Department of Energy & Climate Change

DECC Science Advisory Group

Horizon Scanning

October 2013

Content

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DECC SAG Horizon Scanning

Introduction

This paper sets out advice from the Science Advisory Group (SAG) to the DECC Chief Scientific Advisor (CSA) on ***possible threats and opportunities* facing DECC over the next decade**. In particular, it focuses on what DECC scientists, engineers and social scientists can do to mitigate threats or exploit opportunities. The advice was collected at a Horizon Scanning session hosted by DECC.

Prior to session the DECC CSA asked the SAG "What threats and opportunities DECC should be preparing for and what DECC scientists and engineers should be doing now to respond to these?"

SAG members provided a list of potential threats and opportunities. Which the SAG members then prioritised according to:

- The likelihood of this issue (threat or opportunity) becoming manifest
- The impact of such an issue
- Whether or not (in the opinion of the SAG) DECC was already sighted on this issue

The list was then separated under the headings of **Carbon Reduction**, **Energy Security**, and **Innovation** to help facilitate the session and ensure the full scope of DECC objectives were reflected in discussion.

Here we present the SAG's view on the most significant threats and opportunities facing DECC over the next decade and what DECC's scientific/technical response to these should be.

Area: Carbon Reduction and Climate Change

Issue: Small Modular Nuclear Reactors

Background

Small Modular Reactors[1] (SMR) have been the subject of discussion at previous SAGs. It was highlighted by Sue Ion that this area of technology development could present ***opportunities*** for UK engagement, given the skill base and expertise extant within the UK[2], if pursued in a timely fashion given international interest in these systems.

SMR offer the advantage of lower initial capital investment, scalability, and siting flexibility at locations that are unable to accommodate the more traditional larger nuclear reactors. They also have the potential for enhanced safety and security and the ability to better match load requirement of the grid. Build rates of as low as 24 months, due to modularity and the ability to factory build have significant advantages over the larger traditional systems. Their advantage is that the absolute cost of any system can be smaller because each system is smaller.

The very high capital costs associated with traditional large Light Water Reactor (LWR) systems together with the timescales involved with deployment are proving to be significant barriers to their deployment in Western developed economies including the UK.

Another key advantage of SMR is that it is at a scale that allows 'learning by doing', with the expectation that the knowledge would lead to cost reduction, so even if the initial unit costs were higher than GW+ systems it allowed you to drive down the learning curve, reducing costs.

Issues/Questions	**DECC Response/Action**
Need to design & build UK demo?	Consider & liaise with industry and the US DoE who have a significant SMR initiative in progress with US vendors. Encourage and facilitate assessment of the technology by the ONR
Criteria for suitable sites?	Commission R&D (Inc. Social Science) Consider & evaluate
Possible Build rates?	Liaise with industry
Experience elsewhere in world?	Explore progress being made in the United States and elsewhere
Impact on grid flexibility?	Commission R&D to supplement in particular the work already undertaken by

[1] http://www.world-nuclear.org/info/Nuclear-Fuel-Cycle/Power-Reactors/Small-Nuclear-Power-Reactors/

[2] https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/168047/bis-13-630-long-term-nuclear-energy-strategy.pdf

	the ETI
Public Perception?	Commission Social Science R&D
Plutonium consumption?	Evaluate (with industry)
Impact on UK energy security	Consider & evaluate

Summary: The SMR systems most likely to achieve early deployment internationally are based on innovative application of LWR technology under development and early deployment in the USA. There is a window of opportunity for the UK to become involved, industry to claim scope and for the UK regulator to participate in assessment of the technology so that it could be deployed early in the 2020's. Stimulate active UK participation and commission RD&D

Closing the Fuel Cycle

Background

The medium term (50 yr +) availability of high grade uranium ore may become a problem resource globally if the global fleet undergoes significant expansion. If we are interested in getting out of fossil fuel completely, and obtaining lots of low carbon power within 50 years, with technology which can still function at 100, 400 years into the future – this seems to mean looking at **Fast Reactors**. Overall waste volumes would be lower due to the recycling of what would otherwise be spent fuel. Used in fast reactor systems, the UK's current stock of DU could maintain 100% current generation levels for well over 500 years. The international Generation IV initiative has three Fast Reactors in its portfolio of reactor systems. The Government's recently published Nuclear Industrial Strategy indicated that the UK should re-join this initiative. It also indicated that the UK should keep open the option for recycling.

