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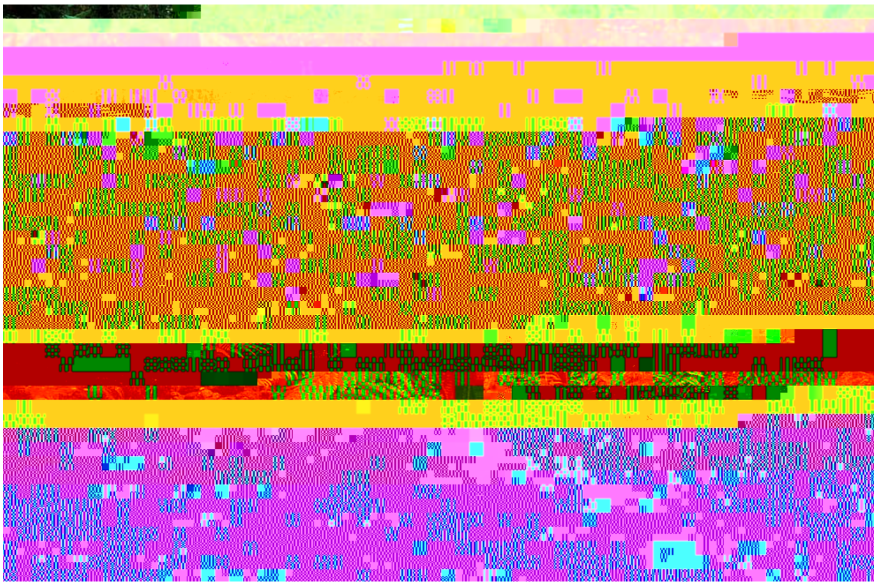

A glimpse of the interior of a rainforest on the Tutoko River Track, Fiordland National Park, New Zealand. *The protection of rainforests through the financial incentives offered by carbon trading schemes was described in this year's ECG DGL 'The Science of Carbon Trading' pp 2-18.*

Sir Frank Fraser Darling, ecologist, 1903-1979

'Wilderness and Plenty', The Reith Lectures 1969. Published by the British Broadcasting Corporation, 1970.

"Now, there is a much greater change to which we are contributing, this time in the planetary atmosphere … I am alluding to the rise of carbon dioxide in the atmosphere … There is a carbon dioxide cycle which naturally keeps levels right. It is a system of great age and stability which we are now taxing with the immense amounts of carbon dioxide we are adding from the fuel we burn. Vegetation is a great buffer: the forested wilderness removes a great deal of the carbon dioxide … sequesters it, giving out oxygen in exchange … But unfortunately we are cutting the virgin wildernesses all the time and reducing tree cover in so many places … the activities of industrial and technological man in our day are adding carbon dioxide and also injuring the capacity of the biosphere to redress the balance."

These prescient and compelling words are from the transcript of one of Dr Frank Fraser Darling's BBC Reith Lectures delivered nearly 40 years ago. He went on to foresee the effects of global warming on the oceans and on marine fauna, and the consequences for the polar icecaps. At the time, Fraser Darling wrote that 'the carbon dioxide problem is as yet remote', but scorned those who said the 'posterity must look after itself', instead 'we should be delving ecologically into the future'.

Now 40 years on the carbon dioxide problem is very real, and commands the attention of politicians, economists as well as scientists. This year's ECG DGL and symposium 'The Science of Carbon Trading' addressed a few of the issues raised by Fraser Darling. In the main lecture, economist **Terry Barker** explained the financial leverage exerted by carbon trading as a way of reducing overall CO_2 emissions. Preservation of tropical rainforests was the concern of two of the speakers in the supporting symposium, **Jon Lovett** and **Matthew Owen**. While the vexed question of whether the use of biofuels can reduce the levels of greenhouse gases was tackled in the remaining talk by **Nigel Mortimer**.

In 1969, Fraser Darling thought that 'not nearly enough data are being gathered' about the effects of global warming. That, at least, is no longer the case, and **Stephen Ball** analyses a recent article in *Nature* on the impact on physical and biological systems due to anthropogenic climate change.

