The Royal Society of Edinburgh

Conference

Climate Change: Science and Society

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Report by Matthew Shelley

This special half-day conference offered an update on the physical science behind climate change and explored how the effects of climate change might be mitigated. Leading national and international speakers led sessions exploring the key issues from both a Scottish and a global perspective. Each of the sessions was designed to reflect the latest thinking from one of the three working groups of the IPPC (Intragovernmental Panel on Climate Change). Shell provided an industry perspective.

The speakers were: Gabriele Hegerl FRSE, Professor of Climate System Science, University of Edinburgh; Stuart Haszeldine OBE FRSE, Professor of Carbon Capture & Storage, University of Edinburgh; Professor Mark Rounsevell, David Kinloch Michie Chair of Rural Economy and Environmental Sustainability, University of Edinburgh; Dr Andy Kerr, Director, Edinburgh Centre for Carbon Innovation; Professor Ottmar Edenhofer, Co-Chair of Working Group III of the IPCC and Professor of Environmental Economics, TU Berlin; and Angus Gillespie, Vice-President CO_2, Shell. The welcome was provided by David Sugden FRSE, Emeritus Professor of Geography, University of Edinburgh.

Introduction

Professor Sugden said the conference would provide an update on one of the greatest challenges facing humankind. This would be against the backdrop of the fifth IPCC report which, he said, is impressive in its quality, clarity and implications. It is also set in the context of the UN's planned Paris climate change conference later this year, which the Professor described as "a last chance saloon" if we want to control the impact of climate change in the decades ahead.

Session 1: The Physical Science Basis

Chaired by Professor Alan Werritty FRSE, Emeritus Professor of Physical Geography, University of Dundee.

Key speaker: Professor Gabriele Hegerl FRSE

Professor Hegerl, who was a lead author of the 2013 IPCC Working Group I report and member of the core writing team of the IPCC synthesis report, summarised the findings of the fifth IPCC report, including a brief account of the observed evidence for climate change from the ocean, atmosphere and cryosphere. She described the detailed process for creating the report (which involved some 200 scientists and approval by the representatives of over 100 governments) and which was widely reviewed to ensure its accuracy and robustness.

The core finding was that evidence for long-term and lasting climate change is unequivocal, with each of the past three decades being successively warmer. The atmosphere and the oceans have warmed, sea levels have risen, but snow and ice have

diminished. At the same time, greenhouse gas concentrations have gone up. Professor Hegerl said that the inescapable conclusion from a huge amount of scientific research is that human activity is influencing the climate. This is because "we are changing the balance between the radiation that the planet gets from the Sun and the heat radiation that goes out from the planet into Space … by adding greenhouse gases to the atmosphere."

Numerous models exist to predict the course of climate change. The rate is sometimes temporarily affected by other factors; for example, volcanic activity or changes in the Sun. In the early 1990s, the rate was faster than anticipated and in recent years it has been slower; but according to Professor Hegerl, the overall trajectory fits the modelling. Almost every part of the world has experienced statistically significant levels of warming that once again, according to the Professor, is a strong indication that "something is going on". She also outlined the evidence for increases in sea temperatures, reductions in snowfall and rising sea levels.

Extensive studies have been carried out to identify whether the changes can be explained by natural processes, but these have been found to have only a small impact. Right now, there is also work taking place to identify how likely specific extreme weather events – such as the Russian heatwave – would have been without the increase in greenhouse gases.

The solid understanding of warming in the 20th and 21st centuries allows scientists to be more confident about their predictions for the future. Professor Hegerl presented two scenarios, one showing what would happen if we continued with "business as usual", the other with "very sharp mitigation". In both cases, warming continued, and the differences between wet and dry regions grew. This is something that is already being detected.

What is clear is that the extent of warming, and the impact on the planet, will be far greater if we fail to act. If serious efforts are made to reduce emissions and mitigate the impact, then the changes and the impact on human society will be far less. Minimising the effects and holding the temperature rise to around 2° Centigrade, concluded the Professor, will involve fast and far-reaching action, at a time when populations are increasing and economies are developing at speed.