Issues/Questions	**DECC Response/Action**
Need to examine the role of FR's in the UK's long term strategy? Need to examine what will be needed to maintain a skill base in recycling technology when a commercial plant may be some 30 years min in the furtute	Consider & liaise with NNL , the NDA and industry Consider & liaise with NNL , the NDA and industry
For some advanced systems there is a need to ensure that the UK is up to speed with international developments?	Commission R&D
Criteria for suitable sites?	Commission R&D (Inc. Social Science) Consider & evaluate

Possible Build rates?	Liaise with industry
Experience elsewhere in world?	Commission R&D
Impact on grid flexibility?	Commission R&D
Public Perception?	Commission Social Science R&D
Plutonium consumption?	Evaluate (with the National Nuclear Lab, the NDA and industry)
Impact on UK energy security	Consider & evaluate

Issue: UK Shale gas (and oil)

Background

UK industry may seek to exploit these (possible) reserves. (Opportunity & threat)

Shale is a source of unconventional gas and its extraction process is known as fracking. Dubbed as a "game-changer" in the USA, the SAG did not think that either the viable shale resources in the UK or the potential impact of shale gas on energy prices was likely to be as significant in the UK. Actual timing and costs for extraction under UK conditions are likely to be lower. Unlike the USA, the UK is not a closed market for natural gas; UK shale gas volumes alone cannot significantly affect European gas prices in general, although shale gas production revenues could be locally and nationally significant.

An updated report on shale gas resources for the Bowland Shale only was published in June 2013 by BGS/DECC. [3]

It is clear that shale gas resource exist in the UK, what is not clear, and is unlikely to be established until 2018, after multiple drilling of multiple basins, is the validation of resource predictions and estimation of the rate of commercial extraction and conversion of resources to reserves (typically estimated at 10%). Rate limiting steps are likely to include:

1) Planning permissions – even if the same rock is drilled in different geographical sites, some aspects of these will need to be individually evaluated.

2) Public permission: Many boreholes will be applied-for as thick shales can be drilled at minimal depths (low cost).

3) Public permission: for impact on UK gas supply, this will be a drilling campaign without precedent in the UK. Single basins in the USA have experienced 2,000 boreholes per year; historical UK onshore deep drilling rates are 5 – 10 boreholes/yr.

4) Supply chain and skills (overlap with BIS). The USA has about 1600 onshore rigs drilling shale gas wells. The UK may have 10 deep rigs, and only single figure capability

[3] https://www.gov.uk/government/publications/bowland-shale-gas-study

for deviated boreholes. This means import or construction of rigs, essential training of staff in operations and UK H&S, and training regulatory public sector staff.

The SAG advised DECC scientists to look closely at possible fugitive emissions (i.e. methane leakages) to ensure that any progress made in shale gas extraction is done so with UK GHG emission responsibilities taken into account. To try and mitigate these fears DECC are currently carrying out a study into shale gas looking at the possible emissions during extraction and use[4].

Issues/Questions	DECC Response/Action
Size of resource?	Commission/encourage university & industry R&D
Reaction of local communities to exploration and exploitation	Commission Social Science R&D
Impact of exploitation on UK (allowable) CO_2 emissions	Consider & evaluate
Use/monitoring/operations of frack seismicity	Liaise with university & industry
Monitoring groundwater contamination	Essential for public confidence. Samples before and after operations. Liaise with university & industry
Regulatory framework adequate (c.f. USA)?	Review & revise if necessary
Impact of fugitive emissions of methane, during frack, during early production, and during gas transport	Consider & evaluate
Water use during Frack	R&D on using gas-based polymers
UK carbon targets? (domestic hydrocarbon production may increase)	Commission R&D and economic assessment to use shale gas levy to fund CCS on shale gas exploitation.
Supply chain and skills	Accessing drill rigs. Training staff. Regulatory and H&S monitoring

Summary: Maintain watching brief (while facilitating as appropriate in other parts of DECC) and commission R&D on possible consequences as above. Consider effects on gas price in particular and how best to hedge against fluctuating gas prices if UK domestic gas production is enhanced by shale gas. For climate impacts in examine mitigation methods for fugitive emissions and also gas combustion in power, industry and built sector

[4] https://www.gov.uk/government/news/davey-uk-shale-gas-development-will-not-be-at-expense-of-climate-change-targets

Issue: Exploration of Methane hydrates

Background

Threat: With rising prices and depleting resources another country (e.g. Japan) may begin to exploit methane hydrates (from sediments on continental slopes).