RUPERT PURCHASE

Achieving the European Union's 2 °C target through carbon trading

***Dr Terry Barker**, University of Cambridge, UK*

ECG Distinguished Guest Lecturer 2008

Introduction

The climate-change problem

The climate-change problem is essentially one of accumulating stocks of greenhouse gases (GHG) in the atmosphere. Economic behaviour and the availability of fossil fuels have led to greatly increased greenhouse gas emissions from human activity, and the unrestrained future increase in emissions is likely to end in dangerous climate change.

Figure 1 shows the expected increases in GHG emissions from a wide range of

The attribution of such extreme events to global warming is supported by the unexpectedly high increase in CO_2 concentrations reported by Raupach *et al*, 2007, in turn attributed to faster-than-expected global economic growth and the increased use of coal in China and other developing countries for electricity generation.

The important feature of future climate

been recognised that a more consistent and indeed in my mind a more ethical treatment would yield the overwhelming costs I have mentioned.

This is obvious intuitively if we postulate that:

1. Business as usual emissions are likely to lead to concentrations above 750ppmvCO_2-eq, and
2. The damages are likely to rise steeply as average temperatures rise over the next century.

The costs rise as the damages to life and health increase for the rich, who can afford to protect themselves, and far more so for the poor. The CBA solution in this case is one of costs so high that immediate and instantaneous elimination of all GHG emissions is justified as well as the use of all our resources in a massive programme to remove CO_2 from the air. This of course in not going to happen and I agree with Marty Weitzman (2008) that this makes CBA meaningless and useless.

Figure 3 shows various targets for climate stabilisation in terms of temperature increases above pre-industrial levels, and GHG concentrations in the atmosphere in CO_2-equivalent parts per million (ppm). The current level is about 430ppm CO_2-eq, but this is affected by SO_2 and other non-GHG emissions that have a net cooling effect. *The Stern Review* range is 450-550ppm CO_2-eq, but a feasible level for scientific study is assumed to be 400ppm CO_2-eq, whilst the safe level for the 2 °C target, allowing for climate sensitivity, would be more like 380ppm CO_2-eq (Hansen *et al*, 2008).

The central question for climate policy

So we must re-direct our economic thinking towards a risk assessment. The central question for climate policy is how to reduce all damaging emissions from human activity as soon as possible, recognising the risks and uncertainties and the opportunities for improving human well-being.

In the atmospheric emissions with GHGs, I include soot, other fine particles, SO_2 and the chemical surfaces of the particles (as well as the chemical soup cooked up by the sun and weather) as an inherent part of the

Why a carbon price is essential

The impact of carbon pricing

The main reason why technology alone is very unlikely to solve the mitigation problem is this “rebound effect” (Sorrell 2007). This effect comes about through improvements in energy efficiency leading to reductions in costs of a technology, which then leads to higher use, so that the energy-saving from the technological improvement if offset by increased demand for energy. Therefore any technological breakthrough without a carbon prr07logi2i[(of)5.5(fset)4.2(by.0026 2(fse3.8(0 -1to)3exfse3.8tra ufse3.8s)4.4(g)]TJ/Tfse3.8n willg t reduction target by 2020 of at least 30% below 1990 levels by 2020. Such a carbon price is a market price similar to the world oil price, but applying mainly to CO_2 emissions from electricity generation. It converts to $45/barrel of oil and would be paid on CO_2 emissions from burning coal and gas (the electricity sector does not use much oil for generation), essentially raising electricity prices (by 70% in the US on year 2005 fossil-fuel use). However, there is a the crucial difference compared to 2007-2008 oil-price increases on a similar scale: the increase in carbon prices would be spread over several years and the revenues from auctioning the emission allowances would accrue to the countries regulating the emissions, not to the oil producers, and so they can be used to compensate those who lose employment and to provide incentives for low-carbon alternative sources of energy. If the energy sector responds rapidly and switches to renewables, nuclear and other low-carbon sources, then the CO_2 allowance costs will fall rapidly. However, emission trading schemes are less suitable for other sectors, especially for emissions from transportation and buildings, and wider portfolios of policies, in which institutional and technical barriers to change are addressed, are more appropriate.

