a last chance for coal

making carbon capture and storage a reality

foreword by Rt Hon Margaret Beckett MP

Jon Gibbins & Hannah Chalmers David Hawkins Graeme Sweeney
Jules Kortenhorst Linda McAvan MEP Alain Berger Ruud Lubbers
Frances O'Grady Mike Farley Matthew Lockwood Ben Caldecott &
Thomas Sweetman Keith Allott Karla Hill & Tim Malloch Sheryl Carter

compiled and edited by Chris Littlecott

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foreword

Rt Hon Margaret Beckett MP

“ EU leadership on CCS will help us attain climate and energy security in a low-carbon world ”

The struggle to avert catastrophic climate change is the most urgent challenge facing the human race. We must take decisive action now to avoid disastrous economic and environmental consequences. European leadership is central to this struggle. A successful outcome to current negotiations over future EU action is a pre-requisite to an effective global agreement at the UN climate change negotiations in Copenhagen in 2009.

We will only succeed if we can secure a low-carbon future for coal. Carbon capture and storage (CCS) technologies are central to the struggle against climate change in the UK, Europe and globally.

That is why, as both foreign secretary and environment secretary, I placed so much emphasis on the development and deployment of CCS technology, both within Europe and through the near-zero emissions coal project that Europe is supporting in China.

I was therefore delighted that we secured agreement at the European Council in 2007 to develop around a dozen CCS demonstration plants in Europe. But the moment of truth is fast approaching. Europe must now deliver the means to bring these plants to market. EU leadership on CCS will help us attain climate and energy security in a low-carbon world.

In Britain, the risks associated with new unabated coal plants are, understandably, a prominent part of the public debate on climate change. But there is another side to this. It is high time that we placed equal emphasis on the opportunity provided by CCS technologies to put the UK at the forefront of a new global industry.

The next six months is a critical period, as the UK develops a delivery plan for our ground-breaking climate change bill and Europe finalises the climate and energy package. Our actions matter to the world. They will influence actions both in the US, and in emerging economies such as China and India.

So I warmly welcome this publication. The wide range of individuals and organisations represented here demonstrates the growing support for CCS, and the measures needed to bring it to market.

Above all, this publication illustrates the need for Europe to agree a financial mechanism that can trigger a new wave of investment to demonstrate CCS technology within Europe and beyond. That agreement is vital to meeting the UK and Europe's emissions targets, and to kick-starting the European and global CCS industry. A prosperous and low-carbon European economy is within reach. Let us grasp it now.

Margaret Beckett was a cabinet member of the British government from 1997-2007. She was foreign secretary from 2006-07, secretary of state for the environment from 2001-06, and secretary of state for trade and industry from 1997-98. She is currently chair of the Intelligence and Security Committee.

introduction
Stephen Hale, Green Alliance

“ Europe must take the lead in financing CCS demonstration projects, and enable the full range of technologies to be assessed ”

This collection shows just how far the debate on climate change has come. It includes contributions from individuals with vastly different backgrounds. All agree that decisive action on climate change in the next decade is imperative. Our tentative steps to date are simply not enough. We have little time to make the transition to a zero-carbon economy. We must accelerate our efforts now.

The contributors shared focus is finding solutions that match the scale of the challenge. We will only succeed if we link climate change with other pressing challenges. Climate change and energy policy, in particular, must be tackled together. We cannot purchase energy security at the cost of climate security. But old thinking is proving hard to overcome in developing energy policy. The political imperative to ‘keep the lights on’ cannot be wished away; but neither can it be used as an excuse to avoid securing a stable climate. We must meet both goals at once.

Carbon capture and storage technology (CCS) could play a vital role in this. Coal is our most carbon-intensive fossil fuel. But given the energy security benefits of coal, and the inbuilt inertia of energy systems, the continued use of coal seems unavoidable. It is here that the potential deployment of CCS becomes of huge political significance. It could enable us to meet our climate and energy security goals while we develop and deploy other low-carbon clean energy sources.

This is a vital issue for global action on climate change. With the USA and China both wanting movement from the other before they commit to a global deal, the potential for a tragic standoff still looms large, with the need for action on coal at its heart. Only Europe can break the logjam. The European Union (EU) is still the de facto leader among developed nations on ambition, resourcing, and political will.

Europe must take the lead in financing CCS demonstration projects, and enable the full range of technologies to be assessed. Where we go, others are likely to follow (as David Hawkins of NRDC argues on

page 10). Whether CCS will become a long-term solution or not, there is a pressing need to demonstrate it at commercial scale. We urgently need a clear picture of its viability and applicability, and the costs involved for its envisaged wider deployment. By doing this as a co-operative European venture, common funding can be found, supply chains built, and costs reduced.

This is an opportunity for Europe to prove to the world that it is serious. The EU climate and energy package currently under negotiation is not yet reaching the necessary level of ambition. A breakthrough on CCS could be key to demonstrating leadership both internationally and in decarbonising Europe.

"in our view, financial support must be accompanied by stringent regulations for new power plant"

It could also bring tremendous benefits to Europe. Section two of this publication explores these, with perspectives covering a range of issues from technical feasibility to the politics and economics of kick-start financing. The CCS demonstration programme could provide the means to develop supply chains and infrastructure hubs; and create the new green collar jobs that our political leaders so frequently highlight.

Europe must provide the means to achieve these benefits. A strong financial incentive that will trigger investment in a programme of demonstration plants is urgently needed. The best option, in Green Alliance's view, is to use allowances from the EU emissions trading scheme (ETS) as a source for financial support sufficient to unlock this investment.

But as well as the potential benefits of CCS, we must not forget the threat contained by the current debate on the use of coal. We must also focus on the risk of a new wave of unabated coal power stations.

There are inevitably different views on the appropriate policy response to this. These are explored in section three of this publication. Some hope that the EU ETS will be sufficient to incentivise CCS deployment, and increase the financial risks facing any new coal plant. Others believe that new construction should be allowed now, provided it is 'capture-ready' to allow for later retrofit with CCS.

Green Alliance is not persuaded by these arguments. In our view, financial support must be accompanied by stringent regulations for new power plant, such as the emissions performance standards (EPS) introduced by the State of California.

This would eliminate the risk of new unabated coal plant, capture-ready or not, which would be deeply damaging to our climate change aspirations and drive up the ETS carbon price for other sectors. An EPS would also help to guarantee the market for CCS into the future.

Leadership on climate change is the litmus test for Europe's ability to project its experience of co-operation into the wider world. The demonstration of CCS and an end to unabated coal would be an immediate tangible expression of the EU being a pathfinder for the transition to a low-carbon world. The political decisions on how to incentivise CCS and guard against the construction of new unabated coal plants must be taken now. Failure on either is not an option.

1

section one the challenge: coal in a changing climate

The challenge of demonstrating and deploying carbon capture and storage technology has both technical and political components, as demonstrated in the two contributions that begin this collection. Although taking each of these issues separately, they concur on one central message: it is time for Europe to lead on CCS.

The technical challenge is dissected by Jon Gibbins and Hannah Chalmers of Imperial College London. In providing an overview of the different CCS technology options they underline the importance of 'learning by doing'. For if CCS technology is to be deployed at the scale required the costs must be reduced and the technology improved. This will only happen if multiple demonstrations can occur together, with at least two tranches of CCS demonstrations needed by 2020. This is a major undertaking, although the technology exists, its assembly into CCS systems at the scale of commercial power plants is still in its early days. Supply chains and supporting infrastructure also need to be developed. Europe needs to think big if it is to reap the rewards of CCS.

The political challenge is addressed from across the Atlantic by David Hawkins of the Natural Resources Defense Council. Much attention is placed on China's rapidly expanding use of coal but, in truth, European leadership on CCS right now in 2008 is perhaps even more required in the USA. David Hawkins lays out the case for action, at the dawn of a new era in US politics; the next US president will face the tough task of re-engaging with global negotiations and proactively demonstrating US intentions. CCS technology lies at the heart of this political landscape for, without internal US agreement on demonstrating CCS, the prospects for a game-changing movement towards a domestic US emissions trading legislation look bleak. Without that, the chances of a 'global deal' on climate change in Copenhagen in 2009 are much reduced in turn. Decisive European action on CCS now could really push this whole chain of action forward. But there is a warning in this message too: European failure would set back US attempts greatly.

