CHANGEHORIZONS

Horizon Scanning for the Defra Partnership

NOVEMBER 2015

STRATEGIC EVIDENCE OF FUTURE CHANGE

Trends and issues for the natural environment and food systems

Summary report
November 2015

Gene editing has accelerated the biotechnology revolution	The impacts will be felt across whole areas of environmental science, food supply, and rural affairs.
Radically new food ingredients are being developed	Natural plant proteins can replace animal protein in food; and new genes will be introduced to the food chain.
The evolving "Smart Countryside"	What are the policy implications to ensure environmental and food benefits?
Challenge and opportunity in rural areas	The pace of change increases, as do the demands on rural areas.
Paris submissions suggest a 2.7ºC rise in global temperature	At current GHG emission rates, a 2°C rise will be exceeded by 2036.
Litigation as a strategy to stop climate damage	…echoing action against the tobacco industry, it creates incentives to act to avoid legal damages.
Rising environmental activism	Rising public, corporate and religious concern over climate change may lead to increased environmental activism.
Resources for the next industrial evolution	Bio-mimicry and 3D printing bring in a whole new chapter in the next 'industrial evolution'.

Also including: Air pollution issues increase; Green cities are burgeoning; Increased extinction risks; Biosphere control through species management

STRATEGIC EVIDENCE OF FUTURE CHANGE

Summary Report, November 2015

SAMI Consulting Ltd have worked jointly with Defra, Natural England, the Environment Agency, the Food Standards Agency and the Welsh Government (the Defra Partnership) on a Horizon Scanning[1] project to help to identify potential strategic threats, risks and opportunities to strategy, policy and operational goals. This has been a very successful example of collaborative horizon scanning, as recommended in the Jon Day review.[2] So far, a database has been generated of over a thousand 'stories' and the links between them.

This report has been produced to bring together some of the major themes identified in the three reports produced to date.[3] Eight main topics are explored and potential questions for the Defra Partnership to consider are proposed. Annex 1 includes updates on some of the topics covered in the earlier reports; and annex 2 contains an inventory of topics covered in the previous reports along with a brief overview of the methodology.

At a time when Defra and its partner organisations are developing new long-term strategies, setting aside time to consider future strategic issues is particularly important. We hope that the key trends and issues identified so far will help to start a discussion on the potential implications for the natural environment and for food.

SAMI Consulting is pleased to have had the opportunity to work with the Defra Partnership on the planning and the scanning for this important project and we wish to acknowledge all the contributions made to its success, in particular from those listed in annex 2.

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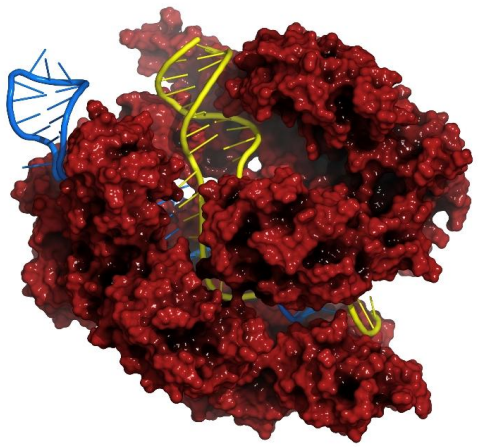
[1] Definition from Jon Day Review of cross-government horizon scanning: Horizon Scanning is the "*systematic examination of information to identify potential threats, risks, emerging issues and opportunities, beyond the Parliamentary term, allowing for better preparedness and the incorporation of mitigation and exploitation into the policy making process.*" As such it is a vital input into long-term thinking.
[2] https://www.gov.uk/government/publications/review-of-cross-government-horizon-scanning
[3] http://samiconsulting.co.uk/5reports.php#Defra



GENE EDITING HAS ACCELERATED THE BIOTECHNOLOGY REVOLUTION

The impacts will be felt across whole areas of environmental science, food supply, and rural affairs

Gene editing techniques are greatly accelerating the pace of change in biotechnology. They allow the rapid and precise transfer of specific genes within species and between species. Gene editing can be applied to crops for animal feed, and to crops or livestock for human consumption.

