grid energy solution but suggested that improvements needed to be made, including new and higher quality crops, new crop rotations, improved market efficiency and more affordable finance. However, overdependence on one particular energy approach can have unsustainable environmental consequences. Policy challenges for biofuels include the tension over land-use between energy and food production as well as issues regarding land rights; rebound effects, such as cheaper energy driving consumption higher; a lack of regulation to combat deforestation; and the need for better transport infrastructure.

The importance of biomass for food and resources led the Forum to consider additional technology options. Dr Heinz Ossenbrink, the Head of Renewables and Energy Efficiency Unit at the EC Joint Research Centre, discussed photovoltaic energy as an efficient option for energy production. Edgar Blanco, the Research & Development Manager at AnDigestion Ltd and a specialist on anaerobic digestion, mentioned various photosynthetic opportunities such as photosynthetic fertilisers and a need for more water-based solutions. Professor Chris Howe, Professor of Plant and Microbial Biochemistry in the the Department of Biochemistry at Cambridge, discussed biophotovoltaics, a new technology that harnesses electrons produced as a byproduct of the photosynthetic process, which could potentially be scaled up to charge mobile phones.

Key questions

Through our discussions, we identified four key areas where more research is needed:

- **How can bioenergy innovation be introduced wholesale into communities and how can technology be implemented in areas of rural poverty?**
- **How can sustainable and cost-effective fuels from biomass be delivered at a large scale, and what would encourage investors and markets to make long-term commitments?**
- **How important are technical solutions to solving global energy problems and how can these be developed in parallel with novel, and potentially unconventional, policy solutions?**
- **Is it feasible or sensible to move towards a circular economy primarily based on biological resources?**

Catalyzing new research

A recurring theme during these discussions centred on ways in which photosynthetic processes can be part of a bioenergy technology 'package' that might also address energy, water, nutrition and waste challenges in the developing world. The term 'circular photosynthesis' was coined to encompass this concept, and the ideas discussed in the Forum have since been developed further and been included in research funding proposals.

It was agreed that although improvements can be made, generally the technological capacity to solve problems already exists. No one technology will provide a solution, and direct and indirect energy savings need to be considered. Thus, in all three of the meetings the necessity for a holistic and multidisciplinary approach to energy was highlighted. The human energy footprint, encompassing food, water, energy and space requirements, must be considered as a whole. This could also help grasp the opportunity to combine energy production with other industry sectors, such as agriculture or waste disposal. Dr Rana Pant, from the Life Cycle Assessment and Environmental Footprint, Sustainability Unit at the EC Joint Research Centre (JRC), advocated a process known as life-cycle assessment, whereby a situation is assessed so that all ramifications of an action or policy are understood so as to avoid shifting the energy burden to a different region, time or part of system.

“Access to electricity is not the end goal in itself, it has to be a means towards an end and it has to mean something for the community.”

Dr Muhammad Tayyab Safdar,
Centre of Development Studies, University of Cambridge

From the ground up

It was frequently emphasised that there needs to be better engagement with and understanding of local populations; different areas need different solutions, and these must be tailored for a local context. For example, Dr Muhammad Tayyab Safdar, a Post-Doctoral Research Associate at the Smart Villages Initiative, pointed out that off-grid energy must serve a purpose, be it improving access to business opportunities, health care or education. The communication pathways between scientist and consumer need to be improved so that public scepticism regarding new technologies can be overcome. Dr John Mullet, the Director of SOWTech and an expert on waste solutions, emphasised that traditional practices are a key barrier to the success of energy projects, and the continued use of inefficient cooking stoves and charcoal was used to elucidate this point. Conversely, rural or developing communities can also be creative and innovative. Community engagement, education and further research into the mechanisms by which behavioural change can be encouraged are required.

Financial and policy challenges were a constant theme of the forum. New markets are needed that can adapt to the business model required for renewable energy sources, which involves heavy initial investment but long-term savings. Currently, companies need a lot of capital and it can be difficult for developing countries to establish subsidies, which may not be necessarily be a sustainable solution but can help demonstrate the viability of business models to encourage future private investment and consumer uptake. These financial barriers are exacerbated by subsidies for

fossil fuels. There needs to be greater policy clarity in developing countries, and globally the international community needs to explore unconventional policy solutions such as carbon passports or pricing, waste taxes and making people aware of the impact of their energy choices.

To aid policy decisions and create interventions that are appropriate for any given area requires interconnected modelling of the different elements. Paul Newell, a statistician in the Energy Science team at the Met Office, highlighted the unified nature of their models for local, regional and global hazards. They can also provide data regarding the best location for wind turbines or solar panels. Dr Jeremy Woods, a lecturer in bioenergy at Imperial College London, introduced the Global Calculator, a tool that shows the major points of action to mitigate climate change and the unforeseen impacts of policy change.

Circular economies

Combining these threads, the final forum focused on circular economies. Rob Mills, the Head of European Energy Markets at Ofgem, observed that in developing communities resource efficiency is often already high as a result of necessity. Again, a holistic view is needed to factor the interplay between household economics, price signals, societal norms and undermining existing markets and all the other possible trade-offs and rebound effects. The mechanisms that help motivate and inform people so they commit to environmental efforts need further research.

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Witnesses: Prof. Sir Brian Heap (Smart Villages Initiative); Dr Heinz Ossenbrink and Dr Rana Pant (EC Joint Research Centre - JRC); Dr Muhammad Tayyab Safdar (Institute of Continuing Education (ICE), University of Cambridge); Edgar Blanco (Andigestion Ltd); Prof. Chris Howe (Dept. of Plant Sciences); Dr John Mullett (SOWTech (Sustainable OneWorld Technologies) CIC); Rob Mills (Ofgem); Paul Newell (Met Office); and Dr Jeremy Woods (Centre for Energy Policy and Technology - ICEPT).

Guests: Dr Nicolette Bartlett (Cambridge Institute for Sustainability Leadership); Dr Matthew Davey and Dr Mariana Fazenda (Dept. of Plant Science); Prof. David Newbury (Faculty of Economics); Dr Marc Ozawa and Dr Isabelle de Wouters (Energy@Cambridge Strategic Research Initiative). Early career researchers included Carolina Feijao (Dept. of Biochemistry), and Richard Sidebottom (Centre of Development Studies).