Portfolios of economic instruments for mitigation: carbon prices, low-GHG incentives and regulation

The literature on mitigation is concerned mainly with quantitative GHG targets, as required by any stabilization target, which has to be absolute in relation to the prospective stocks of GHGs in the atmosphere. However, the economic system driving the emissions is market-based, in which prices play a critical role in allocating resources and encouraging technological change. The low-cost policies all require the use of market instruments via carbon prices, combined in portfolios with regulation and subsidies targeted at clear market failures, most critically the pervasive general market failure in innovation and the specific market failures in the energy markets (e.g. achieving more rapid penetration of hybrid and plug-in vehicles, or exploiting no-regrets options in buildings). The market failure in innovation comes about because those doing the investment, even allowing for patents, are unable to capture all the benefits, which accrue to all those able to copy and exploit the innovation. In consequence not enough innovation is done in a market system (Jaffe *et al*, 2005).

Governments usually have a wide range of policy instruments at their disposal to achieve their targets for climate policy. Indeed, the focus of the IPCC WG3 Report is on the sectoral options for mitigation (7 out of 13 chapters), providing a rich source of detail on the economic potential for mitigation at different carbon prices in energy, transport, buildings, industry, agriculture, forestry and waste management. Good policy portfolios for GHG mitigation will be specific to each country depending on their political systems, the available renewable and other energy resources and the energy efficiency of the stocks of buildings and equipment. Such portfolios will combine policies and measures to produce outcomes that are effective at achieving the main objective, efficient with low costs, or even benefits, as regards effects on GDP, and equitable in that the most vulnerable groups affected will be most likely to benefit. Most important for policies to achieve a wide social consensus, they should also address other potential social benefits, such as improvements in air quality with the associated better human health and higher crop productivity, the increased comfort from better insulated buildings, or reductions in traffic-related pollution.

It is a great advantage that climate policies, both for adaptation and mitigation, are inherently *equitable*. This is because mitigation has its main and central benefit the avoided costs of climate change and adaptation also avoids the effects of climate change. The climate change damages are focused on those who cannot re-locate or otherwise protect themselves against climate-related damages, i.e. those on low incomes, especially in developing countries with relatively large agricultural sectors in flood plains or drought-prone regions. However, there are major exceptions, e.g. energy use per capita may be particularly high in low-quality dwellings occupied by low-income households. In such cases the portfolio should include measures to improve the energy efficiency of dwellings.

One complement to the market-based carbon prices is the use of the traditional regulatory command-and-control approach, which involves agencies (such as Pollution Inspectorates) fixing and forcing energy and GHG standards. Climate, air quality and energy-security objectives are all served by technology-forcing policies of the sort pioneered in California over the past 15 years (Jänicke and Jacob, 2004). The main objection has been their potential inefficiency, but they can be targeted to correct market failures and support investments that are profitable given

The energy system costs

We can find one estimate of these sectoral costs from the price of the allowances times their number, since this is what has to be paid to achieve a target if all the allowances are auctioned. Thus if we expect total UK CO_2 emissions to be 30% below 2000 levels by 2020, the revenue (assuming prices of £66/tCO_2 converted from \$100/tCO_2) would be £25bn in 2000 prices. It is important to put this into perspective. Total UK environmental taxes were £35bn in 2005, current prices, representing 7.7% of total tax

found in tropical forests. Protecting these forests will go a long way towards fulfilling the objectives of the Convention on Biological Diversity.

Analysis of country-level emissions with and without forestry shows both the magnitude of forest-related emissions and their spatial distribution (Table 1). When forestry is included then developing countries with high deforestation rates have per capita emissions comparable to, or exceeding those of developed nations. Under the Kyoto Protocol Clean Development

Management is usually administered by a local committee through by-laws on off-take, plus protective measures such as fire prevention and patrols against unauthorised exploitation. Rewards may be distributed in different ways, often through a village fund. Thus

'Cool Earth'

Cool Earth is a UK based charity launched in 2007 to fund the conservation of rainforests as a means of tackling climate change. *Cool Earth* currently has 20,000 members, who have funded the conservation of over 9 million tonnes of CO_2 stored in endangered tropical rainforests. **Matthew Owen** from Cornwall College outlines the significance of tropical rainforests in balancing the global carbon budget.

Why conserve tropical rainforests?

The atmospheric CO_2 concentration is currently growing at a rate 1.9 ppm/yr [1]. This increase is primarily through fossil fuel use and land-use change, roughly 80% and 20% respectively, with tropical deforestation and degradation accounting for 96% of land-use emissions [2].