- At its simplest, the transfer of genes within species can be used to deliver results that could be achieved with classical cross-breeding (such as introducing the gene for hornless cattle into breeds with horns).
  Some proponents argue that such editing should not be classified as Genetic Modification at all.

- More transformative applications would involve introducing entirely new genes from alien species into food crops, thus changing the nature of the food derived from them. (One potential example may be introducing the genes for fish oils into plants.)
  A rapid introduction of new foods such as these could have profound implications for the global food supply.

It seems clear that, whatever policy is adopted for GM food in Europe, new genetically modified organisms (GMOs) will be introduced worldwide at an ever-increasing rate, with economically valuable traits such as increased yields or disease resistance.

Gene editing may also have uses in other areas of Defra's remit, from conserving endangered species, control of insect vectors of human disease, cheap environmental sensors, to the production of pharmaceuticals or transplant organs in farm animals. With such a wide potential, gene editing is probably, for Defra, the most significant scientific development of the past decade.

What is Defra's position on gene editing? Should gene edited organisms be treated as GMOs? What should government policy be in this area?

What policy is appropriate for GM organisms like these in the human food chain?

What policy is appropriate for "gene drives" where a modified gene line is released into the wild? Should they be banned unless they can be reversed with proven counter-measures?

Are regulatory agencies addressing emerging forms of genetic editing in their GMO-related policies?

Should switching to plant proteins that mimic meat be encouraged by government food and environmental policy?

How could the environmental costs of these new plant-based food production processes be evaluated?

What implications do these emerging changes have for long-term global food security?

What policy is appropriate for gene-edited organisms in the human food chain? (In animal feed; in food crops; and in livestock for human consumption?)

RADICALLY NEW FOOD INGREDIENTS ARE BEING DEVELOPED

Natural plant proteins can replace animal protein in food; and entirely new genes will be introduced across the global food chain

An increasing number of novel proteins and other food ingredients will be entering the global food supply, ranging from natural proteins derived from novel plant sources, through insect sources of protein, to new proteins introduced into food by biotechnology.

All of these routes raise potential concerns over human health and food safety, which must be offset against the potentially positive economic and food security benefits they may bring.

- Several High Tech start-ups are developing food products using carefully selected vegetable proteins to mimic more accurately the meaty, cheesy and creamy flavours of food derived from animal proteins. These products target the majority of meat-eating consumers, not just committed vegetarians.
  If successful, these companies would create Silicon Valley-style disruptive innovation across the human food chain, with profound consequences. As the ecological footprint of vegetable products is typically one tenth that of animal-based food, these innovations suggest a possible future path to feed a growing global population.

- In a parallel development, we are now seeing a number of stories on new forms of animal feed derived from various novel sources including aquatic plants and insects.

- Artificial *in-vitro* meat is being developed, where animal muscle tissue is grown in a laboratory. It is hoped that the cost will eventually become comparable with conventional sources of meat.

- As noted above, gene editing techniques will lead to an acceleration of gene swapping within species and between species. Entirely new genes will be introduced into animal feeds, food crops, and livestock to change the nature of the food derived from them. One example is the hypo-allergenic peanut being developed by Aranex.
  The economic pressures to accept such GM foodstuffs in Europe can only increase. Already, non-GM soya is increasingly difficult to source. Such issues are likely to be repeated across all food categories.

How might the 'smart countryside' support the digitisation of the food chain in a way that enhances food security, and the continued economic growth and competitiveness of the UK agricultural sector?

How could 'big data' platforms like GFW assist UK regulation of forests and forest products, carbon offsets and storage, and climate adaptation policy?

Where might expert systems be usefully applied within environmental monitoring and within the UK farming and food industries?

THE EVOLVING "SMART COUNTRYSIDE"

What are the policy implications to ensure environmental and food benefits?

Like "Smart Cities," "Smart Countryside" is an umbrella term that covers pervasive sensing and monitoring; the use of big data; artificial intelligence (AI) and expert systems; inter-connected physical infrastructure; the growth of precision farming; and the use of autonomous farm machinery. The UK's Strategy for Agricultural Technologies refers to many of these, but a comprehensive blueprint is still evolving for a digital infrastructure for a smart countryside and for environmental monitoring.