Scottish comments: Professor Stuart Haszeldine OBE FRSE

The world is facing a major problem said Professor Haszeldine; after burning vast quantities of coal and oil, we are about to extract "unfeasibly large amounts of gas and shale gas". To confront the challenge, he argued, we need to remove carbon, either at the point of combustion or from the atmosphere, and put it in the ground.

The UK has a "sensible" objective to decarbonise by 80% relative to 1990 by 2050. The challenge is to do this, and keep society running, at low cost. Failure to act will mean catastrophic sea level rise, global warming, ocean death and major extinctions. We need ways to keep extracting fossil fuels and taking them to power stations or chemical plants to get electricity, plastics, fertilisers and other products, without pumping CO_2 into the atmosphere. This can be achieved by capturing and liquefying the CO_2, then pumping it along pipelines into storage areas at least 1km underground. This can reduce CO_2 emissions by 90% at each site, or by 75% along the entire lifecycle chain for coal.

The importance for Scotland is that our offshore oil and gas reserves are in porous sandstone capable of storing Europe's carbon emissions for the next century. "That gives us 100 years of breathing space to make the transition into a much lower carbon

way of generating our energy". The problems are cost of capture, which is currently 25% of energy but may be reduced to 10% or lower, and a perceived safety issue. Professor Haszeldine argued that there are many natural carbon storage sites which have existed for 60 million years without problem and we can replicate these.

Existing oil and gas technology can be used to drill into appropriate pockets; the CO_2 is then injected and prevented from leaking by many layers of impermeable rock. The CO_2 then dissolves into fizzy water. There are examples of leaks from natural CO_2 stores, including geysers which are visitor attractions. The level of escape is minute and there is no danger to people. The storage process is well established – Norwegian company Statoil has been pumping 1m tonnes a year into rocks beneath the North Sea since 1996. Shell has a proposal to build a carbon capture facility at its gas-fired power station in Peterhead and link it to the existing pipeline to the depleted Goldeneye gas field.

In future, we could build a power station at Grangemouth and use the existing pipelines to take CO_2 to the North Sea, which the Professor said would decarbonise the whole of eastern Scotland. "This is the easiest decarbonisation action for any country in Europe," he added. We can also use CO_2 to pump into oil and gas wells, forcing out an additional one to three billion barrels of oil in the UK alone, while retaining CO_2 in very secure storage. The substantial taxes earned could enable the UK to very greatly accelerate the construction of carbon capture and storage (CCS), and the commercial proving of onshore storage reservoirs.

There are other helpful ways of decarbonising; for example, reforestation of Scotland could use biomass to sustainably recapture 5 Mt CO_2/yr, and by the use of more renewables. Some are helpful, but cannot solve the whole problem; others may be prohibitively expensive. Ultimately, he concluded, CCS presents the best option.

Session 1 Q & A

● Asked if it would not be just as effective to raise energy efficiency in order to cut consumption, Professor Haszeldine said that efficiency is clearly beneficial in making better use of resources, and should also reduce costs to users. However, this would not stop the total stock of emissions increasing, but only slow the rate of emissions. He also suggested the consequent reduction in energy costs might encourage people to use more, and that increasing populations and affluence also drives up usage.

● The speakers were challenged on the accuracy of climate change predictions and the existence of research, claiming they are greatly overstated. Professor Hegerl responded that challenges to climate change science, such as the atmospheric negative feedback theory of Richard Lindzen, have been found not to work. Likewise, Judith Curry has written some interesting papers, but her understanding of crucial aspects of attribution science may be questionable, added Professor Hegerl.

● Questioned on the ability of taxation to help reduce emissions, Professor Haszeldine said that this tends to simply penalise the poor and that revenue is not then used to create a clean carbon economy. His preference is for the use of storage certification and heavy penalties to force down emissions.

Session 2: Impacts, Adaptation and Vulnerability

Chaired by Professor David Stevenson, Professor of Atmospheric Chemistry Modelling, University of Edinburgh

Key speaker: Professor Mark Rounsevell

Professor Rounsevell addressed the key questions of whether climate change matters to society and what the impacts will be.