The role of tropical forest is nonetheless understated. If left undisturbed, tropical forests are estimated to sequester 4.4 $GtCO_2e$/yr (15% of all anthropogenic emissions) [1]. Reducing deforestation and degradation therefore not only decreases the release of CO_2 emissions but also moderates the effects of emissions by preserving a sink.

Pristine tropical forests also provide many other varied services at the local to global scales. Rainfall generated from the Amazon supplies the Rio Plata basin, which generates 70% of the GDP of southern South America. Deforestation of the Congo basin has been linked to reduced precipitation by 5-15% less in the US Great Lakes and 25% less in the region north of the Black Sea [3]. Once rainforests are removed, replanting may not restore these complex global weather patterns.

The variety of tropical forests means they occupy different positions on the marginal cost abatement curve, with estimates varying by location and land-use from under \$1 to \$2000 /tCO_2 [4]. We nonetheless estimate that at least half of deforestation emissions could be prevented through investments equivalent to less than \$5 per tonnes of CO_2e.

Rainforests and carbon trading

The UNFCCC/Kyoto agreement established a partial global carbon market infrastructure, but explicitly barred trade in abatement through reduced deforestation. As a result, forest carbon in developing countries is not currently priced. This makes global mitigation unnecessarily expensive, and discriminates against developing countries, who are not able to realise the global market value of their natural carbon assets. But developed (Annex I) countries are allowed to set off their carbon targets against their domestic forest sinks. This disparity is unethical, economically inefficient, and environmentally dangerous.

Only the carbon market can deliver the required scale of abatement through reduced deforestation. In a perfect market each unit of carbon – sunk, emitted or avoided – would be accounted for globally and floated to achieve a global market-clearing carbon price equilibrium.

However, carbon price stability is crucial during the transition period to a low carbon global economy. Jon Lovett has described the Reduced Emissions from Deforestation in Developing Countries **(**REDD) scheme, which promotes carbon trading as a means to reduce deforestation (see accompanying article). Compensation under the REDD scheme could perhaps be further exploited to decrease the global emissions cap to a level needed for a 2 °C stabilisation. In this way the cost of global mitigation can be reduced, while maintaining the stable carbon price essential to drive technological transformation.

The earliest that barriers to global trade in deforestation carbon abatement can be dismantled is 2012. A hiatus in significant abatement of deforestation until then is untenable. Urgent action is required by the UK and like-minded partners to guarantee the future redeemability of forward investments. This will unlock the potential for rapid growth in finance flows for cost effective abatement through reduced deforestation in developing countries.

How can tropical rainforests be protected?

Cool Earth has achieved much through public support for targeted conservation of endangered forest. To scale-up the efforts of the NGO community, national level governance and leadership is critical.

Forest protection considerations need to be fully integrated into national poverty reduction and growth plans. A range of schemes to support this are being established, such as the World Bank's Forest Carbon Partnership Facility (FCPF) – which will help countries prepare to take advantage of future REDD benefits and provide a limited fund which will purchase credits from successful emissions reductions programmes. The Congo Basin Forest Initiative and GEF will also offer assistance to developing nations.

The specificities of forest types, communities and opportunities means that forest protection will ultimately be secured through projects – ideally, but not necessarily, fitting into a coherent national programme. From the wealth of experience and lessons available, certain principles for successful projects are clear:

1. Finance mechanisms are needed that promote new forest business models that will provide local and global ecosystem services, and support communities who depend on forests for their livelihoods.
2. Forests can be fenced. Protected area programmes can work, but they need to integrate poverty reduction and alternative livelihoods elements and address tenure/rights issues.

3. Sustainable Forest Management, developed with and for communities, will often be the best way to prevent deforestation and at the same time contribute to poverty reduction objectives. Forest communities know best how to protect their forests assets. Carbon finance will often work best as a supplement to other forest-derived income streams.
4. Successful projects need to employ sophisticated monitoring and verification techniques to ensure the market credibility of their carbon assets.

In order to obtain sufficient finance (particularly from the private sector) for the establishment of large-scale forest protection schemes, successful projects need to generate desirable and credible forest assets. These assets are likely to incorporate carbon and non-carbon elements and should be capable of being integrated into the future carbon market.

What financing mechanisms are appropriate?