Mapping applications like the Global Forest Watch (GFW) unite satellite imaging with open data and crowd-sourcing to monitor forests worldwide almost to the individual tree in near real time. Satellite data feeds combined with local sensor networks could also enable a wide variety of agricultural automation. Intelligent soil and water sensors, and sensors to track and monitor the health of crops and livestock, could combine to create much more precise and more autonomous farming.

Both analysing the resulting massive datasets, and using them to create autonomous agricultural and environmental infrastructure, will require the use of artificial intelligence and expert systems. Expert systems could assist in the effective and efficient analysis of agricultural and environmental big data. Scientific and technical expertise could be significantly enhanced (or perhaps replaced) by evolving AI expert systems.

Implications for agriculture and the environment might include improved water use efficiency; improved food security; and improved animal health and safety. Additionally, integrated crop and livestock monitoring could connect to smart food sensors from farms and processing plants, digital product tracking in grocery distribution, and wearable health monitors. This could create a smart digital food chain from farm to consumer.

Two key constraints to the evolution of a smart countryside could be: infrastructure costs, and cybersecurity. Costs have been steadily decreasing over time. Cyber threats, in contrast, are increasing – from organised crime, foreign countries, hacker collectives, and malicious individuals. While a wealth of data and instantaneous updating may improve how the natural environment, water, and food are managed, it will also require constant vigilance.

Should there be a 'reset' of rural policy to reflect the changing position of farming and other activity?

Is there adequate evidence on the effects of climate change on a rural environment in rapid change?

Should rural policy on agri-environment be better coordinated with flood resilience and integrated catchment management?

CHALLENGE AND OPPORTUNITY IN RURAL AREAS

The pace of change in rural areas increases, as do the demands on rural areas

Under their green and pleasant surface, rural areas across the UK are going through a quiet revolution. New forms of production compete with new forms of leisure and consumption. The rural policy agenda, which was traditionally focused on farming, may need to change and adapt.

- With the ongoing urbanisation of rural areas, there are nearly ¼ million houses planned in Green Belt areas in England, after 3 years of the National Planning Policy Framework (NPPF). There is also a large pipeline from commercial, leisure and infrastructure developments. Meanwhile large tracts of land are bought by foreign investors, and smaller farms are amalgamated into larger units.
- There is also a counter trend of urban greening, in terms of tree planting, food cultivation, maintaining urban ecosystems and other 'ruralisation' of urban areas.
- Meanwhile there are new forms of rural economy. While some traditional farm products become less viable, imports now exceed domestic production. Around a third of farmers and growers are using wind, solar, farm by-products and energy crops to produce clean low-carbon energy, together with organic or recycled materials for a circular economy.
- However, farm-based activity appears to be a diminishing part of a rural economy. This is now dominated by manufacturing and services, from speciality 'visitor economies' to 'community shop' cooperatives which bring new life back to depopulated villages.
- Some trends in the rural environment need to be carefully monitored, for instance the apparent decline in the UK's forests for the first time in 50 years. Most critical is the degradation in the national soil resource, as some studies suggest that the UK has perhaps '100 harvests left'. The principle of 'ecosystem services' aims to counter such trends, with new methods of assessment and payment. But these will be tested in coming decades by the increasing droughts, floods and storms anticipated from climate change.

Is it time to review climate change impact mitigation plans across the whole of Defra's remit to take account of scenarios with more extreme rises in global temperature?

What analysis of the effects of higher temperature rises is available, and should more be commissioned?

Are the planning horizons for major infrastructure projects well enough understood, and suitably factored into mitigation plans? Are ways of speeding up infrastructure plans being considered (e.g. for flood defences, transport and energy systems including coastal nuclear power stations)?

What continued monitoring of carbon emission plans is required?