Methane clathrate (CH_4•$5.75H_2O$), also called methane hydrate is an abundant source of fossil fuel in form of methane stored in water crystals that look similar to ice. The majority of deposits have been found in either polar continents but substantial deposits have also been located in Siberia and Alaska.

The SAG pointed out the ***threat,*** that with rising fuel prices another country may begin tapping into these reserves. Japan has recently confirmed doing just this as it looks for alternative fuel source after the negative press surrounding nuclear energy and Fukushima.

One problem is fugitive emissions from production, since methane is a more potent greenhouse gas and it is thought the comparative impact of CH_4 on climate change is over 20 times greater than CO_2 over a 100-year period[5] (but less over longer periods). Even if fugitive emissions are largely avoided the total carbon content of methane hydrate deposits is thought to be perhaps an order of magnitude higher than that of 'conventional' fossil fuels. This makes net 100% CCS even more important, if these deposits are to be used safely.

Issues/Questions	DECC Response/Actions
Additional CO_2 emissions & global warming	Consider & evaluate. Establish principle of 100% CCS.
Risk of leaks and/or uncontrolled release of methane (powerful GHG) from exploration and/or production	Commission Research

Summary: Maintain watching brief and commission relevant R&D (e.g. modelling of consequences, ways of achieving 100% CCS - e.g. conventional CCS + air capture)

Issue: Effective reduction of emissions from Industry & Transport

Background

Carbon dioxide (CO2) accounted for about 83 per cent of the UK's anthropogenic (man-made) greenhouse gas emissions in 2011.

In 2012, an estimated 40 per cent of carbon dioxide emissions were from the energy supply sector, 24 per cent from transport, 17 per cent from business and 15 per cent from the residential sector. The need for reduction of emissions from transport is reflected in the DECC Carbon Plan. However the speed to technology development, and the level of innovation

[5] http://epa.gov/climatechange/ghgemissions/gases/ch4.html

required poses a challenge to achieving the required level of decarbonisation in the transport and industrial sectors. The methods of decarbonisation are unclear. Many rival technologies exist, but few appear to have backing from vehicle manufacturers at the scale required for impact in the UK, Europe or globally. How does DECC propose to make real progress and impact in testing pilot technologies by 2020, and rolling out (e.g. national vehicle electrification delivery systems) by 2030 ?

Issues/Questions	DECC Response/Action
Balance production of biomass for energy use with other land uses (see IASSA –IIASA, CCTAME, ,2012)	Commission periodic technical reviews
Air capture of CO2 may be a sensible way to offset emissions and allowed continued use of fossil fuel use in certain sectors (e.g. aviation, surface transport, industry)	Commission R&D on negative emissions technology (including air capture)
Clear understanding of appropriate options for specific sectors & technologies is needed	Link with BIS work on industry CCS[6] (R&D & technical reviews, liaise with Industry etc.) and particularly develop and implement a joined-up power sector and industry CCS strategy

Summary: Develop a joined-up CCS policy and development strategy for power and industry with BIS. Commission R&D & technical reviews on biomass/land-use and negative emissions technologies

Issue: Risk of Climate Tipping Points being crossed

Background

There is evidence of abrupt changes in Earth's climate in the past, which leads to concerns that similar tipping points could be crossed in the future prompted by anthropogenic climate forcing. Many potential climate tipping points have been identified based either on the palaeoclimate record (e.g. collapse of the Thermohaline Circulation or the Asian monsoon), modelling (e.g. dieback of the Amazonian or Boreal forests) or theoretical considerations (e.g. destabilization of marine hydrates).

In many cases the changes associated with tipping points would be fast relative to the changes in forcing and/or irreversible. They are therefore likely to be difficult to adapt to, and might be considered as a "climate emergency", or even one way to define "dangerous climate change" in the context of the UNFCCC.

[6] http://www.ukccsrc.ac.uk/centre-research/october-december-2012-ccs-industry-workshops, https://www.gov.uk/government/publications/carbon-capture-and-storage-ccs-costs-for-uk-industry-high-level-review

There are promising signs that many tipping points may be preceded by characteristic changes in system variability, such as critical slowing down. However, methods for detecting precursors in time-series of systems that are not close to equilibrium (such as the contemporary climate) are not yet well developed.

In addition, there is relatively little literature looking at the probability of given tipping points being crossed (apart from subjective expert assessments), or on the impact of a given tipping point being crossed (apart perhaps from THC collapse). Both of these pieces of information are required to get a more objective assessment of the risk associated with climate tipping points, and to plan for any associated climate emergencies.