He began by looking at the evidence for Europe and describing direct impacts such as more heat waves, dry spells and forest fires, and identifying the geographical areas likely to be affected. The Professor argued that while many of the impacts will be negative, some will be positive – and in other cases we simply don't know.

While the environmental results of climate change may often be limited in Europe, Professor Rounsevell argued that the social consequences are likely to be much greater. These too could vary greatly, depending on how effective we become at adaptation and mitigation. "What is really important to consider here," he said: "is that there are multiple drivers of change. There is a whole range of things we know are going to happen throughout society over the next 50 to 100, years and we have to plan for these."

A great deal of the scientific literature on climate change looks at single factors and drivers. According to the Professor, it is essential to look at multiple factors, as many of the impacts of climate change will be indirect – for example, agriculture will be strongly influenced by the water sector, and biodiversity by changes in land use. If we do not think about multiple sectors, we risk both over- and underestimating the impacts. We also have to think in terms not just of environmental outcomes, but also of social risk and vulnerability.

Professor Rounsevell has used a variety of indicators to begin assessing Scotland's capacity to cope with a whole variety of social and economic changes into the future. These envisage everything ranging from the relatively utopian to dystopian. Even here, he suggested that social trajectories are unlikely to be straight, as our actions and responses to external drivers will change over time. What emerges is a highly complex set of possibilities combined with a large number of uncertainties, not least from the predictive models being used.

When planning mitigation and adaptation strategies, the Professor said great care has to be taken. Some may be good for adaptation but poor for mitigation, or *vice-versa*. Biofuels may provide an alternative to fossil fuels, but can have implications for biodiversity. Equally, there are often considerable uncertainties about what the actual benefits or disadvantages will be. This leaves societies in a difficult position, as they have to decide on what actions to take in order to cope with climate change and all the other relevant factors that will combine to shape our future world.

In conclusion, Professor Rounsevell reasserted that:

- we must consider multiple drivers, not climate change alone;
- indirect impacts through cross-sectoral (and cross-scale) interactions are crucial for impact assessment;
- there are uncertainties associated with both climate models and impact models;
- impact assessment is more meaningful when it includes societal adaptation and vulnerability; and
- there will be trade-offs between climate change adaptation and mitigation.

Scottish comments: Dr Andy Kerr

Dr Kerr considered the need for people to have clear information about the risks they face if they are to adapt to climate change.

Seventeen years ago, the UK Climate Impact Programme tried to encourage local authorities, and others, to prepare for climate change by presenting the first sub-national scenarios for the century to come. These, according to Dr Kerr, got little response, as they could not say much more than that things would get warmer and wetter. Later on, the UKCP09 scenarios offered something more practical. This was akin to a "horse racing bet", which gave percentage-based probabilities on everything from seasonal temperatures and rainfall to sea level rise. According to Dr Kerr, this type of data was easier to take on board.

UK and Scottish adaptation programmes have now been implemented and from this year, in Scotland, public sector organisations have a duty to start reporting on what they are doing to manage climate change. One "extremely intelligent" development, said Dr Kerr, has been the increasing focus on risk management in the UK. This approach encourages practical action by identifying hazards, and our exposure and vulnerability to those hazards. People can tackle their exposure and/or vulnerability and thereby cut climate risks. One example might be to stop putting buildings on flood plains.

Clear indicators of adaptive capacity and the extent to which things are genuinely changing are currently being developed. Vulnerability to climate change can be reduced by many means, including increased social cohesion, said Dr Kerr. When severe storms hit electricity supplies in southwest Scotland, the community on Arran responded well, with people checking on neighbours and caring for the elderly. By contrast, a less cohesive community near Ayr failed to cope well, despite facing the same challenge.

Dr Kerr criticised the UK Climate Change Risk Assessment (CCRA) and its implications for Scotland, because it lacks substance on which people can act. He also described it as "horribly skewed to the wider UK issue", with a strong focus on London and the southeast". One example is the warning about drier summers – this currently applies in southern Britain but not Scotland. As a result, said Dr Kerr, there is a mismatch between what scientists are saying and what the public are told.