PARIS SUBMISSIONS SUGGEST A 2.7ºC RISE IN GLOBAL TEMPERATURE

At current rates of GHG emissions, a 2°C rise will be exceeded by 2036

The preparations for the November Paris Climate Change conference indicate that most countries have begun to acknowledge the threats posed by global warming as 146 countries have produced National Carbon Plans. This is a positive starting point but may not be enough as it seems that significant climate change may happen faster than previously thought.

Both Defra and DECC are aware of the issues around the causes and impacts of climate change. Nonetheless horizon scanning continues to identify new factors to consider.

- Analysis by the Climate Action Tracker suggests that the Paris plans are insufficient to keep global temperature rise within the 2ºC threshold, and that a 2.7ºC rise is more likely. If the National Carbon Plans are not delivered on, this rise could be much higher.
- In their planning documents, Shell have suggested that a lack of government action will lead to a 4°C rise by 2100, and others suggest that a glut of cheap coal might lead to a coal renaissance, also causing a 4°C rise.
- Higher temperature rises will cause significant impacts not just for the UK but also globally: more frequent and intense extreme weather events; changes to habitats and biodiversity; increased arid areas, causing crop failures and severely affecting food security.
- Warming seas emit CO_2. With such a feedback cycle, the polar icecaps melt more rapidly and coastal sea levels rise; this, together with an increasing probability of floods, would threaten the UK coastline further.
- With current CO_2 levels already around 405ppm – close to the 450ppm threshold considered necessary to keep the world within a 2ºC rise – calculations indicate that continuing to burn fossil fuels at current global levels means global temperatures will reach 2ºC above pre-industrial levels as early as 2036.
- This increased speed of change would have significant impacts and could bring them within the planning horizon for major infrastructure projects – for example, it took 30 years to bring the Thames Flood Barrier to reality.

Do the relevant agencies have contingency plans in place to manage a possible upswing in environment-related litigation?

Will scientists in future require malpractice insurance?

LITIGATION AS STRATEGY TO STOP CLIMATE DAMAGE

Litigation may become a dominant tool in addressing climate change, leading to more governments and companies taking action to avoid future legal battles.

Following a group successfully challenging the Dutch government for taking inadequate action on climate change, other similar cases are arising. A group of Belgian activists is planning to sue their government into taking more action against climate change. A small Peruvian community is suing a German energy company, because glacial melting is threatening to burst the banks of nearby lakes and flood their farmland. As the German energy company produce one per cent of global greenhouse gas emissions, the village is litigating for one per cent of the damages.

An increase in this type of litigation presents a risk to both governments and corporations, echoing the kind of lawsuits brought against the tobacco industry. It creates incentives for businesses and governments to act to reduce their climate change emissions in an attempt to avoid legal penalties. It may also lead to a more sophisticated carbon market that allows companies to offset emissions on a global scale. One additional concern could be potential litigation against scientists for providing inadequate data and analysis, illustrated by the case of the Italian scientists prosecuted for ‘inaccurate, incomplete and contradictory’ earthquake risk data after the L’Aquila earthquake. While their conviction was overturned on appeal, the related conviction of the civil protection agency official involved was upheld.

How can relevant agencies ensure that environmental interest converts into opportunities for civic partnership, rather than risks of civic protest – or litigation?

What data could and should the UK Government encourage citizens or partners to collect on its behalf?

How could public-private partnerships further reduce risks and impacts of climate change?

Is the involvement of religious groups an opportunity to mobilise public action on climate change? Should working with religious groups be explicitly on the policy agenda?

RISING ENVIRONMENTAL ACTIVISM

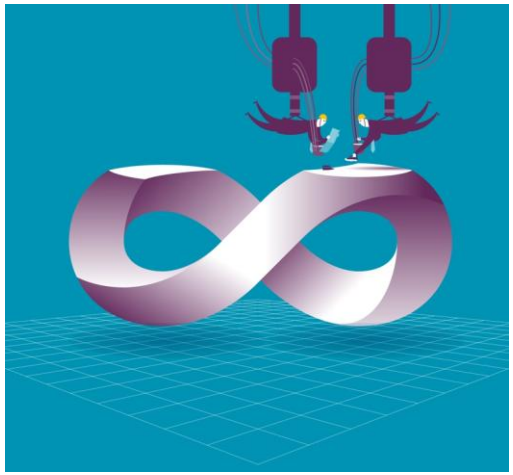
Rising public, corporate and religious concern over climate change may lead to increased environmental activism

Global and national surveys show climate change as one of the highest public concerns worldwide, with people increasingly worried about an increasing incidence of impacts like flooding, sea level rise, extreme weather events, and droughts. Where new concerns arise, new social taboos often follow. Citizens are using social media to “name and shame” people they believe are wasting water by posting photos and video evidence on social media, or using apps that send evidence directly to the authorities responsible.