If it is apparent that we are entering a tipping point then simply reducing emissions, even to negative values, is unlikely to reduce the forcing due to elevated GHG levels sufficiently quickly to avoid positive feedback effects. Other interventions, such as Solar Radiation Modification, might be more effective. While adverse effects of SRM can be expected, these have to be counterbalanced against the possible extremely serious consequences if a tipping point is passed, also with adverse and (by definition) irreversible effects. In these circumstances SRM or other interventions could give time for emission reduction and air capture to have an effect, no doubt backed up by considerable political urgency if a clear tipping point is being held back temporarily by SRM.

Irrespective of whether or not these and other tipping point can be assessed with any accuracy, there are also absolute limits to adaptation: once they are crossed adaptation is no longer possible and irreversible change occurs. Some of these relate to the large-scale tipping points, but there are also physical and ecological limits, technological limits, financial barriers, information and cognitive barriers, and social and cultural barriers.

In addition to these physical threats, the *political threat posed by an* inability to agree global governance regime for responsible development or deployment, even if deemed necessary, exists.

Issues/Questions	**DECC Response/Action**
Can reliable precursors of climate tipping points be identified ?	Commission R&D
Monitoring – Do we have the data needed to inform above? Can we get it?	Consider & evaluate
What are the likely likelihood and impacts of each climate tipping point?	Commission R&D
Consider responses to give rapid intervention if (certain types of) tipping points become evident - e.g. Solar Radiation Modification (SRM)	Consider and evaluate Commission R&D
What are the likely limits of adaptation?	Commission R&D

Summary: The notion of abrupt changes in the climate system is one way to define the concept of dangerous climate change in the context of the UNFCCC. Although many potential climate tipping points have been identified, the risk associated with each of these (i.e. likelihood x impact) has not been objectively assessed. DECC should encourage UK research councils to pursue this agenda and commission work where necessary to synthesis the outcomes into an objective risk assessment of the most worrisome climate tipping points. Because of the very serious consequences if a tipping point is passed then possible fast-acting interventions that could be deployed to arrest a tipping point process (e.g. Solar Radiation Modification) should be considered and researched.

Issue: No international agreement on global climate change

Background

Lack of an effective deal on emissions reductions post-Kyoto is a ***serious threat*** to DECC and has far wider consequences.

Issues/Questions	**DECC Response/Action**
Are there alternative ways to get a deal?	Commission Social Science R&D (game theory approaches?)
Basis for emissions control on CO2 consumption rather than production?	Consider & evaluate
Understand possible role of SRM and CDR (negative emissions) including avoidance of the tipping points or climate emergencies	Consider & evaluate (as above)

Summary: Explore alternative emissions control measures (e.g. green taxation, possibly at EU level) and negotiating strategies and commission relevant R&D (e.g. modelling approaches)

Issue: Reframing of climate targets in term of rates rather than magnitudes

Background

Current climate policies are framed in terms of the ultimate magnitude of global warming (e.g. less than 2^{o}C) and focus on carbon budgets in future will intensify this. However, the ability of complex systems such as ecosystems or economies to adapt also depends on the rate of climate change as much the ultimate magnitude of climate change, at least in the short term.

There is therefore a case for ***adding*** elements to the climate change negotiations for avoiding dangerous rates of change, ***as well as*** the ultimate magnitude of change. This has the added benefits that (a) rates of climate change are as much constrained by contemporary trends as by the sensitivity of climate to CO2 increase, and (b) framing in terms of rates allows a more adaptive policy that can respond to varying rates of observed warming.

In order to achieve such a reframing it will be necessary to understand the rates at which societies, economies, ecosystems and species can adapt, as well as the limits of adaptation.

Issues/Questions	DECC Response/Action
How do impacts vary with rate of change?	Commission R&D
Do we understand how fast humans and ecosystems can adapt?	Commission R&D
Are cumulative emissions still the best guide to impacts?	Commission R&D
Are there rate limits to adaptation?	Commission R&D

Summary: The ability of complex systems (such as the economy and ecosystems) to adapt to climate change depends fundamentally on how fast climate change occurs. Furthermore the rates of future climate change over the next few decades are constrained by more than the ultimate sensitivity of the climate system. There is therefore a case for augmenting the concept of dangerous climate change by attention to rates of change as well as ultimate magnitudes.