There are various options for attracting institutional investment to the protection of rainforests. These range from the securitisation of mixed incomes generated from pooled projects, to taking equity control over forest-derived carbon assets. But the success of any of these financial tools depends upon establishing a fundable carbon credit scheme.

Capital markets have little experience of investing in forest product derivatives. The international timber trade is dominated by Swiss, Chinese and Lichtenstein registered producers. Domestic trades are similarly opaque and account for up to 80% of demand in nations such as Brazil.

As such, it is doubtful that the potential volatility in carbon pricing could be accommodated in a fixed income instrument. This leaves an equity mechanism as the more likely way of securing funding.

The Kyoto Protocol's Joint Implementation mechanism offers the best chance of success since it would allow forest-derived credits without affecting price stability. However, in order to attract the scale of investment needed, some level of precedent-setting investment by a developed nation would be required, ideally for a duration greater than 15 years.

Cool Earth is working to develop a better understanding of these opportunities on the part of capital markets. Ultimately, a global carbon price will stabilise around the lowest cost of emission mitigation. Avoided deforestation is the most likely supplier of such mitigation and it will have to play a central role in future negotiations concerning the post-2012 carbon market.

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Accounting for biofuels: green, black or shades of grey?

***Nigel Mortimer**, North Energy Associates Ltd.*

Current controversy

"Biofuel" is a term which covers a range of liquid of gaseous fuels which are produced from organic materials and can be used as alternatives to conventional transport fuels, such as diesel and petrol that are derived from fossil fuels. Since these organic materials, or biomass feedstocks, absorb the same amount of carbon dioxide (CO_2) as they release subsequently when the biofuels is burnt, they offer apparent prospects of being "carbon neutral".

However, the actual benefits of biofuels, as potential means of assisting the mitigation of global climate change, depend on many factors and complex interactions. In particular, it is necessary to determine the total greenhouse gas (GHG) emissions associated with their production and use. In addition to CO_2, other GHG emissions, such as methane (CH_4) and nitrous oxide (N_2O), have to be taken into account.

Depending on the biomass feedstock and its original source, how and where it is cultivated or otherwise derived, and how it is converted into a biofuels, total GHG emissions can vary from a very low, or, indeed, negative, value to very high values that exceed those from the production and use of conventional transport fuels. Whilst such results have been interpreted in different ways by people with different perspectives, the Biofuels Working Group of the Royal Society concluded that "each biofuels option needs to be assessed individually on its own merits" (Royal Society, 2008).

Life cycle assessment

The necessary scientific approach to resolving the current controversy over biofuels involves the application of life

Transport Fuels Obligation (RTFO). It is possible that all accounting methodologies will be modified to include the effects of direct and indirect land use change (LUC). It is relatively easy to accommodate the GHG emissions effects when alternative land uses do not involve the creation of a useful product such as food.

However, when food or other production is displaced by the cultivation of a biomass feedstock, it is necessary to determine the nature of the displacement and its effects on total

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NIGEL MORTIMER,

North Energy Associates Ltd.,
Watsons Chambers,
5 – 15 Market Place,
Castle Square,
Sheffield S1 2GH,
United Kingdom

Tel: +44 (0) 114 201 2604
E-mail: nigel.mortimer@northenergy.co.uk

Biographical details

Nigel Mortimer is one of the founding directors of North Energy Associates Ltd. This consultancy company has been involved in the practical implementation of sustainable energy development since 1991. Nigel has a BSc in Physics and a PhD in Energy Technology. Nigel formerly held the Chair of Sustainable Energy Development at Sheffield Hallam University where he was the Head of the Resources Research Unit. His specific expertise within North Energy includes life cycle assessment. He has managed and undertaken research and consultancy contract work on a broad range of projects in the United Kingdom and elsewhere. His current work involves the evaluation of primary energy inputs and greenhouse gas emissions associated with biomass energy technologies, biomaterials and biochemicals. Clients for this work include the European Commission, the Department for the Environment, Food and Rural Affairs, the Department of Business, Enterprise and Regulatory Reform, the Environment Agency, British Sugar plc, Biofuels Corporation plc and the Northeast Biofuels Consortium. Nigel is a member of the Royal Society's Biofuels Working Group which recently published "Sustainable Biofuels: Prospects and Challenges.