Citizens are starting to undertake environmental monitoring themselves, and a number of different projects are being trialled by academics and 'citizen scientists'. Innovations in micro-sensors are creating mobile phone add-ons as sophisticated as lab equipment. These enable anyone with a smartphone, a sensor, and the appropriate app to measure air quality, water contamination, or food ingredients. Such technologies provide an opportunity for cost savings on monitoring activities. They could enable ‘citizen science’ of increasing quality to complement – and challenge – official monitoring. Using a social-media-connected community as a human sensor network could help agencies get eyes and ears out into the field to aid incident management.

Increasing citizen activism is paralleled by strong signs of a value shift in the commercial and financial sectors. Banks, asset owners, and managers are increasingly worried about climate change impacts and risks, and are making those concerns known to governments worldwide. For example, 120 investment fund CEOs have written an open letter to government finance ministers urging them to agree long term greenhouse gas emissions goals at the forthcoming Paris Climate Change Conference.

Public activism and private sector concern regarding environmental issues may also be increasingly amplified by the moral authority of churches. More and more religious groups are calling for their members to take action and to hold governments and organisations accountable for their environmental performance. The Church of England, the Roman Catholic Church, the United Church of Canada, and a variety of Muslim initiatives including Green Muslims, are all calling for action to address climate change and environmental degradation.



How to regulate and assess the impacts of novel forms of material or waste, as they move around in a circular economy?

Should we build bio-type flood defences and other infrastructure? Do we have the necessary skills and supply chains?

How should policy-makers respond to concerns on UK 'resource security', while material requirements are changing so rapidly?

RESOURCES FOR THE NEXT INDUSTRIAL EVOLUTION

'Bio-mimicry' and 3D printing bring in a whole new chapter in the next 'industrial evolution', with new challenges for UK environmental policy and resource security.

Bio-mimicry aims to 'learn from nature' in the design and manufacture of more efficient products, and 3D printing then makes this possible at smaller and larger scales.

- 'Bio-mimicry' principles hold great potential for greater efficiency, less material waste, and better integration with ecosystems or health systems. Examples of bio-mimicry include wind turbines, air conditioning, and automotive design. Industrial production using 3D printing also ranges from large scale flood defence installations, to micro-scale dental or bio-medical components.
- Some bio-mimicry applications use novel forms of biological process: for instance, "biological buildings" where biodegradable pellets are mixed into the concrete, to heal over future cracks. The potential is huge, as are the potential risks or side effects.
- In terms of raw materials, 3D printing (or indeed '4D printing' of responsive materials and components), tends to use specialised composite resins and electrostatic or UV-sensitive additives, which changes the industrial materials requirement.
- More widely, new forms of decentralised 3D printing may change the scope of regulation. Neighbourhood co-production centres may emerge in unusual locations, manufacturing to designs which are crowd-sourced globally. Meanwhile there are concerns on the 'resource security' of the UK and EU, increasingly dependent on foreign regimes, and the need for novel and specialised materials could exacerbate such risks.

Meanwhile there is a major push (industry / policy / NGO) towards a 'circular economy' of low inputs / low waste / high recycling. Even human sewage can be a source of gold and other precious metals. This raises questions on how to regulate for waste which isn't waste, raw materials which aren't raw. Note however that the 3D printing / bio-mimicry revolution may run counter to this, as complex and customised assemblages are more difficult to re-use or recycle. As yet there has been little discussion on this.

ANNEX 1:

OTHER TOPICS IDENTIFIED

This annex includes updates on some of the topics covered in the earlier reports.