Area: Energy security

Issue: Nuclear Generation, Waste Disposal & Communities

Background

DECC clearly needs to put further effort into understanding and engaging with communities on currently proposed Nuclear New Build sites. However, if the level of new nuclear deployment required turns out to be greater than can be accommodated at currently available sites, community concerns where there is no legacy of civilian nuclear operation may pose a *threat* to DECC achieving its energy/decarbonisation objectives. Additionally, and at first sight apparently separate from the New Nuclear issue, there is also the issue of Geological Disposal of the UK's legacy wastes from its historical nuclear programmes. For both issues, much better understanding of the diverse views and concerns held must be achieved, and discussed in a more open, balanced and transparent way. The interaction between the two issues may also be critical for many; policy tends to treat these two problems as separate, but research shows for example that the final destination of waste is a key concern of host communities, while the rationale for waste disposal cannot be discussed totally in isolation of the benefits of low carbon electricity generation from nuclear power.

Issues/Questions	**DECC Response/Action**
What are the challenges ahead when engaging communities on existing New Build sites?	Evaluation of existing demos/case studies and lessons learned from both failed and successful approaches to community (waste and power generation) engagement elsewhere.
How has the Fukushima accident impacted underlying public perceptions of nuclear risks and benefits in the UK?	Initial review of existing knowledge on public and local community concerns in the UK. Some primary research may be needed on post-Fukushima views
Are there significant threats to the realisation of the more ambitious nuclear expansion plans (only important if these plans – e.g. Carbon Plan 75GW scenario – are themselves realistic given economic, materials and engineering constraints?)?	Consider & evaluate

Summary: New Nuclear brings with it significant challenges at community level. While DECC clearly needs to put significant effort now into understanding and engaging with the public on currently proposed New Build sites, a longer term strategy has also to consider the societal implications (both generation and waste siting) of greater levels of deployment.

Issue: Communities resist heat networks

Background

Deployment of heat networks may run into local resistance. *(Threat)*. DECC need to consider options for rational choices on use of heat.

Heating and cooling is one of the dominant forms of energy use and carbon emissions in the UK. This has tremendous potential for change in the UK over the coming decade as a result of climate change, developments of improved technologies (such as heat pumps which can both heat and cool, and tri-generation with district networks) and low energy refurbishment of the built stock. Although there has been increased policy and research in this area, the complex socio-technical interactions of shifting to a low carbon provision of heating and cooling are poorly understood particularly in relation to the phasing of different but interdependent systems such as district heating which requires long term strategic planning, community acceptance of technologies and, unintended consequences of adopting specific technologies.

Heat networks[7], often referred to as district heating schemes, supply heat from a central source directly to homes and businesses through a network of pipes carrying hot water. This means that individual homes and business do not need to generate their own heat on site.

The 2009 Poyry report[8] suggests that residential heat networks become cost-effective in areas with heat demand at a density greater than 3 MW/km^2. It is estimated that 20% of the UK heat demand has at least this heat density and at the top end of Poyry's projections, where certain barriers are overcome, up to 14% of the national heat demand could be served by heat networks. DECC is developing a heat networks model to better understand their potential. Initial results from the modelling suggest that up to 20% of UK domestic heat demand might be served by heat networks by 2030. The modelling shows heat networks are an attractive option as they can offer efficiency gains compared with individual heating systems.

DECC published a heat map for England, which will assist local authorities in planning. It shows that nearly 50% of heat demand in England is concentrated with enough density to make heat networks worth investigating. DECC have also recently competed work on "*Homeowners' Willingness to Take up More Efficient Heating Systems*."[9]

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[7] https://www.gov.uk/government/policies/increasing-the-use-of-low-carbon-technologies/supporting-pages/heat-networks

[8] Poyry, April 2009,The potential and costs of district heating networks

[9]https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/191541/More_efficient_heating_report_2204.pdf

Issues/Questions	DECC Response/Action
Options include District Heating, burning gas in homes, CHP, heat-pumps and others. What is optimal mix of options, and location of district heating i.e. where is it suited best ?	Commission R&D
What is public perception of issues relating to heat pumps, and how might public concerns be allayed?	Commission Social Science studies
What can be learned from example of previous transitions in domestic energy technologies?	Consider & Evaluate

Issue: Possible type failure of new generating plant and particularly CCS

Background

The SAG noted that history indicates that when a major switch in energy system technology occurs some level of plant failure can be anticipated. This is illustrated by the winding failures when 500 MW and 660 MW turbo generators were first introduced in GB, the low initial availability of Advanced Gas Cooled Reactors and the problems experienced in the early use of very large gas turbines for combined cycle generation. Although these difficulties have been overcome successful operation was only achieved at considerable cost and delay.