This article is based on a presentation by Dr Mortimer at the ECG's 2008 Distinguished Guest Lecture and Symposium 'The Science of Carbon Trading'.

Biophysical remediation of petroleum hydrocarbon contaminated soil in Yorkshire

Our industrial past has left us with a large number of brownfield sites, many of which contain elevated concentrations of contaminants in the soil and groundwater. These substances pose potentially significant human health risks as well as impacting on groundwater, surface water, and flora and fauna.

ECG committee member **James Lymer** from the engineering and environmental consultancy firm, Wardell Armstrong LLP, describes some of the regulatory and practical considerations of cleaning-up contaminated land in the UK.

Contaminated land legislation

In the UK, new policy initiatives and various pieces of specific legislation for dealing with contaminated land have been introduced since the 1990 Environmental Protection Act.

Part II(a) of the Environmental Protection Act 1990 Part II(a) of the Environmental Protection Act 1990 was introduced under Section 57 of the Environment Act 1995 and came into effect in England and Scotland in 2000 and Wales in 2001.

Under Part II(a), the statutory definition of contaminated land is:

- land which appears to the Local Authority in whose area it is situated to be in such a condition, by reason of substances in, on or under the land, that:
  a. significant harm is being caused or there is a significant possibility of such harm being caused; or
  b. pollution of controlled waters is being, or is likely to be, caused.

Part II(a) was extended in 2006 to include radioactivity in England and Wales, but this currently only applies to human exposure to radioactivity.

Local Authorities Local Authorities are responsible for the inspection of contaminated land and for ensuring remediation is undertaken where necessary. Local Authorities also maintain a Public Register detailing the regulatory actions that they have implemented.

account and may require investigative

frequently encountered in site

The National Centre for Atmospheric Science Graduate Summer School in Atmospheric Measurement

The National Centre for Atmospheric Science (NCAS) Graduate Summer School in Atmospheric Measurement is an annual two-week field course for atmospheric science PhD students beginning their second year of research. Cambridge University student, **Ailsa Benton**, reports on her time at the 2007 Summer School.

(NCAS) Graduate Summer School in AtmosphericMeasurement 2007. One of the meteorological challenges we encountered!

In September 2007, I joined around twenty other early-stage Ph.D. students on the Isle of Arran, Scotland to participate in the second NCAS summer school on atmospheric measurement. The ten-day period started at the tranquil Kildonan hotel on the south of the island, where we had lectures on all aspects of the atmosphere, ranging from chemistry, to meteorology, to the atmospheric structures of other planets.

It was eye-opening to realise just how broad a subject it is and to see what different educational backgrounds brought people into studying the fascinating topic of our planetary atmospheres. The setting provided an ideal opportunity to discuss with our peers the challenges we had so far found in our post-graduate studies. We were also fortunate enough to gain a wide overview of the subject from experts in the specific fields – an experience that cannot be gained simply from undergraduate courses.

The course wasn't just limited to theoretical lectures. We also travelled to the north of the island to a field centre used by students of many ages and academic disciplines to carry out a number of field studies including:

- tracking sondes
- measuring the carbon monoxide concentration of air in different regions
- calculating back-trajectories for air packets
- deducing boundary layer profiles from meteorological data.

The scope for applying these skills coming to our Ph.D. studies was evident. For my work, the application of meteorological data to chemical species measurement is invaluable in making sense of data and its origins. Teamwork and planning for extreme weather (see photograph), particularly when climbing a mountain such as Goat Fell are essential skills for application to my varied work on research ships, in remote locations and even in urban areas!

The summer school finished with the participants having the opportunity to present some of their own work, and to plan future field campaigns with mythical budgets. I hope that some of these will be realised in the near future!

AILSA BENTON

2nd Year NERC studentship Ph.D. Student,

University of Cambridge

NOTE: The National Centre for Atmospheric Science (NCAS) Graduate Summer School in Atmospheric Measurement is an annual two-week field course, aimed at atmospheric science PhD students who are about to start their second year of research. The course comprises a week of lecture-based presentations outlining aspects of atmospheric science (e.g. Atmospheric Chemistry & Field Measurements; Synoptic Meteorology; Atmospheric Aerosols), delivered by experts drawn from the UK Universities and Research Institutes. The second week involves practical exercises in Atmospheric Measurements, including weather forecasting, measurement of pollutants and use of radiosondes. The course is based upon the island of Arran, and is held in September every year. Bursaries are available for NERC-funded PhD students. Further details are obtainable from the course website, http://ncasweb.leeds.ac.uk/summerschool2008/ .