It was always recognised that the decisions made in the European Parliament and in Council negotiations this year would have global influence. What is becoming clear is that the CCS decisions in particular have a real chance of claiming a double dividend. The speed at which CCS has risen up the agenda means it could inject fresh momentum at home and abroad, setting Europe on a rapid course to reduce emissions while also enabling much more proactive climate politics for partners in China and the USA.

demonstrating CCS: a tight learning timetable

Jon Gibbins & Hannah Chalmers, Imperial College London

> “ there is only one opportunity for the EU to develop a credible CCS capacity in time for it to influence important climate change outcomes ”

Carbon capture and storage is essential globally because there is little chance of it being economically and socially sustainable for China, India (and the USA) to stop using coal in time to avoid dangerous climate change. This means that it needs to be available as a proven option in time for the negotiations of post-2020 global mitigation plans. Europe’s commitment to CCS before 2020 is important, and quite possibly critical, for the success of the post-2020 negotiations for two reasons:

- time is very short indeed to develop CCS to the stage where it is proven enough to allow the necessary large numbers of multi-billion Euro projects to go ahead on a routine basis;
- if a leader on climate change such as the EU is not prepared to take up CCS then why should anyone else? CCS involves spending large amounts of money on additional equipment and fuel solely to achieve a very significant reduction in carbon dioxide (CO_2) emissions.

An effective EU programme on CCS involves building the proposed 12 demonstration projects quickly – industry is ready to start doing this – so that there is time for a second tranche of semi-commercial plants before 2020, as shown in figure 1 (page 9). The second tranche allows lessons learned from the first tranche to be tested and also builds capacity in the industry. Big gains are likely to be made in cost and performance in the second tranche; it should also establish the technology as a routine option.

This two-tranche programme might build about five to ten gigawatts (GW) of generation in the first demonstration tranche and perhaps an additional 10-15 GW in a second tranche. This may sound like a lot, but a total of 20 GW of CCS power plants, even at full load, would deliver only about five per cent of current EU electricity demand or about one per cent of current EU energy demand. And fossil fuel power plants are likely to operate below full load much of the time in 2020, as they adjust their output to complement fluctuating generation from renewables and also, in some countries, inflexible generation from nuclear.

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The most important thing at the moment is to get funding in place for the first tranche and to remove regulatory barriers to using that funding to deploy initial CCS plants as soon as possible. All that the second tranche requires now is that we move fast enough to leave time for its deployment before 2020. Time is of the essence. No amount of money spent later will be able to speed up the required learning process beyond a certain rate, and any delay now makes it less likely that CCS can be presented as a viable option during post-2020 climate change negotiations.

"a strategic pipeline system for Europe could make CCS feasible even where storage is not available locally"

All three of the main approaches to CO_2 capture from fossil fuels, but particularly from coal, need developing in the first tranche: post-combustion, pre-combustion and oxyfuel (see box 1). Predicted performance and cost difference between these approaches are small. So users are likely to want to employ the approach that best matches their application, the type of fuels they have available and the site conditions. CCS from gas also needs attention; although emissions from gas per unit energy produced are lower than those from coal they soon become significant in a carbon constrained world.

It is also important that the benefits of using biomass with CCS to remove CO_2 from the air and place it in secure geological storage are not overlooked. Although other routes are being explored, using biomass to produce electricity (or hydrogen) with CCS will probably be the most effective technical way to achieve 'negative emissions'. NASA climate scientist James Hansen has recently identified this route as potentially key to tackling climate change risks, with a strong possibility that it may be necessary if we are approaching dangerous climate change too rapidly.

A range of geological storage options are available within the EU for the compressed liquid CO_2 that is captured from power plants (and other large point sources). In fact, the large amounts of CO_2 storage capacity under the North Sea may eventually be more valuable to Europe than its oil and gas reserves. In the changeover, though, developing CO_2 storage under the North Sea can complement oil and gas production activities and increase indigenous oil production through Enhanced Oil Recovery (EOR), as well as supporting the existing offshore industry base in Europe.

Transporting CO_2 in large pipelines can be relatively cheap. This means that a strategic pipeline system for Europe could make CCS feasible even where storage is not available locally. Apart from the need to develop the physical infrastructure, measures to allow transnational movement of CO_2, and for collective handling of liability for stored CO_2, will also be required for the EU economy as a whole to adopt CCS effectively.

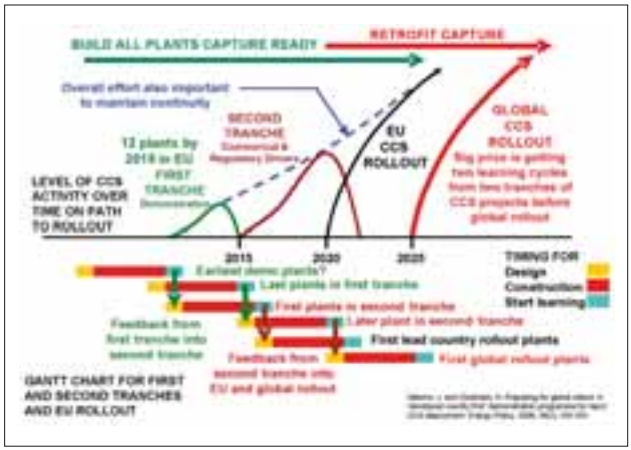
It is essential that plans and regulations for deploying CCS more widely in the EU proceed in parallel with starting up the 12 plant demonstration programme, and that getting these first CCS projects started is a priority. This first tranche of demonstration plants will produce only about two per cent of EU electricity and can therefore be treated, to some extent, as a special case. While the first tranche is being implemented there will be plenty of opportunity to develop EU policy and regulation to cover the much larger amount of activity in the following second tranche of CCS plants and subsequent full-scale rollout. Indeed, the formulation of EU policy on wider CCS

"an effective EU programme on CCS involves building the proposed 12 demonstration projects quickly"

deployment will require time, to take into account a range of important external factors, such as the outcome from post-2012 climate negotiations and fuel price developments, and internal factors, such as the types of renewables deployment that materialise in the EU and potential growth in electric vehicles.

There is, however, only one opportunity for the EU to develop a credible CCS capacity in time for it to influence important climate change outcomes. Industry is ready to start designing and building the first EU CCS demonstration projects once funding to cover the additional costs of CCS and the necessary legal and regulatory cover are in place. Any years lost before the EU CCS demonstration programme goes ahead cannot be recovered.

figure 1: sequencing CCS deployment – the big picture



box 1: types of carbon capture technology

Post-combustion capture can in principle be added to 'wash' out the CO_2 from the combustion products leaving any conventional coal or gas power plant, although it is possible that some plants that have not been built 'capture ready' will not have the necessary space available to build the very large units needed to do this and to add essential connections and equipment within the power plant itself.

Pre-combustion capture involves first gasifying the fuel by partial combustion with oxygen and then additional steps to turn the product gas into hydrogen and carbon dioxide, separate the carbon dioxide and finally to burn the hydrogen in a gas turbine. All of these steps involve extra costs and loss of useful output. The whole integrated concept (e.g. integrated gasifier Combined Cycle, IGCC, for coal) also needs further proving for use in power generation.

In oxyfuel combustion the fuel is burnt with oxygen to produce a mixture of carbon dioxide and water vapour. Most of the additional energy and a lot of the cost goes into making the oxygen; it is relatively easy to separate the carbon dioxide at the end. Ways to control flame temperatures in oxyfuel combustion also need to be developed, based on existing approaches or new concepts.

All of these three main processes to generate electricity from coal and capture the CO_2 are currently being developed. They all are predicted to be able to capture 90% or more of the CO_2 in the coal and to give about 36% LHV efficiency with current technology (a similar efficiency to many existing sub-critical steam plants). Costs for each are also probably fairly similar, although exact values are hard to ascertain in today's rapidly changing markets.

Post-combustion capture uses a proven base plant and the capture element itself is ready for trials at around 150 MW on coal for existing amine solvents, then full scale thereafter. New post-combustion solvents (including ammonia) are currently being trialed at smaller scales. IGCC plants with CO_2 capture are near-proven in refineries, and are ready for first-of-kind power plant trials using coal. This could be at about 800MW (with two gas turbines), but everything can be tested properly at 400MW. Oxyfuel pilot trials are now taking place at 10MW – 30MW pilot scale, with larger plants planned once results are available.

1

Europe can show the way forward: a view from the USA

David Hawkins, Natural Resources Defense Council

> “ what EU parliamentarians may not realise is how significant their action will be to legislators in the United States ”

Policy makers on both sides of the Atlantic are wrestling with the challenge of squaring the continuing use of coal as an energy source with the compelling need to protect the climate. At the heart of the coal and climate debate lies CCS, a technology to capture CO_2 from industrial sources and dispose of it in geologic formations.

In the United States, high profile climate change bills such as Warner-Leiberman have been introduced in Congress. They contain provisions designed to speed deployment of CCS systems but have not been voted on to date. Instead it is in the EU where the first real action on CCS deployment policies is likely to occur, given the consideration of this issue in the EU Climate and Energy Package in late 2008. What EU parliamentarians may not realise is how significant their action will be to legislators in the United States.

Why is CCS important?

Coal use today is responsible for large and mostly avoidable damages to human health and our water and land. Coal use in the future, along with other fossil fuels, threatens to wreak havoc with the earth’s climate system. While the fastest and cheapest method to cut global warming emissions remains energy efficiency, and increased use of renewable energy resources provides another essential tool, CCS is the only method to address CO_2 emissions from the coal we use.