In December 2012 the DECC Gas Strategy highlighted the possible need for investment in up to 26 GW of new gas generating capacity by 2030. This will be supported by the parallel development and commercialisation of carbon capture and storage technology[10]. Although primary responsibility for effective operation will lie with the plant operators and equipment vendors, such a large programme of new generating plant would benefit from a careful overview to ensure that no single unproved technology becomes dominant and that any optimism bias is suitable controlled.

Issues/Questions	DECC Response/Action
First of kind ; factor it into policy & projections	Include a delay in the anticipated date of effective operation
Systematic non-functioning	Identify and monitor the various technology choices being made by

[10] https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/65654/7165-gas-generation-strategy.pdf

	plant operators and equipment vendors. Monitor the availability of plant as it is commissioned.
Study evolution of technologies	Commission a short review of historical lessons of the availability of new large generating plant, with particular reference to CCS.
If fossil fuel is off the agenda do we need a backup strategy	Consider contingencies if CCS plant does not work at the expected availability.
What level of confidence can be placed in new large generating plant? E.g. AP 1000, BWR, EPR or Hitachi ABWR reactors	Ensure a good understanding of worldwide operating experience
Will the anticipated transmission links using HVDC have the same level of robustness as conventional AC transmission?	Ensure a good understanding of worldwide operating experience. For HVDC links this is available through CIGRE.

The SAG recognise that the UK must provide a re-vamp across the energy sector, however, with regard to CCS, they highlighted that history suggests when a country is first to trial a new energy technology there are likely to be teething problems of varying severity.

Issue: A possible nuclear incident in the UK

Background

A major civil nuclear accident in the UK or elsewhere in the world poses a *threat* to the emerging UK Civil Nuclear Programme (Threat)

Issues/Questions	**DECC Response/Action**
Plan for scientific response	Appropriate instantaneous access to knowledgeable nuclear scientists and engineers is essential. DECC should ensure it keeps and updates a register of key personnel akin to that utilised for the post Fukushima UK response.
Contingency planning. The ONR has already reviewed and mandated industry to put in place additional back up and contingency systems	Keep abreast of International plans and contingencies e.g. those advocated by the European Union 'Stress Tests'
Scenario planning – Consider sudden halt of nuclear programme? (e.g. due to impact of common mode	DECC to ensure National Grid have assessed the impact of loss of several

failure in several large plants which could make a significant dent in the UK's generating margin)	large plants due to common mode failure (this applies to large generating plant of any technology not just nuclear)
Education on nuclear power and radiation. Much improved general understanding of risks and proportionality associated with all forms of energy technology would be helpful	DECC to work with other Depts eg Education and Skills

Summary: Fukushima showed that, when well qualified expertise is drawn together, a coherent appropriate response can be developed. This can both support Government decision-making, and be used to handle the media and address public concern. It is essential that an appropriate cohort of nuclear engineers and scientists working in the sector and in academia is maintained and accessible instantaneously by DECC. Fukushima also emphasised the need for improving the availability of readily accessible, easy to understand, information about radiation and nuclear energy systems

We know that nuclear energy has encountered significant public acceptance problems in many countries. Current research suggests that general support in GB is not unconditional, but has equally not reversed as might have been expected after Fukushima. DECC needs to understand the reasons for this. In addition, risk communication research shows clearly that just telling people about the science or risks involved in nuclear is rarely sufficient, and may indeed backfire – people must be engaged in an honest and open dialogue about the issue, and the potential benefits, risks and current institutional implications of adopting nuclear in any future energy system.

SAG suggests that DECC social scientists commission research and take part in studies which seek to determine the wide range of views which underpin concerns about nuclear energy and about radiation with view to developing better strategies for engagement

Area: Innovation

Issue: Unilateral SRM Geoengineering

Background:

There is a growing discussion in the scientific literature about the efficacy and potential impacts of Solar Radiation Management (SRM) Geo-engineering, especially through stratospheric aerosol injection or cloud brightening. This discussion is largely motivated by concerns that (i) 2°C of global warming cannot be avoided by conventional mitigation of CO_2 emissions alone, and (ii) the avoidance of climate tipping points would require an emergency action that would need to be much faster-acting than conventional mitigation.