He then turned to the direction of climate services in Scotland. At the moment, there still tends to be a one-way push – passing out information then asking what people are going to do. Experience shows that it is far better to work together. The most effective approach is to find out what a group's or organisation's objectives are, then to work with them to explore how they will be affected by climate change so that an appropriate response can be formulated.

One valuable initiative is that Scotland has set up a National Centre for Resilience. Part of its work involves preparing emergency teams for the impact of natural hazards. Longer-term projects include building social cohesion so that, whether an emergency is caused by climate change or by something else, communities can cope.

Session 2 Q & A

● Professor Rounsevell responded to a question about whether it is realistic to look at climate change simply within a European context. He agreed that the impacts, and responses, of each country or continent will have effects beyond their borders. For

example, reforesting Scotland could lead to greater imports, meaning more is grown elsewhere.

● With power stations shutting and the intermittent nature of wind energy, the issue was raised of how Scotland can 'keep the lights on'. Dr Kerr emphasised that Scotland is part of a GB network. He said that there is much the UK can do to develop a properly integrated system that makes the most of resources and compensates for issues such as the variability of wind.

● Dr Kerr responded to a question about whether industry is modelling for climate change by saying that it is, but that this tends to be within a broader context of planning for all the potential opportunities and risks that lie ahead.

● Concern was raised that Scotland could become complacent, as recent reports, such as one from PWC, have suggested that the localised impact of climate change would be limited. Dr Kerr said there is a new UK risk assessment taking place and those taking part are highly aware that globalisation means that forest fires in Russia or floods in Pakistan can matter here as they hit the world supply chain.

Session 3: Mitigation of Climate Change

Chaired by Professor David Sugden FRSE, Professor of Geography, University of Edinburgh

Key Speaker: Professor Ottmar Edenhofer

Despite the global economic crisis and mitigation efforts, Professor Edenhofer said global carbon emissions are "rising and rising and rising".

There are four underlying components driving emissions:

- GDP per capita (economic growth)
- Population
- Energy intensity
- Carbon intensity

Energy efficiency has increased in the last decade, but the gains from, e.g., more efficient homes and cars, have been outweighed by economic and population growth. Additionally, the long-standing trend of decarbonisation of energy has reversed due to the growing use of coal for power. Professor Edenhofer said: "Many people in Europe believe we are in an age of renewable energy, but this is not the case. We are in the middle of a coal renaissance."

Continuing with business as usual could lead to a 4°C mean temperature rise. By limiting the increase to 2°C above pre-industrial levels, the worst effects of climate change could be avoided. And while he emphasised that there are many uncertainties about climate change, the Professor said that the 2°C target as a "pragmatic precautionary principle" does not allow for a "wait and see" approach.

He then turned to how we can keep to the target by thinking in terms of the "cumulative carbon budget". This budget determines the increase in global mean temperature. The budget would allow for the release of a further 1,000 gigatonnes of CO_2. This would demand emissions reductions of 40%–70% by 2050. Depending on the rate of emissions reductions, negative emissions need to be achieved towards the end of the

century. With current trends continuing, the budget would be used up in about 20 to 30 years.

The electricity sector is a large source and decarbonisation requires the development of large-scale carbon capture and storage. Change is also needed in areas such as land use; e.g., through reduced deforestation. The less carbon capture and storage is possible, the more afforestation will be needed to sequester CO_2 from the atmosphere. This could have knock-on effects; for example, on agricultural production and food security.

According to Professor Edenhofer, it is also important to act now, or the scale and speed of change will have to be far greater. He added that if we act now, the cost of adaptation and mitigation will be relatively modest and will still leave room for significant economic growth. Speaking personally, he said that one implication of climate policy is that large amounts of fossil fuels must remain underground – which devalues assets for their owners. However, all economics must take account of scarcity and the most scarce resource is the CO_2 disposal space in the atmosphere.