Because coal is so abundant, it is likely to continue to supply a significant fraction of global energy needs for some time. Hence, capture of CO_2 from coal-based sources followed by geologic disposal is essential to square this expected coal use with climate protection.

The hundreds of new coal plants that are forecast to be built around the world in the next 25 years will emit 30 per cent more carbon dioxide in their operating lives than has been released from all prior human use of coal, unless they are equipped with CCS. We simply cannot afford to build any more coal plants without CCS.

Legislators therefore need to create policy frameworks that speed deployment of CCS, especially in the electric power sector, which in many countries is the largest single coal user. Complete CCS systems have not yet been put in place and they result in higher electric generation costs. Without policies designed to make deployment a reality, CCS will not be broadly employed.

Fortunately, we know enough today to implement large-scale CCS for coal plants now in the design stages. Properly selected and operated disposal sites can retain injected CO_2 for the required long periods of time and CCS activities can be conducted safely if an effective regulatory regime is put in place to license and monitor operations.

Policies and markets

The policies needed to spur CCS deployment are well understood by analysts but not yet embraced by legislators. The core policy is the adoption of a broad-based cap on emissions of CO_2 and other global warming emissions from a range of sources. The EU emissions trading scheme (ETS) is an early example of this core approach but such a cap and trade program has not yet been enacted in the United States.

Nearly all analysts agree that the market signal from cap and trade programs in either the EU or the USA will not be high enough in the next decade or so to spur investments in CCS. Complementary policies are needed to create the conditions for earlier CCS deployment. The key policies include performance standards designed to ensure that new coal investments employ CCS, and financial support to spread the added costs of the first generations of CCS more broadly.

EU parliamentarians are now considering just such a package of measures. Well designed policies can apply CCS on new coal plants with only very modest impacts on retail electricity prices. Government support of initial large-scale CO_2 injection projects can help speed deployment and build confidence. While EU parliamentarians are rightly focused on the impacts of these policies in Europe, it is worth considering the considerable ripple effects the EU decisions will have elsewhere, especially the USA.

The EU can show the way forward

The final form of EU action on CCS that will be agreed in this year's EU Climate and Energy Package will send a strong signal. But will it be positive or negative?

Business groups and NGOs across the Atlantic will pick up on the EU's decision and carry that message to the US Congress. This matters because conflict about the role of coal is a major obstacle to the enactment of serious policies in the USA to limit carbon emissions. Coal supplies about half of US power generation and the political influence of coal producers, shippers, and users is strong and widespread. Impacts on coal use and energy prices continue to be central arguments against adoption of climate protection laws in the USA. In fact, it is very likely that perceptions of the timing and viability of CCS will be a major influence on when the US Congress enacts climate legislation and the level of ambition for its CO_2 targets.

With political will, CCS can be deployed promptly and broadly. Proposals to finance CCS are a hot topic in the US Congress but do not appear likely to be enacted in the waning days of the current administration. But the issue of cutting global warming pollution and the role CCS can play will receive early attention by the next president and Congress. What Europe does on this issue in the next weeks and months will resonate with US policy makers very soon.

There are many good domestic reasons for EU leaders to push forward the ambitious CCS policy measures which are before it. But sending a message that CCS deployment is going to happen now will also be a major step in breaking down a significant obstacle to effective action on global warming in the USA.

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section two
the opportunity: kick-starting the CCS industry

The articles in section one set out the core technical and political challenge for CCS and underlined the necessity of European leadership to tackle the problem of emissions from unabated coal plant both at home and abroad.

In section two, our contributors consider the opportunities such a move would provide, not just in respect to the necessity of CCS as a tool in the global effort to reduce carbon emissions, but also its more immediate tangible benefits.

The potential for CCS to become a new energy industry in its own right is outlined by Graeme Sweeney of Shell, while Alain Berger of Alstom provides details of the already existing technical feasibility of CCS power plant construction, as recently inaugurated at Vattenfall's Schwarze Pumpe plant in Germany. Similarly, Ruud Lubbers, former prime minister of The Netherlands and now chairman of the Rotterdam Climate Initiative, shows how, in the case of Rotterdam, partners are coming together to plan the reuse of existing infrastructure in the creation of a regional CCS network.

All of these activities require skilled labour. The future deployment of CCS technology in energy-intensive industrial sectors would in turn secure many more existing jobs, which might be at risk unless ways can be found to reduce carbon emissions within Europe. The way forward for Frances O'Grady of the Trades Union Congress is therefore that CCS has to become part of a wider green industrial strategy. This view is supported by Mike Farley of the UK's Clean Coal Task Group, who shows how industry and unions are working together to find a way forward on this crucial technology.

But none of these longer-running benefits will be captured unless a way of funding CCS demonstrations in the immediate future can be found, preferably at the European level through a demonstration programme that can cover the range of CCS technologies and infrastructures and stimulate the necessary supply chains. This message comes through very clearly from all contributors, who point to the high initial costs and first-mover business risks that need to be overcome.

The need for kick-start funding is therefore identified as the core requirement for enabling European action on CCS. Jules Kortenhorst of the European Climate Foundation sets out how the recent analysis by McKinsey and Company shows that in due time CCS can be supported by the EU emissions trading scheme (ETS), but needs financial support now to get started.

Linda McAvan MEP takes this on to the more specific issue of how a demonstration programme can be funded, and urges support for the mechanism she has proposed in the European Parliament alongside fellow MEPs Chris Davies and Avril Doyle. This would deploy additional allowances from the ETS once CO_2 had been stored, creating a real incentive for action.

establishing a global carbon capture and storage industry

Graeme Sweeney, Shell

“ technology will be key to the changes required to reduce CO_2 emissions on a large scale ”

We in Shell believe that a post-2020 commercial deployment of CCS – in concert with other low carbon sources of energy – will be a prerequisite for meeting energy demand and reducing emissions in line with an aspired level of mid-century stabilisation. But to achieve this we need the regulations, the financial incentives and all the other pieces of the jigsaw in place as soon as possible.

CCS is one of the few technologies that is entirely climate change driven and early deployment will not happen without policy intervention. The technology is in its infancy, so ensuring it is deployed with the required urgency will require transitional financial support to make it commercially attractive whilst costs are progressively brought down through learning by doing.

To reduce CO_2 emissions on a large scale, Shell believes that existing technologies must be rapidly deployed and a range of new innovations must be brought to market. In particular, as fossil fuels continue to deliver the bulk of our energy requirements, the need to rapidly deploy CCS will become paramount.

Shell has estimated that, for every year we delay the widespread deployment of CCS beyond 2020, we will see a one part per million (ppm) increase in long-term CO_2 stabilisation levels. In other words, deployment by 2020 can still result in a 450 ppm stabilisation. Waiting an additional year will result in an extra one ppm increase, and so on. CCS must be commercially viable by 2020, with some 100 major facilities, such as zero emission coal-fired power plants, in operation or under development around the world. Additionally, all new coal power plants built after 2020 – at the latest – should be using CCS.

In support of this need, the G8 has called for 20 plus projects to be identified by 2010, and the EU Council of Ministers has backed a demonstration programme of 10 to 12 large scale plants (greater than 500 megawatts) in the EU. A handful of other individual projects are also now in planning around the world. By 2020, this could translate into 20 plus projects in each of the EU, USA and China, a ten project programme in India and smaller programmes in Australia and South Africa.

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However, although there is much talk about CCS, there is little in the way of a financial framework to usher in this technology at an accelerated pace.

Moving forward in the EU and major developed economies

McKinsey & Company have estimated in their September 2008 report, *Carbon capture and storage: assessing the economics*, that the European CO_2 market needs to trade in the range of 60 – 90 Euro per tonne of CO_2 to effectively fund the first CCS coal-fired power stations in the EU. (Discussed in more detail in the next article by Jules Kortenhorst of European Climate Foundation.) These early facilities will require new infrastructure, such as pipelines, the development of storage sites and the establishment of monitoring programmes. Later facilities will benefit from this infrastructure and utilise technologies tuned more specifically to CCS. In the longer term a CO_2 price of less than 40 Euro per tonne may be sufficient for the widespread deployment of CCS.

"CCS is one of the few technologies that is entirely climate change driven and early deployment will not happen without policy intervention"

An initial price of 75 Euro plus per tonne of CO_2 is clearly out of the reach of the current CO_2 markets, so a mechanism is required to supplement the CO_2 price in the EU ETS to the tune of 12-15 billion Euro to fully fund the proposed EU demonstration programme. The demonstration programme will see 10 to 12 large scale demonstration plants that will abate around 60 million tonnes of CO_2 annually.

By the end of 2008 the supporting mechanisms for a European CCS project pipeline should be in place. This includes a legal framework to permit the underground storage of CO_2, a CO_2 price to drive long-term deployment and, critically, a funding framework to kick-start the industry and deliver essential infrastructure.