Research is in its infancy but some widely-supported conclusions are already emerging. Firstly, approximate economic costs suggest that the direct costs of deploying SRM geoengineering would be cheap relative to conventional mitigation, such as to be in the range of individual nations or even very rich individuals. Unilateral SRM geoengineering is therefore possible, although the indirect costs i.e. environmental externalities are currently very uncertain. Secondly, climate model simulations show that SRM probably could successfully offset global average warming due to greenhouse gases, but there would be residual regional climate changes especially in rainfall and weather extremes – with *winners* and *losers* writ large. For example, recent results suggest that stratospheric aerosol injection in just the northern or southern hemisphere would have radically different impacts on rainfall in sub-Saharan Africa (Haywood, Jim M.; et al. (2013): Asymmetric forcing from stratospheric aerosols impacts Sahelian rainfall)[11].

The relative cost and speed of SRM in comparison to conventional mitigation, and the lack of progress on the latter, may encourage some nations to bring SRM to the negotiating table. The possibility of unilateral implementation of SRM, and the consequences for regional climates, also arguably implies a risk to human security. For these reasons, it is important that DECC has foresight of the possibly impacts of SRM geoengineering.

Issues/Questions	**DECC Response/Action**
What would be the consequences of different types of SRM geoengineering for regional climates and ecosystem services ?	Commission R&D
Politics & tactics of geo-engineering for international negotiations on this subject that may occur	Commission Social Science R&D (game theory approaches?)
Another international treaty may be required	Consider & evaluate potential support for a possible overall Treaty on Environmental Protection

[11] http://www.climate-engineering.eu/single/items/haywood-jim-m-et-al-2013-asymmetric-forcing-from-stratospheric-aerosols-impacts-sahelian-rainfall.html

Research to identify regulatory gaps	Commission appropriate studies
Need to improve Knowledge base on Public perception	Commission engagement activities & studies

Summary: Solar Radiation Management (SRM) geoengineering is considered by some to be fast and cheap compared to conventional mitigation of CO_2 emissions. The cost of SRM implementation is arguably in the reach of very rich individuals or corporations – implying the possibility of unilateral action. However, SRM plus greenhouse warming would leave significant regional climate changes that imply winners and losers, and these impacts need to be understood. Rapid development of International governance of SRM geoengineering should also be a priority.

Issue: Negative emissions technologies (NETS)

Background:

Only one of the Representative Concentration Scenarios (RCPs) being considered by the IPCC AR5 has a non-negligible chance of avoiding greater than 2^{o}C of global temperature increase. Furthermore this scenario (RCP2.6) assumes long periods of significant ***net*** negative global CO_2 emissions, implying the widespread implementation of Negative Emissions Technologies (NETs) (a.k.a. Greenhouse Gas Removal methods)– such as Biomass Energy with Carbon Capture and Storage (BECCS).

There are at least two important conclusions that can be drawn from this. Firstly, it may be that 2^{o}C cannot be avoided through conventional mitigation alone - which may lead some nations to become discouraged about this target in the context of the UNFCCC. Secondly, that avoiding 2^{o}C might be feasible through a combination of conventional mitigation (i.e. emissions reductions) combined with BECCS or some other NET – which may encourage some nations to consider NETs as a necessary part of a strategy to avoid dangerous climate change.

However, most existing NETs imply large-scale changes in land-use. For example, BECCS, as currently envisaged, would require a significant increase in land-area used to generate crops, potentially leading to large areas of forest or agricultural land to be replaced by energy crops. It is critically important that the trade-offs between CO2 mitigation through NETs and the direct impacts on food, water and biodiversity are understood globally.

NETs that are based on direct air capture of CO_2 are obviously of interest since they present different characteristics than BECCS. Costs may appear to be high but are already estimated to be within current ranges typical of offshore wind (order £200/tCO_2 avoided) and wave power (order £500/tCO_2 avoided)[12]. High costs are also acceptable for premium uses such as

[12] Assuming an electricity generation cost of £50/MWh for natural gas, the recently agreed offshore wind strike price of £155/MWh gives emissions savings against gas of less than 500kgCO_2/MWh (the carbon price is irrelevant here) for a carbon abatement cost of around £200/tCO_2; similarly for the agreed strike price of £305/MWh for tidal and wave projects carbon abatement costs are around £500/tCO_2.

transport - for every £50/tCO2 charged for NETs the cost impact is equivalent to only an extra $22 on a barrel of oil[13].