AIR POLLUTION ISSUES INCREASE

Personal monitoring could raise political profile

What might be the early indicators that air pollution is becoming a personal issue for citizens and their families? What horizon scanning will Defra need to undertake to monitor shifts in public opinion in this area?

What actions can environmental regulators take to protect their reputation if the target of public opinion shifts against them?

Is it possible to quantify more precisely how much of the increased life expectancy since 1970 is due to improved air quality in the UK?

The issues around air quality are well recognised within Defra, and the Volkswagen 'defeat device' news has raised its profile with the public. Over the year, our horizon scanning identified several important new developments which need to be taken into consideration:

- The death toll from nitrogen dioxide appears to be greater than that from particulates alone (28,000 across the UK). The total from both pollutants may be 60,000 per year, compared with mortality from skin cancer at 2,800, and from asbestos at 3,000 deaths.
- Cheap, portable pollution sensors are becoming available, enabling concerned citizens to measure their own and their children's exposures.
- Big data techniques are allowing online pollution maps to show predicted pollution levels in real time at street-by-street levels of detail.
- Non-transport sources of nitrogen oxides (NOx) in the UK are greater than those from traffic.

The combination of increased awareness and citizen science capabilities creates the likelihood of more forceful campaigns. For instance, activists could publish school league tables based on air quality.

There is a real risk that air pollution will be seen as a failure of environmental regulation.

More positively, life expectancy in the UK has increased by ten years since 1970. Rough, non-expert calculations suggest that perhaps one of these ten years may be due to the success of reducing overall levels of air pollution since that time.

GREEN CITIES ARE BURGEONING

New forms of greening of cities bring opportunities but also problems for urban planners and ecologists.

There is a renaissance of urban greening and 'green infrastructure' around the UK. Many social innovations now promote local food production and healthy eating, and there are new techniques in vertical gardening and cultivation. Many studies show that urban greening has positive effects on public physical and mental health, for property prices, and for the local economy. For climate change impacts and adaptation, a 10% tree cover can reduce urban 'heat island' effects. Urban green infrastructure is also emerging in new shapes and locations, for instance on disused transport structures or in wildlife corridors.

However there are unresolved issues such as management of street trees, invasive pests and disease, and the challenges in finding public funds for management of urban greening.

Should urban greening be the remit of Communities, local government or government departments?

Do we need different approaches to delivering ecosystem services in urban rather than rural environments?

INCREASED EXTINCTION RISKS

As global pressures on biodiversity increase, it's estimated that perhaps 50% of all known species could be lost in the next 50 years.

Scientists estimate that global species loss is now at 1,000 to 10,000 times the background rate: as many as 30% to 50% of all species may be heading toward extinction by mid-century. 99% of the loss is caused by human activity. This mass extinction, combined with climate change, and disruption of water cycles, nitrogen cycles and others, means that major tipping points become more likely every day. Oceans are particularly vulnerable, as shown by new insights on the interaction between climate change and oceanic flows. The consequences for the UK environment and biodiversity are as yet little known.

Should Defra aim to influence the supply chains and consumption patterns, which are indirectly linked to global species extinction?

BIOSPHERE CONTROL THROUGH SPECIES MANAGEMENT

There is increased awareness of the role of ecological habitats and species in climate adaptation.

For instance: mangrove swamps to protect coastal locations, beavers as flood resilience experts, or wolves as forestry managers. New technology can be part of this, for example the use of ceramic "Lego" to help coral reefs re-grow. There is a crucial focus on coastal ecosystems and megacities, where the greatest concentration of population lives in the most vulnerable locations.

With current projections of a global temperature rise of around 3 degrees, is the UK doing enough to make its ecosystems more resilient to climate stress?

Could the 're-wilding' of marginal land help generate resilience and biodiversity?

ANNEX 2 – PROJECT REVIEW

CLUSTERS OF CHANGE AND EMERGING SIGNALS

An inventory of subjects covered in the three reports

The “Strategic Evidence of Future Change” project delivered three reports during 2015. The first, in March was primarily a “scan of scans” – a review of previous scanning work. The second (June) and third (September) were based on new scanning of a wide range of sources, and brought together subjects which were categorised either as “clusters of change” – a group of inter-related stories – or “emerging signals” – stories which were felt to be significant.