The issues are the same in the major coal economies of the developed world, such as Japan, the US and Australia. In the latter two countries the development of the necessary frameworks is now being discussed, but somewhat behind the EU. CCS will also be required in a number of developing countries, particularly China, India and South Africa. Projects could be kick-started through access to the same funding arrangement as is required for the EU demonstration programme.

By 2020 it is feasible to have established a global CCS industry. But the challenge will surely test our collective ability to build new markets, then fund and deliver advanced technologies. Without it, the possibility of slowing and ultimately stopping the inexorable rise in CO_2 levels will escape us.

Shell's response

Shell is a partner in several CCS joint ventures aimed at establishing best practices and securing public acceptance. This includes the CO_2SINK project in Germany and the Australian Otway project, which will inject 100,000 tonnes of CO_2 into a depleted natural gas reservoir 2,000 metres under the ground. We are also bidding on a project in The Netherlands to take CO_2 from our Pernis refinery and re-inject it into two depleted gas fields. Additionally, we are partaking in the International Energy Agency project to pipe CO2 330 kilometres from a coal gasification plant in North Dakota, for re-injection in an oilfield in Canada.

Together with Qatar Petroleum, we have signed a $70 million research collaboration with Imperial College London to provide the foundation for new CO_2 technologies that can be applied in Qatar and beyond.

Currently we have more than 15 CCS opportunities in the 'project funnel' and we aim to have up to 10 CCS projects in development by 2010 covering unconventional assets, refineries and third party power plants. This includes Canada, where we announced plans in July to capture approximately one million tonnes of CO_2 at our Scotford oil sands upgrader.

assessing the economics of carbon capture and storage

Jules Kortenhorst, European Climate Foundation

> " we believe CCS is a necessary part of swift and efficient transition to a safe, clean, prosperous low-carbon economy "

On September 22, 2008, McKinsey & Company issued their report *Carbon capture and storage: assessing the economics*. This independent report analyses the costs and benefits of European-wide deployment of CCS. It builds on the input of over 50 companies, stakeholders and CCS experts. It is particularly important in the current EU debate on CCS because it provides an up to date fact base, including a potential CCS deployment roadmap, against which policy makers can assess their decisions.

The report builds on the assumptions of the Stern report, the Intergovernmental Panel on Climate Change, the International Energy Agency and others that, in the absence of a comprehensive low-carbon solution, CCS will be a necessary transitional technology to ensure Europe can meet its carbon abatement targets. McKinsey conclude that CCS will not become a fully commercial reality without policies that create incentives for companies to test and implement CCS.

The European Climate Foundation is part of the drive for energy efficiency and renewables. However, our analysis agrees with the assessment that a comprehensive zero-carbon energy solution may not arrive quickly enough. That is why we believe CCS is a necessary part of the swift and efficient transition to a safe, clean, prosperous low-carbon economy.

With the aim of rapid transition to a low-carbon economy in mind, ECF has summarised several key conclusions of the McKinsey report:

- All the technologies necessary for the CCS value chain – which include capture, transport and storage of CO_2 – are ready for demonstration-scale deployment now. But further small pilot scale testing alone will not be sufficient to catalyse development of the technology in the time frame needed to tackle climate change. While McKinsey recognise that additional technologies are likely to be developed, sufficient work has been done on existing technologies to conclude that commercial demonstration is the next logical step.

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- The McKinsey report is based around an assessment of three phases in the development of CCS: a demonstration phase from 2012-2020; an early commercialisation phase from 2020-2030; and a full commercialisation phase beginning around 2030.

- Crucially, the report establishes that full commercialisation in 2030 (following cost reductions historically associated with similar technology learning curves) will be cost competitive under the EU ETS at a cost of around 30 to 40 Euro per tonne of CO_2. This conclusion implies that policy makers can be confident that utilities and industrial emitters will choose to install CCS rather than purchase an emissions allowance on the open market. However, it also implies that before the costs of CCS fall to meet the carbon price under the ETS, investors will have little economic incentive to pursue CCS and that it will therefore be incumbent on governments to create the proper incentives.

- The report also addresses the costs associated with the development period. McKinsey estimates that the demonstration phase might cost 60 to 90 Euro per tonne of CO_2 abated due to the smaller scale and efficiency of these plants as a result of their focus on proving the technology, rather than commercial optimisation, and because of more significant variability in scale. The report estimates the early commercialisation phase costing 35 to 50 Euro per tonne of CO_2 abated.

- Finally, McKinsey point to the fact that before the industry can develop to full commercial maturity, there are several regulatory barriers remaining to be addressed. These issues, particularly around storage liability and the legality of storage, currently pose uncertainties and risks that make CCS investment difficult. The proposed EU directive addresses most of these issues. The final details, and the subsequent process to cascade down to member state law are important steps to reduce the regulatory risk.

As EU leaders have rightly recognised, our region and our world cannot meet our climate targets if we continue on a business as usual path in emissions from energy generation and industrial processes. The McKinsey report is the latest in a growing body of analyses indicating that CCS could be critical in getting off the business as usual trajectory, but only if we move quickly.

> "we conclude from the report that the EU needs both a carrot and stick approach to spur CCS development and deployment"

We conclude from the report that the EU needs both a carrot and stick approach to spur CCS development and deployment: public funding for a targeted CCS demonstration programme combined with an emissions performance standard that will eliminate unabated coal power generation and create certainty for investors. In the absence of both incentives, CCS deployment will be delayed and we are likely to see a growth in European and global emissions from coal-fired power plants and industrial emitters.

kick-start financial support is critical

Linda McAvan MEP

“ large-scale demonstration of CCS is important because it proves its viability as an integrated system, without which investors will not commit the finance needed ”

Countless studies and declarations tell us the scale and urgency of climate change is greater than previously predicted. Yet, although we are making good progress in some areas, the total of all our practical responses still falls short of what is ultimately needed to head off a global catastrophe.

Renewables and energy efficiency measures are the long-term solution and should remain our priority. However, they are unable to provide sufficient mitigation soon enough. Fossil fuels still represent more than three-quarters of all the world’s traded energy supply, while coal alone accounts for around one-quarter of Europe’s carbon emissions.

Based on its technical and economic potentials, CCS technology fitted to large combustion installations could make a substantial additional contribution to climate mitigation in Europe, particularly towards the planned 2050 emission cuts of 50 per cent or more.

CCS is also a vital component of global efforts to fight climate change. Carbon emissions from China’s increasing coal use are set to double to more than 5,000 million tonnes per year by 2030. To prevent China’s carbon emissions from cancelling out the emission savings made in Europe, the development of CCS is essential.

The debate on CCS has moved forward rapidly in the last 12 months. Many of the myths, fears and uncertainties surrounding the technology have been laid to rest. The technological feasibility of carbon storage projects has been proven. The Sleipner project in Norway has injected over ten million tonnes of CO_2 in a deep saline formation with no leakage. In Germany, the Schwarze Pumpe power station is the first coal-fired plant in the world to capture and store its own CO_2 emissions. (Discussed in more detail in the next article by Alain Berger of ALSTOM.)

The safety concerns about CCS have also been put in perspective. The EU legal framework currently being negotiated will ensure only sites suitable for CCS can be selected. Volcanically active areas or areas on earthquake faults will therefore not be chosen. The

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Intergovernmental Panel on Climate Change special report on CCS concluded that it is very likely that 90 per cent or more of the CO_2 injected in appropriately selected and managed sites would remain underground for at least 1,000 years.

There remains concern among MEPs that public funding will be diverted from renewables to CCS, but there is a growing understanding that the demonstration of CCS at scale prior to its commercial deployment is necessary. Large-scale demonstration is important because it proves the viability of CCS as an integrated system, without which investors will not commit the finance needed to then deploy many times over.

"finding the money to finance the demonstration projects must happen without further delays and at sufficient scale"

The particular characteristics of electricity and climate mitigation markets, as well as the scale of the technology, mean that demonstration will not be funded by the private sector alone. This is a classic example of market failure that is reliant on public policy and law to fix. Some form of partnership is needed where private firms (or consortia) deliver demonstration projects, mixing their own resources with additional public aid that compensates for first-mover disadvantages.

Finding the money to finance the demonstration projects must happen without further delays and at sufficient scale: first, because industry often has long lead times for design, planning and gaining permits; and second, because politically we also need to show support for CCS at the international negotiations.

Individual governments could provide funding to projects, as the UK is planning to do in one case, but a larger co-ordinated European programme, as called for in several recent EU summits, will have more impact.

To these ends, along with my fellow MEPs Avril Doyle and Chris Davies, who both lead important parts of the climate & energy package, I have tabled a key amendment (Amendment 500) in the revision of the ETS directive. If successful it will create a reserve of up to 500 million allowances (permits to emit one tonne) from now until 2020 to reward successful CCS demonstration projects.

The intention is that the overall design and cap of the ETS is unaffected. This will be a time limited scheme that provides the necessary short-term support to the technology. The scheme's selection criteria would ensure that we test each of the key technologies, each of the key geologies, and that the projects are spread sensibly and fairly across Europe. A programme of eight, ten or even twelve projects should also include one or two that are outside Europe, for example as part of our bilateral technology co-operation with China.