As well as achieving net negative emissions NETs are also important in that, in combination with 'conventional' CCS, they allow genuinely 100% net CO_2 neutrality with fossil fuel use, and could in future allow atmospheric GHG levels to be ***reduced*** to long-term tolerable levels (e.g. 350 ppm).

Issues/Questions	**DECC Response/Action**
How feasible is it to avoid 2°C of global warming through a combination of conventional mitigation and Negative Emission Technologies (NETs)?	Commission R&D
What are the consequences of different degrees of NET implementation for ecosystem services?	Commission R&D
What NETs are available, particularly direct air capture and other means of avoiding obvious land use limitations	Commission R&D

Summary: The only scenario considered by the IPCC AR5 that has a high probability of avoiding 2°C of global warming assumes widespread implementation of Negative Emissions Technologies (NETs). It is important to understand how feasible this is, and the consequences for food, water and biodiversity.

Issue: Novel low carbon technologies (e.g. efficient Solar to hydrogen)

Background

The SAG expressed their concern that while DECC are beginning to put in place policy and investment to encourage a number of existing technologies (e.g. new & improved wind farms and gas-fired plants) there seems to be little investment into research on promising novel technologies. The SAG suggested a new efficient solar to hydrogen generation method as an example of a significant and far-reaching *opportunity* that is currently being researched but is poorly funded in academia but *if* successful could eventually be capable of meeting global low-carbon energy needs for the foreseeable future

Issues/Questions	DECC Response/Action
Identification of promising technology opportunities	Create & maintain horizon scanning & foresight unit?
Effective promotion of innovation in potentially valuable novel technologies	Create & enhance long-range funding partnerships with research councils, TSB, new industry consortia etc.

[13] http://www.cambridgeenergy.com/archive/2005-10-26/CEF-Gibbins.pdf

Horizon Scanning: Overview

Overall the SAG has identified a number of areas where DECC needs to ensure an appropriate level of in-house expertise and financial resources to maintain a watching brief on emerging new technologies, undertake periodic technical reviews and commission appropriate small-scale R&D studies. These include biofuels, methane hydrates, and fugitive emissions from fracking, for example.

In some cases (e.g. SRM geoengineering, climate tipping points and greenhouse gas removal (GGR, or negative emissions technologies) appropriate and relevant R&D might usefully be promoted via targeted co-funding with Research Councils, the TSB and others. A significant effort to develop GGR technologies emerges as an important long-term objective, especially to deal with future intractable emissions from aviation and agriculture.

For many energy technologies R&D funding has been much reduced and fragmented in recent decades. Where government funding of RD&D is not appropriate DECC should consider active promotion of and incentives for industry funding of academic & commercial research via sectoral consortia like Oil & Gas UK, to ensure an appropriate "arm's length" relationship between funders and researchers. This mechanism could also be appropriate for proactive facilitation of technology assessments on novel nuclear generation, and the nuclear fuel cycle for example.

There are numerous areas where DECC needs to promote & commission social science investigations & engagement rather than technical R&D, including limits to adaptation, effective incentives for emissions reductions, alternative frameworks for international climate agreements and community responses to nuclear waste disposal, district heat networks, and wind-farms.

In general DECC could probably influence and stimulate RD&D funding by other bodies by greater pro-active small-scale involvement and pump-priming activities, without seeking direct control, across a broad range of energy and climate change areas within its remit

Annex: Other issues raised

List of issues identified by the SAG that lie outside of the terms of reference of this exercise. The SAG feel that these should be (and in many cases are already) considered carefully by DECC

International Climate Change team

- Possible development of bilateral or regional voluntary agreements on CO2 reduction
- Possibility of change of USA opposition to post-Kyoto international agreement
- Potential for Global agreement on carbon taxation rather than cap-and-trade
- Possible developments w.r.t. carbon ***consumption*** metrics and implications for UK
- Need to provide "plain language" interpretation of IPCC conclusions..

Carbon Budgets Team, HMT

- Need for significant Economy- wide carbon price to create incentives
- Possible mechanisms to apply taxes to fossil fuels at source

Carbon Budgets Team, DECC Strategy

- Need for coordinated approach to climate change and Energy cost & security objectives w.r.t. fossil fuel exploitation.

DECC Strategy

- Possible consequences of UK exit from EU
- Need to ensure successful operation of ETS (to deliver carbon price)
- Need for greater emphasis on possible co-benefits (air quality, energy security etc)

Department of Energy & Climate Change
3 Whitehall Place
London SW1A 2AW
www.gov.uk/decc

URN: 13D/292