This Annex lists these subjects and identifies where they may be found. All three reports and their associated Executive Briefings are available on the SAMI Consulting website at http://samiconsulting.co.uk/5reports.php#Defra .

March report – Clusters of change

Smart Countryside: How could the concept of Smart Cities and associated digital technologies be applied to create opportunities for improved countryside management? Page 12

Big data and food security: Are we missing opportunities to exploit Big Data concepts to assist food security? Page 16

Genetic Editing: New techniques are dramatically speeding up the biotechnology revolution – what will be the effects? Page 19

Public attitudes to climate change: What factors are affecting public attitudes and how may these change? Page 22

March report – Emerging signals

Artificial intelligence and expert systems; Artificial intelligence research has accelerated in the past few years and expert systems are becoming available as web-based services with many applications. Page 25

Non-transport air pollution: Transport may be responsible for less than half of both particulates (PM2.5) and emissions of nitrogen oxides (NOx). Page 29

Massively distributed energy source: Increasingly inventors and designers are embedding very small-scale energy generators and harvesters in products, creating the possibility of massively distributed energy generation. Page 32

Increasing challenges and solutions for water quality: There is a race between changes that will increasingly damage water quality and research and innovations that could offer detection, solutions, or prevention. Page 35

Decline in nutritional value of staple crops: One previously little remarked effect of increasing atmospheric CO_2 concentrations is the negative impact on the nutritional value of crops. Page 38.

Environmental monitoring by citizens: Smartphones are increasingly being connected to environmental sensors. These open up more opportunities for 'citizen science' of increasing quality to complement or challenge official monitoring. Page 40

June report – Clusters of change

Greening cities: How can Defra promote a green infrastructure led design approach for urban environments? Page 12

Future Food - is closer than you would think. Innovations in agriculture and food production are maturing and interlinking to create new commercial products and food industries. Page 15

Invasive species… not all bad? Potential benefits identified. Page 20

New threats to water quality: Threats to water quality are emerging from pharmaceuticals and pesticides; and new responses are also being developed. Page 22.

Citizen mobilisation: Divestment campaigns and religions' stances are raising the profile of climate change; other environmental campaigns continue. Do online campaigns represent a step-change? Page 25

June report – Emerging Signals

Global energy price deflation? The cost of renewable energy has reached grid parity in some parts of the world and we may be entering an era of global energy price deflation. Page 29

Inhibiting pests via hormones: Influencing the hormone systems of selected insect species can reduce insecticide use. Page 30

Flood defences: Living with, and "banking", water rather than trying to fight it***.*** Page 31

Environmental regulation can increase productivity and so need not harm growth. Page 32

Radical new approaches to materials Several projects have highlighted possible new materials which could benefit the environment in the longer term. Page 33

Promising new ways of using waste could have regulatory implications***.*** Page 34

New approach to marine re-construction: Ceramic "Lego" help rebuild diminished coral. Page 36

September report – Clusters of change

Energy source developments: Controversy over carbon capture and storage, and continued new sustainable energy source developments. Page 13

Energy storage and distribution: - New developments of battery technology and smart grids offer ways of responding to renewable energy generation***.*** Page 17

Physical resource sustainability: Economic growth creates challenges for resource sustainability and is driving innovative new approaches to construction and re-use of waste. Page 21

Cultural attitudes to sustainability: Shifting cultural attitudes to sustainability - no longer a fringe value, sustainability is becoming a mainstream concern. Page 24

Health risks from chemicals: Both the "cocktail effects" of chemicals in combination and the potential health effects from fracking are causing concern. Page 28

September report – Emerging signals

Connected infrastructure and cybersecurity: The increased connectivity of "smart countryside" brings with it an increased threat of cybercrime and malicious damage. Page 32

Innovative sources of protein from insects and algae – may be potentially disruptive to existing animal/fish feed supply chains and create new markets that would also need new infrastructure and may need new regulatory systems. Page 34