The European Parliament Environment Committee votes on 7 October, after which Parliament and the Council of Ministers will begin to negotiate directly. This amendment will hopefully be supported by all the EU institutions as the only serious proposal on the table for providing the necessary short-term support for CCS. With European Parliament elections next June and the crucial December 2009 Copenhagen meeting fast approaching, this is the last chance for some time to get this policy right, and so it is very much a plan that deserves to succeed.

CCS technology: ready to demonstrate

Alain F Berger, Alstom

“ CCS deployment is already vital to achieve the carbon reduction targets for the EU power sector ”

The Schwarze Pumpe pilot plant was inaugurated on 9 September, 2008, and is the first power plant in the world to demonstrate the technology of oxy-combustion for CCS. The result of the development of CCS technologies by Vattenfall and Alstom, the plant will complete an initial three-year testing programme, and is then scheduled to run for at least ten years.

Built next to Vattenfall’s existing lignite-fired 1600 megawatt (MW) Schwarze Pumpe power plant in Germany, the 30 MW pulverised coal demonstration plant, for which Alstom is supplying the oxy-boiler technology, contains all the necessary components to demonstrate the complete oxy-fuel chain, starting with oxygen production and ending with CO_2 purification and compression. The 30 MW pilot plant will provide the technical basis for the construction of much larger 200 –300 MW demonstration power plant by 2015.

The erection of the pilot plant and the commissioning of the boiler have now been completed and an extensive test program launched. During the first test period, lignite will be the focus of the testing while bituminous coal will later be used. The tests will yield essential data on heat transfer, combustion efficiency, emissions, dynamic behaviour, plant design, performance, cost, and economics for both greenfield and retrofit applications.

Through a co-operation agreement signed between Gaz de France and Vattenfall, the CO_2 captured at Schwarze Pumpe will be used for enhanced gas recovery and storage at Europe’s second largest onshore gas field, Altmark, during the three-year trial period. CO_2 will be injected at depths of 3,000m, and methods will be investigated for extending the natural lifetime of a gas field combined with permanent CO_2 storage.

Technology insight: what is oxy-combustion?

Oxy-fuel firing represents one of several methods available to capture CO_2 from power plants. Research and testing of oxy-fuel applications are being pursued by European and US suppliers in collaboration with utilities, academia, the US Department of Energy and the EU. Based on economic studies of a range of CO_2

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mitigation technologies, oxy-fuel firing is competitive compared to other pre-combustion and post-combustion technologies

Oxy-fuel firing technology is a process in which fuel is burned in a mixture of high purity oxygen, essentially eliminating the presence of atmospheric nitrogen in the flue gas. This gas can be processed relatively easily to enrich the CO_2 content to more than 99 per cent purity. The CO_2 can then be used for industrial applications such as enhanced oil or gas recovery (EOR or EGR). Alternatively, the flue gas can be dried and compressed for geologic storage, which results in near-zero gaseous emissions from the power plant.

"oxy-fuel firing is competitive compared to other pre-combustion and post-combustion technologies"

Starting in 1998, Alstom has investigated the technical and economic viability of the oxy-fuel firing concept compared to other CO_2 mitigation technologies. Oxy-fuel firing technology is itself relatively low risk and deployable in the near future. It uses proven, reliable, commercially available technology, and project economics are also expected to improve as the CO_2 value chain is clarified and infrastructure is developed. For these reasons, the development of oxy-fuel firing is important to the electric power industry as an attractive option for CCS.

Supporting CCS deployment worldwide

CCS deployment is already vital to achieve the carbon emissions reduction targets set for the power sector in the EU, with awareness growing all the time of its global applicability. Every effort must be made by governments worldwide to ensure that long-term policies and market regulations are put in place early enough so that equipment suppliers can develop the necessary production capacities and end users can plan power fleet adaptation.

Post-combustion CCS solutions should be given a much higher priority in development programs worldwide. These technologies are the first ones available for the rapid deployment required to achieve the necessary reductions in carbon emissions. But other approaches must also be encouraged, as a portfolio of technologies will be needed to ensure that the CCS industrial challenge is addressed with the most reliable and cost effective solutions.

For developing countries, funding assistance should be provided for early large-scale demonstration projects based on technologies adaptable to the expanding coal power fleet. In this regard, post-combustion technologies must be given dedicated attention because of their potential. The UK government, for instance, has taken this clear stance in its competition for the first large scale CCS demonstration plant in the UK. The UK competition is focused on post-combustion technology and specifically calls for technology transferability to rapidly developing countries like China.

CCS infrastructure for Rotterdam's industrial zone

Ruud Lubbers, Rotterdam Climate Initiative

> " we believe that CCS is an addition to good climate policy, not a substitute. It is a necessary addition nonetheless "

Rotterdam has high climate ambitions, both for the city and the harbour. Our target is to reduce CO_2 emissions by 50 per cent in 2025, relative to 1990. This 50 per cent ambition coincides with a period of expansion of the industrial complex within the harbour. It is a daunting challenge.

Since 2007, the city of Rotterdam, the Rotterdam Port Authority, the DCMR Environmental Protection Agency, and the business organisation Deltalinqs (as a representative of the companies in the Rijnmond region), have been working together through the Rotterdam Climate Initiative to realise this 50 per cent reduction. Three simple principles guide our approach:

- If you don't need it, it doesn't cause emissions.
  Therefore emphasise energy saving and energy efficiency;
- If it is not dirty, it requires no cleaning.
  Therefore emphasise stimulation of sustainable energy;
- If you can, collect it, re-use or store it.
  Therefore emphasise CO_2 capture use and storage.

Despite maximum efforts on energy efficiency, use of biomass and use of residual heat, this will not be sufficient to meet our ambitious 50 per cent emissions reduction target within industry. It is clear that the greater part of this reduction must be achieved by capturing and storing CO_2 underground through the deployment of CCS. We believe that CCS is an addition to good climate policy, not a substitute. It is a necessary addition nonetheless.

Implementation of CCS

Rotterdam offers unique opportunities for implementing CCS. There is already an existing CO_2 pipeline infrastructure that can become a stepping stone for a larger CO_2 transport network. Possible storage sites will become available on the Dutch continental shelf in the form of depleted gas fields. And within Rotterdam's industrial complex there are sources of pure CO_2 which present low capture costs. The relative costs of CCS are therefore favourable compared to similar industrial complexes elsewhere in Europe. As a result, we believe that the successful development of CCS can become a

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positive reason for new industry to establish itself and invest in the Rijnmond region.

In July 2008 we published the report *CO_2 capture, transport and storage in Rotterdam* on the CCS possibilities for Rotterdam. This included a step-by-step approach with cost estimates towards large-scale implementation of CCS within the power sector and industry. The main conclusion of this report is that Rotterdam can start capturing, transporting and storing five million tonnes of CO_2 underground per year by 2015. By 2025, 20 million tonnes of CO_2 will be able to be captured and stored per year. This will allow Rotterdam to contribute one third of the emissions reductions needed to meet the climate targets set for the whole of The Netherlands by the national government.

> "development of CCS in Rotterdam is of importance to the successful achievement of global climate policy"

The successful development of CCS in the Rotterdam region will require large efforts and decisiveness from regional and national government in respect to both the provision of the financial resources required and the development of clear legal conditions.

The Rotterdam Climate Initiative approach

We believe that the realisation of CCS in Rotterdam requires the following:

1 **fast realisation of phase-1 infrastructure**
Investments in infrastructure are required to make a fast start with the capture of 2.9 million tonnes of 'pure' CO_2 in the Rijnmond region and to secure larger-scale demonstration projects. This phase must bring together the CO_2 sources with solution providers in the areas of CO_2 transport and storage, as well as the Dutch government and financial institutions, to develop a bankable business plan by the end of 2008.

2 **anticipating infrastructure expansion**
Expanding the phase 1 infrastructure so that it can cope with up to 20 million tonnes of CO_2 annually requires a careful assessment of storage scenarios and the associated infrastructure requirements.

3 **developing demonstration projects**
Demonstration projects are essential to reaching our target. In 2009, we aim to reach agreements with five emitters about possible CO_2 capture projects. Financial support, possibly from the government, will be needed to develop these demonstration projects due to the gap between their cost and EU allowance prices.

4 **developing and reserving storage locations**
The development of storage capacity is linked directly to empty gas fields becoming available. The storage capacity available over time is sufficient to store the Rijnmond's CO_2 for approximately 40 years. The government should reserve fields for CO_2, in consultation with the concession holder and the

drilling platform operators. Arrangements should also be made to prevent the early closure of platforms.

5 **organising the growing CO_2 network**
The development of CCS in Rijnmond will create a larger and more complex CO_2 network with various sources, transport pipelines and storage fields. Accelerating the development of this network will require clear regulation and financial support from the government. In consultation with the CCS Task Force, the RCI will investigate what is required.