The competing interests can, claimed the Professor, be reconciled through carbon trading or taxation, as these provide investors with realistic expectations with regard to scarcity. They would also encourage carbon-free technologies and carbon capture and storage. “There is,” he asserted “a splendid opportunity for carbon taxation around the world.” For finance ministers, it is more attractive than taxing labour or capital and the revenues could be used for climate change programmes or for infrastructural development to increase economic competitiveness. “In short,” Professor Edenhofer said: “it is better to tax ‘bads’ than ‘goods’.”

Session 3 Q & A

● The Professor was asked if he is proposing ‘totalitarian interference’ in the free market. His response was that all economics have to reflect scarcities and that the economic system in East Germany had collapsed precisely because it failed to do this. He said: “This has nothing to do with a totalitarian point of view … it is rescuing a free market economy.”

● Asked if it would be better to remove subsidies rather than impose taxes, Professor Edenhofer said that both are needed: the removal of subsidies and, in addition to that, a carbon price which reflects the scarcity of the limited disposal space of the atmosphere. Care would, though, be needed as there are some countries where it would hurt the poor.

Industry comments: Angus Gillespie

Mr Gillespie offered an “unashamedly commercial” view of how a gas and oil company deals with these “turbulent times” of climate change.

There are two particular issues big business must reconcile:

1) The short-term pressure for shareholder performance and the need for long-term investment.

2) Maintaining cash flow during a transition to low carbon energy production.

According to Mr Gillespie, Shell fully accepts that fossil fuels have a major role in climate change. While there is a clear need for energy transition, the task is vast, immensely

expensive and will take time – though the company supports the aspiration of zero emissions by the end of the century. He described the challenge of rebuilding our energy system to limit temperature increases to 2°C as "frightening", and claimed the costs make it look "almost unattainable".

Shell favours carbon pricing and believes that the fastest way to decarbonise is to replace coal with gas for energy generation. It is also pushing ahead with large-scale carbon capture and storage (CCS). The company has invested $12bn in biofuels as an effective short-term means to reduce vehicle emissions. According to Mr Gillespie, the business priorities are on risk management, exploitation of commercial opportunities and developing the staff competencies to deal with the climate change challenge.

Mr Gillespie explained how CCS is being developed and deployed at Peterhead and said that other projects are underway around the world from Australia to North America. "You can see, we are trying to play a part in getting these technologies moving," he said. Another 22 CCS schemes are already running or about to come on line, which will account for 40m tonnes of carbon a year. However, the IEA wants to see 7,000m tonnes a year stored by 2050 in order to achieve the 2°C target.

At present, CCS costs c$125 per tonne, but Shell believes that new processes can be developed to radically cut the capture cost, which is about 80% of the total. The need is to reach $60–$80 per tonne. Looking at the cost of low-carbon energy sources, Mr Gillespie believes that CCS on coal and natural gas can be competitive with other technologies such as offshore wind.

CCS is still in its demonstration phase. While the technology is well-established and CO_2 transportation is relatively straightforward, the challenge is to do it all cost-effectively and at scale. Mr Gillespie said that Shell believes that government subsidy support should be removed from alternative energy sources once the technology is commercial, but that public investment is required to make sure the new market can be established.

Mr Gillespie reiterated that replacing coal with gas can halve fuel sector emissions in the short term, that robust carbon pricing would push market development and that there must be a sincere commitment to CCS. In conclusion, he said: "My fear is that … we end up demonising fossil fuels and losing sight of the fact that fossil fuels are really valuable to the economy – it's the CO_2 that's the demon."

Q&A

● Asked how much CO_2 the CCS process itself involved, Mr Gillespie said there is an "energy penalty" of 10–20%, depending on the plant, but that the net gains are huge. The aim is to have plants that are so efficient that the figure drops to zero.

● Mr Gillespie was questioned about Shell's membership of "anti-climate change" bodies. He said some are not anti-climate change but have sometimes been sceptical about particular issues. Shell, he claimed, works to change views within certain key organisations. In the case of ALEC (the American Legislative Change Council), the company is currently performing a cost-benefit review of whether it should sever its links.

Professor Sugden then brought the Conference to a close by offering the Vote of Thanks to all the participants.