Bio-mimicry to reduce environmental damage replacing 'heat, beat, treat' in industrial processes by mimicking nature's efficiencies. Page 35

3D printed infrastructure created in situ offers the promise to create new structures quickly and more cheaply than traditional poured concrete construction. It may also be possible to create structures and shapes that are not possible with traditional poured concrete. Page 36

2ºC threshold to be exceeded by 2036? Current indicators show that the trajectories for greenhouse gas emissions are such that remaining within the 2ºC threshold is unlikely. Page 38

El Niño – third strongest on record. Forecasters have upgraded it to 'unusually strong'. Others are suggesting that the 2015 El Niño could be the strongest since 1950. This could be used to support or deny climate change. Page 40.

September report – Evolution of previous trends

Biofuels trade-off: Progress in developing second and third generation biofuels may be able to avoid the trade-off between biofuel production and food. Page 42

Health effects of nitrogen oxides (NOx) pollution: Recent research has quantified the deaths from air pollution, pushing it further up the political agenda. Page 44

Gene editing becomes mainstream: The technique of gene editing, using the CRISPR–Cas9 technique continues to show the potential to transform many areas of bio-science. A wide range of applications is now being seen. Page 45

Religions engage with climate change: Religious groups are becoming active and holding governments and organisations to account. Page 47

METHODOLOGY

Scanning

The Horizon Scanning was carried out by three distinct groups:

- SAMI Consultants focus on the broader STEEP (Society, Technology, Economics, Environmental and Politics) categories.
- Academics at Manchester University, who were sub-contracted to provide focused scanning on specific environmental issues.
- The Defra Partnership itself. There are many existing scanning activities conducted within the partnership, though the degree of formality varies between the different organisations. The Partnership scanners input data on their respective specialist areas into the scanning database.

Konrad Bishop, Defra	Helen Doran, Natural England
Nick Dales, Natural England	Marie Fox, Environment Agency
Sarah Bardsley, Environment Agency	Jason Dinsdale, Environment Agency
Becky LeAnstey, Environment Agency	Rachel Gibson, Environment Agency
Patrick Miller, Food Standards Agency	Gary Kass, Natural England

Scanners analysed data from a range of sources, from peer-reviewed journals and patent applications to online blogs and articles. For the March report, several existing scanning databases were examined and data from them included where relevant – this was termed a "scan of scans".

Scanners used their knowledge and judgement to:

- Assess whether the story had a possible implication for the natural environment and food systems.
- Assign it to one or more Defra Evidence Action Plan areas augmented with some extra categories relating to food ("EAPs+") and add other metadata (e.g. date, publication, weblink).
- Capture why they believe the story is important in free-form text.
- Identify relationships between stories through common causes or implications.

Each item – or "story" – was stored in a database using a software tool called Futurescaper. A total of 1057 stories were entered into the database over the course of the project.

Analysis and report

For each report, SAMI consultants analysed the stories entered during the relevant period, using the facilities of the Futurescaper tool. At each stage the Defra Partnership team made selections of which content to include in the report.

The steps in the analysis process were:

- Futurescaper was used to analyse the collected scanning data. First the number of stories for each of the EAPs+ was calculated (noting that many stories will be in more than one EAP+).

- Secondly an overview of the data was produced covering:
  - the top 15 factors by "Popularity" – a function of the number of stories it is associated with and the number of causes (upstream factors) and effects (downstream factors).
  - the top 15 causes (the most influential factors).
  - the top 15 effects (the most affected factors).

- Next, ***"Clusters of change"*** - groups of inter-connected stories in the system – were identified using Futurescaper to assess the extent of inter-connectedness.

- ***"Emerging signals"*** - stories which have been identified by the scanners either as being a new or emerging trend, or of high importance.

- An "Expert Panel" of academics in parallel assessed the topics, providing input on both the science and the policy implications.

- A draft report was produced and reviewed by the Defra partners and final revisions to the report were made.

- An Executive Briefing document – "Change Horizons" – was produced to provide an overview to a wider audience.