Other web link: The National Centre for Atmospheric Science http://www.ncas.ac.uk/

Meeting report: 2008 Environmental Chemistry Group Distinguished Guest Lecture and Symposium

The Science of Carbon Trading

The 35th RSC Environmental Chemistry Group Distinguished Guest Lecture and Symposium took place in the Council Room of Burlington House on Wednesday March 12th 2008. An enthusiastic and well-informed audience heard four talks on carbon trading and related topics. The quality of the presentations was matched by the range of questions from those attending, reflecting the scientific, focused on the ways in which Life Cycle Analysis (LCA) could bring a perspective to the current differing views around biofuels. These range from ‘ . . . there is no such thing as a sustainable biofuel’ (George Monbiot) to ‘assess each biofuel on its own merits ‘ (Sustainable Biofuels: Prospects and Challenges” The Royal Society, January 2008).

When LCA is applied to biofuels for GHGs, co-product allocations (all biofuels have side and waste products) and land use has considered and there are competing accounting methodologies by which these can be evaluated. The Renewable Fuels Agency Technical Guidance, BSI PAS2050 and the European Commission Renewable Energy Directive all use different approaches to accounting for land use and GHG consequences. Harmonisation of accounting processes is needed, GHG emission savings need to be accurately calculated (as do displaced foods and carbon store destruction), and good (and new) technological choices have to be made.

The **ECG 2008 Distinguished Guest Lecture** examined the way in which carbon trading could achieve the EU 2 °C target. **Dr Terry Barker** (4CMR, Dept. of Land Economy, University of Cambridge) began by noting the 70% increase in greenhouse gas (GHG) emissions which occurred between 1970 and 2004. He suggested that the existence of good fossil fuel reserves combined with strong demands for energy security will further increase GHG emissions; as will the long term trends in grassland and virgin forest removal – generally consequent on the desire for private gain at the expense of public loss.

The 2 °C (above pre-industrial) target is set by the EU as one for which serious anthropological climate change can be avoided and it is recognised that GHG emissions have to start being reduced as soon as possible (the 2 °C target is effectively equivalent to stabilising carbon dioxide in the range 445-490 ppm (*cf.* Stern: 450-550 ppm)). All countries and sectors will have to decarbonise to restrain climate change even though it is the industrialised countries which are currently responsible for the forcing inputs.

Having identified a scenario target, Terry Barker went on to develop the symposium theme that the achievement of the target depended on the critical policy instruments which drive decarbonisation and GHG removal technologies. The EU Emissions Trading scheme is the largest mitigation policy action and carbon ‘taxation’ is its driver. And he cautioned that simple increases in energy efficiency tend to lead to increased energy use unless the carbon price remains high enough to act as an incentive for decarbonisation.

In order for the policy instruments to act effectively carbon trading has to have credibility and currently its credibility resides in its creation as a government policy instrument with two strands: a carbon tax and an emission permit scheme. Such schemes are open to collusion and transaction costs are high, but

> “Policies that provide a real or implicit price of carbon could create incentives for producers and consumers to invest significantly in low-GHG products and technologies.”

There are difficulties in policy implementation:

- How can the market potential be estimated in relation to private costs?
- How can the economic potential be weighed against the social costs?
- And how can the discrepancies between the government target carbon dioxide price ($30 per tonne) be balanced against that obtained by projecting current prices to 2010 ($70 per tonne)?

But data show that the cost of stringent mitigation measures introduced now (i.e. sufficient to achieve the 2 °C target) would have a 3% impact on global GDP by 2030 (for the US, -0.7% by 2010 and zero % by 2020) – a negligible macro-economic cost for global GDP.

In the UK an effective policy needs several strands:

- A rising real carbon price ($100 per tonne by 2030) guaranteed by government to reduce the risks of

‘Attributing physical and biological impacts to anthropogenic climate change’

In the May 15th 2008 issue of *Nature*, a group of scientists from the USA, Australia, China, the West Indies, and countries in Europe and in South America analysed the scientific evidence which links the IPCC’s conclusions on climate change with the modifications that are occurring in physical and biological systems on all continents and in most of the oceans of our planet. Atmospheric chemist and ECG committee member **Stephen Ball** provides a commentary on the methodology and the conclusions of the *Nature* article.