6 **public acceptance**
The RCI is asking the Dutch government to lead communications about the climate and CCS. All parties will have to think about involving the public in the further development and implementation of CCS, both in terms of safety and monitoring.

Conclusion

We believe that the timely development of CCS in Rotterdam is of importance to the successful achievement of global climate policy. Rotterdam can make a real difference by being a pathfinder for CCS, which we view as a necessary addition to energy savings and sustainable energy as we make the transition to a low-carbon economy. The world is changing and so is Rotterdam.

Realising a low carbon footprint in a historically energy intensive industrial complex like Rotterdam will be an interesting and challenging journey. We are determined to succeed, and warmly invite others to join us.

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CCS in a green industrial strategy

Frances O'Grady, TUC

> " the successful development of CCS is perhaps the single most urgent technological development required to address global warming "

The unprecedented loss of Arctic ice this summer is proof enough that real-time climate changes are ahead of scientific models. Coal accounts for around 40 per cent of CO_2 emissions annually. We have to move much more quickly to deal with coal, or we won't resolve the challenges to our planet of global warming.

As the eminent US climate scientist, James Hansen, wrote in his appeal to Gordon Brown in 2007: "Coal caused fully half of the fossil fuel increase of CO_2 in the air today, and in the long run coal has the potential to be an even greater source of CO_2. Due to the dominant role of coal, solutions to global warming must include phase-out of coal except for uses where the CO_2 is captured and sequestered."

The successful development of clean coal energy with CCS is perhaps the single most urgent technological development required to address global warming. Its feasibility, or otherwise, needs to be established with the utmost speed. CCS has the potential to reduce emissions from fossil fuel power stations by up to 90 per cent. It is the only technology option currently available that could allow a flexible fossil fuel, in combination with non-fossil fuels, to continue to be used for electricity generation without adding to the damaging effects of climate change.

While for the Trades Union Congress (TUC) and our affiliates this is fundamentally an environmental challenge, CCS delivery also represents a unique opportunity to help shape a green industrial strategy, to rapidly decarbonise our industrial and energy base, and to create new skills and employment opportunities.

Crucially, CCS is essential if the increase in CO_2 emissions from the rapidly developing economies of China, India and other nations reliant on coal are to be contained and reduced. Historic responsibility for CO_2 emissions lies with the developed world. If developing countries need space to grow their economies, then we have to provide the means for a low-carbon future.

The Intergovernmental Panel on Climate Change (IPCC) special report on CCS (2005) found that around 60 per cent of global CO_2 emissions from fossil fuels originate from a core of around 7,900 heavy emitting stationary sources globally: power stations and energy-intensive installations such as steel and aluminium works. These sites each emit more than 100,000 tonnes of CO_2 a year, an aggregate total of 13.5 billion tonnes of CO_2 annually. Potentially, current systems for power plants are capable of capturing 85 to 95 per cent of CO_2.

The IPCC report identified CSS as part of "a portfolio of measures that will be needed" to achieve the stabilisation of greenhouse gas emissions. The TUC therefore supports an ambitious CCS development programme, and not just to secure the capture of CO_2 from the UK's handful of fossil fuel stations – the UK burns just 60 million tonnes of coal annually – a fraction of the 2.4 billion tonnes of coal burnt in China. For if we are to achieve the emissions reductions set out in the Blue Scenario of the 2008 Energy Technology Perspectives report by the International Energy Agency (IEA), we are likely to be faced with the global challenge of deploying around 55 power plants with CCS each year between 2020 and 2050.

Ideally, we believe that the UN should head a global CCS initiative, leading a consortium of developed countries in a co-ordinated research and development programme for CCS applied to a range of power and other industrial processes: coal, gas, steel, cement and others. CCS industrial clusters are therefore clearly the way forward. Concerted government support is required for regional CO_2 transport and storage networks covering power and industrial installations, as the UK regional study by Yorkshire Forward has shown. CO_2 transport is likely to involve very low unit cost, at under £2 per tonne of CO_2 transported. The Yorkshire Forward proposals for the Aire valley network cover 13 power plants and other installations emitting over 60 million tonnes of CO_2, confirming the economies of scale available for this cluster of large emitters situated close to suitable storage sites in adjacent North Sea gasfields.

The UK is uniquely placed to become a world leader in CCS technology, with its skills and capital resources, technological know-how, power station infrastructure and geological advantages of access to depleted North Sea gas and oil fields for CO_2 storage.

Europe is therefore in a unique testbed position to get to the stage of mass CCS deployment by 2020. We need every one of the desired 12 CCS demonstration plants in Europe to be operational by 2015, and probably more besides. Such a programme, in which the UK must take an above-average share, would be sufficient to build confidence in the technology and develop the necessary capacity in the industry to allow commercialisation from 2020.

In addition to their activities to regulate CO_2 storage, EU member states need to provide incentives for the adoption of CCS. In the longer term, hopefully well before 2020, such incentives will be provided by the carbon price under the EU ETS or global equivalent. But, if not, CCS will need to be mandated.

The success of CCS is not simply an environmental necessity for trade unions. Many potential CCS candidate plants – coal and gas for now – offer decent terms and conditions of employment in long-standing union agreements, in power generation, steel manufacture, chemicals, paper and pulp manufacture and many other energy intensive sectors. Further industrial opportunities would be secured in the domestic mining sector, and in rail freight through the movement of coal from mines and ports to power installations.

The success of CCS is therefore vital in cutting greenhouse gas emissions and securing quality jobs and investment. The industrial opportunities are enormous. The TUC has called on the UK government to lead a concerted skills and training strategy in research and development, project management, manufacture and construction. It will require funding and co-ordination across many sectors to ensure that we have the capability to deliver an unprecedented re-equipping of our energy and industrial base to secure a low-carbon future.

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towards cleaner coal: industry and unions working together

Mike Farley, Clean Coal Task Group

> " the technologies for carbon capture, transport and storage all exist "

The Clean Coal Task Group, a joint industry, unions and government advisory body, was initially formed as an initiative of the Trade Unions' Sustainable Development Advisory Committee, with the remit "To identify appropriate policy and supporting economic instruments and regulatory framework that would take forward the research, development and promotion and initiation of clean coal and carbon capture and storage technologies."

Following the creation of the UK Coal Forum in 2006, the Clean Coal Task Group has continued to meet and provide input and advice to the TUC, the UK Coal Forum, and other interested groups and bodies. The Clean Coal Task Group is focused on:

- developing a framework for the successful deployment of clean coal (including CCS);
- security of supplies and energy costs (and their consequences for fuel poverty and costs to industry) as well as emissions; and
- employment opportunities in power generation, mining and equipment supply.

Accelerating CCS deployment

The Clean Coal Task Group recognises the leadership which the EU has provided on CCS to date, but now considers that there needs to be a significant acceleration in development, demonstration and deployment of the technology.

We believe this can be achieved by a composite approach with the following elements:

- CCS regulations in place by 2010;
- at least 12 CCS demonstrations in Europe by 2015;
- development of incentives by 2010 to support the second tranche of CCS projects (to be committed by 2015 and operational by 2020);
- funded feasibility studies to establish CO_2 pipeline infrastructure to capture the economies of scale from industrial and power clusters, as in Rotterdam or the Aire Valley, Yorkshire;
- development of a strategy to implement CCS on all new plants

as soon as possible and on capture-ready plants by 2025, subject to a review against milestones on the completion and success of demonstration projects; the carbon price versus costs of CCS; the capacity of the industry to implement the programme.

A composite approach combining the five strands listed above would demonstrate a commitment to clean fossil power with CCS and answer those critics who suggest that permitting carbon capture-ready coal plant is a retrograde step. We also suggest that all other fossil fuel combustion power plant greater than 150 megawatt equivalent (MWe) or emitting more than one mega tonne per year (Mt/y) of CO_2 should be built capture-ready from 2009.

Importance of fossil fuels and CCS

The EU and the UK government clearly recognise the continuing importance of fossil fuels for power generation globally and the potential value of CCS for carbon abatement. The Clean Coal Task Group endorses this and wishes to stress the importance of these proposals on CCS (and capture-readiness) to set a global example. We do not believe that policy initiatives on capture-readiness and CCS itself for newly built plant in Europe should draw distinctions between new coal and gas installations. CCS will be needed for both fuels if emissions reduction targets are to be met.

Status of CCS technologies

The technologies for carbon capture, transport and storage all exist, albeit at various scales and readiness for full-scale deployment. Storage is underway at a scale of one Mt/y in sites in Norway, Algeria and USA. The scale-up issues are not so much technical as regulatory. Pipeline transport of CO_2 is also routine in the USA on a comparable scale. Carbon dioxide capture technologies exist and have been demonstrated, but on a much smaller scale than now required. This is particularly the case for post-combustion and oxyfuel technologies, hence the need for large scale demonstration projects.