‘Attributing physical and biological impacts to anthropogenic climate change’, Cynthia Rosenzweig [+13 co-authors], *Nature*, 2008, **453**, pp 353-357.

Natural systems respond – have always responded – to variations in climate. Thus a warm spring might prompt the early return of migratory birds or advance the flowering of certain plants [1]. Many physical systems also respond to climate: the advance/retreat of glaciers, the timing of peak flows in streams and the springtime thawing of sea ice or frozen rivers [2]. In Europe in particular [3], there has been a history of making observations of the timing of natural events in relation to climate (mainly temperature), including studies in dedicated phenological gardens. There are also instances of records going back centuries compiled by non-scientists who noted the dates of natural events, either simply as a pastime or to discern the optimum timing for agricultural practices [4].

Today’s climate is being influenced by natural variability and by additional forcings due to human activities, and the latter is beginning to impact natural systems. Last year’s Fourth Assessment Report from the Intergovernmental Panel on Climate Change (IPCC) concluded that, globally, it is likely that many natural systems are being affected by anthropogenic climate change. Pattern congruence statistics were used to compare the spatial distribution of aggregated system changes consistent and not consistent with warming with, firstly, the sign of the observed temperature change within the grid boxes and, secondly, a measure of the natural temperature variability within grid boxes calculated from a range of climate models. These tests found that the global pattern of system responses is very unlikely (<<1%) to be explained by the climate's natural variability. On the continental scale, the probability that the correlated pattern of system responses and temperature changes is due to natural variability is less than 5% for Asia and for North America and only around 10% for Europe. For other continents, the pattern congruence is less significant due to the paucity of observational data (also tropical and subtropical regions have less pronounced temperature seasons making phenological events harder to discern). In contrast, the pattern of system responses correlates well with observed temperature changes for the global data and for many continents and, since the IPCC has concluded that most of the observed temperature changes are very likely (>90% probability) to be due to anthropogenic greenhouse gases, Rosenzweig *et al* conclude that "anthropogenic climate change is having a significant impact on physical and biological systems globally and in some continents".

There are issues with using a binary indicator to aggregate climate impacts. For example, a large number of studies within one 5° × 5° latitude-longitude grid box pulling predominantly in the same direction of "consistent with warming" (such as there might be in Europe) yields just one piece of aggregate information for the pattern congruence tests. Also as discussed in a review of Rosenweig *et al's* article in the same issue of *Nature* by Zwiers and Hegerl [6], the pattern congruence tests are insensitive to some of the more subtle aspects of climate change attribution because they implicitly assume that the effects of local climate change are manifested locally within the same grid box. Instead, it is likely

Sustainable management of arsenic contaminated water and soil in rural areas of Latin America

Final project summary

This two-year project has been an international partnership investigating the sustainable management of arsenic contaminated water and soil in rural areas of Latin America. The target zones are near Calama in the Antofagasta region of northern Chile and the province of south-east Cordoba in the Chaco-Pampean plains of Argentina. In both areas high levels of volcanic arsenic are affecting rural water supplies and agriculture through contaminated soils and irrigation water. In Antofagasta, Chile, copper mining is an additional source of arsenic contamination.

A previous account of this EU-funded project appeared in the *ECG Bulletin* July 2007. The final meeting for the project was held early in December 2007 in Bell Ville, Argentina, one of the sites of the Argentinean field trials. The meeting was divided into an update and briefing session for the partners, and included a field visit to a local dairy farm, which had participated in trials measuring arsenic concentrations in milk, as well as a two-day workshop.

The meeting was attended by partners from the Agrarian Technological Institute of Castilla y Leon (ITACYL) (Spain), University of Valladolid (Spain), the Centre for Transdisciplinary Studies on Water Resources (C.E.T.A) (including the Facultad de Ciencias Veterinarias, Universidad de Buenos Aires) (Argentina), the Scientific Technological Mining R6(Agra04 Tc0.cw(6(M)4 d14 ei)1mont)3.9re,

Forthcoming meetings for environmental chemists

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