By the time CCS is commercialised in 2020, around 500 gigawatt (GW) of new fossil power plant (coal and gas) will have been built. If these plants are not capture–ready and retrofitted with CCS, then, as leading climate scientist James Hansen fears, their emissions will be locked in. The prime targets for the first few years of commercialisation of CCS will be the capture-ready power plants built prior to 2020.

Urgent need for incentives

In the coming years it is clear that financial support will be required to ensure the demonstration at commercial scale of CCS technologies. The funding for such incentives could be the recycling of revenues raised by the auction of CO_2 allowances for power plants under the EU ETS. Full auctioning is envisaged from 2013 and could raise an estimated £30 billion per year for EU governments from a carbon price of 40 Euro per tonne of CO_2. Appropriate funding support systems have been established for renewables and good quality combined heat and power. The principle of intervention to overcome a market failure is clear.

> “financial support will be required to ensure the demonstration at commercial scale of CCS technologies”

Conclusion

The time is right for EU member states to initiate a significant acceleration in the development and deployment of CCS. Industry in the UK, supported by the trade unions, is ready to respond to clear signals which recognise the importance of the technology and give it positive support alongside other climate change mitigation measures. The UK government should support UK companies which can go on to offer the technology globally, bringing added value to the UK.

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section three
making it happen: regulatory ways forward

The arguments made in section two in favour of demonstration funding for CCS are persuasive. Over the coming decades there will be many other low-carbon technologies that will require funding support for them to be deployed at scale. Governments will need to provide public money in support of the public good of climate protection. In this respect, arguments in favour of support for CCS stand on a solid foundation.

Yet the question remains whether kick-start funding alone will be sufficient to achieve the ultimate goal of reduced carbon emissions. The need for Europe to start reducing emissions within the next decade, and to make reductions of perhaps 90 per cent by 2050 is an incredible challenge. Climate campaigners believe that it will simply be unachievable if new unabated coal plants are permitted and constructed without CCS while the technology is still in the demonstration phase. Two key critiques flow from this, and are tackled here in section three.

The first is set out by Matthew Lockwood of IPPR. He argues that the jewel in the crown of EU climate policy – the emissions trading scheme (ETS) – would be placed under severe strain if new unabated coal plants were to be built. His conclusion is that only a moratorium on unabated coal will suffice to protect the ETS.

The second critique concerns whether the concept of 'capture-ready' will be sufficient to deliver the wider deployment of CCS technology. Supporters argue that new unabated coal plants can be built with a view to retrofitting CCS technology at a later date, at least for post-combustion processes. Opponents point to the weaknesses in this approach, notably its dependence on the carbon price as a motivator for action and the poor record of similar historical attempts to address sulphur pollution. These weaknesses are contrasted with the approach taken by California in its use of an Emissions Performance Standard (EPS) for the power sector.

That approach is advocated here by Ben Caldecott and Thomas Sweetman of Policy Exchange, who set out how a European EPS would provide a means of ruling out unabated coal and could, over time, be progressively tightened to reduce emissions from other fossil fuels. Keith Allott of WWF-UK takes a similar view, with a focus on the historical weaknesses in the capture-ready approach, before lawyers Karla Hill and Tim Malloch of ClientEarth consider which of these options will deliver the real emissions reductions that Europe needs to make. All three of these viewpoints come to the conclusion that an EPS would be the more effective policy tool for avoiding increased emissions from unabated coal, and would provide market clarity on the need for CCS deployment beyond the EU demonstration programme.

Green Alliance shares this analysis, and sees the regulatory certainty of an EPS as a necessary defence against the continued construction of unabated coal. We would do well to learn from California's experience, which is the focus of the case study which closes this collection.

Sheryl Carter of NRDC explains how the California EPS is already starting to stimulate plans for CCS power plants. And there are now nascent hopes that a similar approach might be possible at federal level in the USA. This collection ends how it started, with a reminder that it will be European action now that makes such a move in the USA politically possible.

new coal build and the EU emissions trading scheme

Matthew Lockwood, IPPR

> “ uncertainty about the future of the ETS is in danger of feeding on itself ”

Why exactly does a new coal-fired power station at Kingsnorth, in the UK, matter? The key is to see the issue within the broader context.

Climate change is a global problem, so what really matters is that we get an effective global response, which means commitment and action by the large emitters, including the USA and China. The leadership of the EU, especially through its own actions, is crucial.

The EU’s climate and energy package is at the heart of this leadership by example, and the emissions trading scheme (ETS) – covering power generation and heavy industry – is the jewel in the crown. This is the world’s only major carbon market, and if other countries and regions are to follow the European lead, it is essential that the ETS is effective in reducing carbon emissions.

By common consent, the ETS has so far been completely ineffective. The caps have been too generous and the carbon price too low. Time frames are far too short to influence investment decisions. But phase two (2008-2012) has now seen a carbon price established, and the European Commission has put forward bold proposals for phase three (2013-2020), requiring a 21 per cent reduction in emissions from 2005 levels.

These proposals have radical implications for coal-fired power generation, as the most carbon-intensive form of power generation. The cheapest way to reduce emissions in the sectors covered by the ETS is to switch from coal to gas in power generation. According to analysts at Deutsche Bank, if these proposals are put in place, about a quarter of Europe’s oldest and most inefficient coal-fired plants would close down by 2012, and another third by 2020. Companies would have to build up to 60 GW of new gas-fired capacity to replace them.

If a large number of new coal plants are built across Europe instead, there are serious doubts that the phase three cap would hold, especially after 2015, as even advanced supercritical coal technology is much more carbon intensive than gas.

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The only way in which the cap could be met would be if CCS could be rolled out on a large scale well before 2020. Clearly, we do urgently need to accelerate the development of CCS across Europe. But while demonstration plants should be in operation by 2015, most industry experts doubt that large scale deployment of CCS is possible before 2020.

Yet, as of mid-2007, energy companies across the EU had plans to build over 70 new coal-fired power stations. In the UK, if Kingsnorth is given approval, it is likely that other proposals will come forward. But why would any energy company still consider new coal plants in the light of the plans for phase three of the EU ETS? The answer is that there is still considerable uncertainty about whether those ETS proposals will be enforced rigorously all the way out to 2020. Uncertainty about the phase three proposals exists not only because they have yet to be agreed by the Council of Ministers, but also because companies anticipate that if other big emitters like China and the USA do not come on board as part of a wider global deal, European politicians may well be less willing to go it alone and rigorously enforce their own climate policies in the future.

> "the UK government, along with its European partners, should act now if the ETS is to be effective in guiding energy market investment"

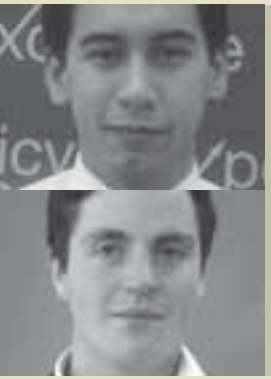
Thus, uncertainty about the future of the ETS is in danger of feeding on itself. The uncertainty means that carbon prices are discounted, and makes new coal investment a reasonable hedge from a commercial point of view. But at the same time that new investment would put the phase three cap in danger, and makes Europe's leadership less credible with key countries like the USA and China. This in turn creates new doubts about the viability of global deal, which in turn makes it even less certain that the phase three cap would be rigorously enforced.

This is a period of delicate balance, and at the same time, potential instability. This is why in a recent report *After the coal rush: assessing policy options for coal-fired electricity generation*, IPPR argued for an EU-wide temporary ban on new coal investment, at least until 2010, when the picture on a global deal should be a lot clearer.

In responding to its critics on Kingsnorth, the UK Government argues that the EU ETS is the solution, balancing environmental issues with security of supply and other considerations through a carbon price, which is the appropriate tool for a liberalised energy market. But the ETS is still a work in progress and, as a policy-driven market, long-term credibility is the key to its success. The UK government, along with its European partners, should act now if the ETS is to be effective in guiding energy market investment.

setting the standard

Ben Caldecott & Thomas Sweetman, Policy Exchange



> " many EU member states were the first to industrialise; together the EU can be the first to decarbonise "

Coal will continue to be a significant part of the global energy mix for the foreseeable future. It is the world's most abundant fossil fuel and accounted for 25 per cent of global energy consumption in 2005. Demand for coal is expected to double by 2030, with up to 4,500 GW of new power plants (approximately 45 times the size of UK supply) being built. Unfortunately, it is not hard to see why. As a source of energy, coal itself is relatively cheap, proven and often found within or close to the largest sources of demand. Energy security is a serious concern and with the United States, China and India having nearly 50 per cent of global coal reserves, concerns over cost and security will ensure they continue to use this plentiful resource.

In the transition to a low carbon global economy, all effective means must be utilised. CCS should be part of the suite of options available to policy makers to tackle emissions. One key problem, however, is that CCS is currently at the demonstration stage and, as yet, no commercial scale plant has been built.

Energy sector emissions, primarily from unabated coal plants, account for around 20 per cent of global greenhouse gas emissions. It is crucial, therefore, that both existing and planned coal power plants incorporate some form of CCS technology as soon as possible. This must happen in tandem with a rapid expansion of renewables.

In the UK we are in an excellent position to bring CCS to market. It could be fitted to existing power stations and those proposed, such as that at Kingsnorth, going a long way towards solving our looming energy crisis yet without compromising our climate goals.

However, given that CCS is still at the demonstration phase, how do we ensure that power plants built now are ready for CCS when it matures in five to ten years time? The UK government's approach is to use a concept called capture-ready, whereby it requires companies to guarantee that any proposed power station will be compatible with CCS when it becomes available. As no large-scale CCS system has been built, it is almost impossible to proscribe

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detailed requirements for what this might be. Despite large amounts of work on the subject, the general definition appears to be along the lines of "keeping a spare field next door to put the equipment". Furthermore, it fails to take into account the potential economics of actually transporting and storing CO_2 once captured.

The end result is a recipe for disaster, as changing technical specifications and economic uncertainties mean that we are in real danger of building fossil fuel power stations now, that cannot be fitted with CCS later. Worse still, due to the size and cost involved in building such power stations, they are unlikely to be replaced for 20 to 30 years. Thus, at one stroke, we are condemning ourselves to the prospect of up to 30 years of high carbon emissions with dire consequences for our environment.

Our solution, proposed in a recent Policy Exchange report, entitled *Six thousand feet under: burying the carbon problem*, is that rather than trying to predict precise engineering standards, we should introduce emission performance standards. This is because it is emissions, rather than the finer points of engineering, that really matter when addressing climate change.

Performance standards are nothing new and have been used successfully in other policy areas, such as controlling car emissions. By using this option, government would be sticking to what it can do best, namely setting the framework and leaving businesses to get on with the task at hand. The provision of a clear framework would also allow industry to make solid investment decisions with respect to future generation.

Finally, emission performance standards would also be relatively straightforward to implement. The conversion of the EU fleet of fossil fuel power plants to CCS could be done in as little as three steps. A potential phased scenario is outlined here:

First, as part of the EU climate and energy package, member states should introduce a rule that all new fossil fuel power plants built after 1 January 2009, must have average annual emissions of 350 kg CO_2/ MWh. This would eliminate new-build coal without CCS, but still permit new-build gas (which is far cleaner than coal), to avoid power shortages. Developing new coal plants with CCS is still feasible within this emission limit.

Second, the emission performance standard becomes ever stricter for new plants. This is for two reasons, first, to bring gas into the CCS requirement; second, to bring coal fully fitted with CCS into the requirement. This standard could be introduced from 2015, and be 170 kg CO_2/MWh, which permits efficient coal with CCS. A separate standard of 70 kg CO_2/MWh could be considered for gas plants, to maximise the benefits of decarbonisation. Bringing in gas by 2015 also ensures that companies cannot just rely on building gas plants to escape developing CCS. We thus avoid the prospect of a second dash-for-gas and ensure investment in clean coal.

Third, older existing plants are brought into the system, by CCS retrofitting. This can share the same standard of 170kg CO_2/MWh for coal, and potentially 70 kg CO_2/MWh on gas, for the same reasons outlined above. We propose 2020 as the date that existing plants must become retrofitted with CCS.

If these standards are met, they would allow us to meet our energy needs at the same time as our climate change targets. All this without falling into the trap of attempting to predict technical requirements that will almost certainly change as time moves on and technology improves.

Historically the EU has been at the forefront of finding ways to tackle climate change with the world's first large-scale carbon trading scheme, the toughest targets and the most imaginative solutions. Many EU member states were the first to industrialise; together the EU can be the first to decarbonise.

captured by king coal

Keith Allott, WWF-UK

> “ the decision on the consent ... for Kingsnorth in Kent is now seen as a litmus test of the UK government’s claims to international leadership on climate change ”

Alarm bells should be ringing ever louder in Whitehall and Brussels. The impacts of climate change are occurring even faster than scientists had predicted, and with the rapid melting of the Arctic sea ice, we are now witnessing the first great tipping point in the Earth’s climate system. Climate scientists tell us that global emissions need to be on a downward path within a decade at most. The political timetable is equally urgent. A strong international climate change agreement needs to be struck at Copenhagen in December 2009. To win this vital endgame, strong and compelling leadership from the UK and EU must play an essential role.

It is therefore deeply worrying that much of the response from business and government appears to be reverting to business as usual. Nowhere is this more apparent than the plans in the UK and other EU countries for a new generation of unabated coal-fired power stations, with the decision on the consent for E.ON’s proposed coal station at Kingsnorth in Kent now seen as a litmus test of the UK government’s claims to international leadership on climate change.

Why on earth is the UK government – or to be more precise, the business department BERR – pursuing such a reckless course? The main argument put forward is the familiar claim that new coal stations are essential in order to keep the lights on. Yet a study for WWF-UK and Greenpeace by leading energy consultants Poyry found that if the government acts to deliver on its EU renewable energy target for 2020, and its own energy efficiency goals, there is simply no need for new baseload generation capacity until the 2020s. Moreover, delivering on these targets would slash the UK’s gas consumption by up to 42 per cent and cut CO_2 emissions by up to 37 per cent from 1990 levels. Clearly, meeting the renewables target will require a dramatic ramping up in ambition and effective new policies, but there is no reason why it cannot be achieved.

The next argument is that high emissions in the UK don’t really matter because they will be offset under the EU ETS or the Kyoto Protocol’s clean development mechanism (PDM). Put aside the fact

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that many CDM credits do not represent real, additional emission reductions. The fact is that true leadership is judged by action on the ground.

The third argument for new coal stations is that they will be capture-ready. In other words, that they will be designed to allow CCS facilities to be fitted at some (unspecified) later date. At its baldest, this concept simply involves leaving space on the site to accommodate CCS equipment. As one leading US environmentalist says, on this basis his driveway is "Ferrari-ready", just don't expect it to happen any time soon.

WWF-UK commissioned experts at Edinburgh University's Scottish Centre for Carbon Storage to explore what would be needed to make capture-readiness a remotely credible concept. They concluded that, for it to have any relevance, it must be accompanied by a binding condition requiring full CCS to be installed by 2020 or the station's licence should be withdrawn.

This approach has significant dangers, however. Once new capture-ready stations are built, future governments are likely to face strong pressure to abandon or weaken the retrofit requirement, especially if CCS proves difficult or costly. The station operators could be expected to press for continued operation without CCS (in the name of keeping the lights on) – or for the government, and the taxpayer, to pick up the hefty bill for a CCS retrofit. Recent history offers ample grounds for caution.

In the 1980s and 1990s, the main environmental concern with coal-fired power stations was their contribution to acid rain. The UK's longstanding reluctance to address the issue earned it the label of "the dirty man of Europe". Eventually, in the late 1980s Margaret Thatcher's government proposed a target to fit 12GW of coal-fired capacity with sulphur scrubbers, or flue gas desulphurisation (FGD) equipment. After industry lobbying, this figure was reduced to eight GW at the time of privatisation in 1990.

In practice, even this commitment was not fulfilled. PowerGen (one of the two privatised power companies, which was later acquired by E.ON, the company behind Kingsnorth) fitted FGD to only one station instead of the two that were promised. PowerGen successfully fought off pressure from regulators, and pocketed the £250 million cost of the retrofit which had essentially already been paid for by the taxpayer. Further attempts by the Environment Agency in the late 1990s to clamp down on the sector's sulphur emissions also fell foul of fierce industry lobbying, based around the familiar threat of energy security and gas dependency.

"An emissions performance standard is a market friendly approach that does not specify any particular technology"

Eventually, a significant programme of FGD retrofits took place in the middle of this decade. Tellingly, this investment was driven by an EU directive on large combustion plants which set a binding sulphur emission limit for any power station that wanted to run at baseload from the start of 2008.

Overall, it took two decades to bring sulphur emissions from the UK power sector under control even though – in stark contrast to CCS technology now – FGD abatement had already been fully proven on an industrial scale. In the end, only a legally binding emission limit forced industry and government to take the issue seriously.

"WWF and other NGOs are calling for a greenhouse gas performance standard to be introduced now for all new and replacement power stations"

When it comes to the vital issue of cutting carbon emissions, we simply cannot afford a repeat of this sorry tale. That is why WWF and other NGOs are calling for a greenhouse gas performance standard to be introduced now for all new and replacement power stations in the UK and in Europe. An emissions performance standard is a market-friendly approach that does not specify any particular technology. Highly efficient gas stations, renewables and coal with fully operational CCS would all comply. In our view, the standard should be set at 350g of CO_2 per kWh – achievable by highly efficient gas stations with heat recovery – but tightened over time once CCS technology has been proven.

An emissions performance standard is already in force in California (as outlined by Sheryl Carter of NRDC later in this publication), and would provide much greater certainty to investors and decision-makers than a vague and unenforceable capture-readiness requirement. It is key to ensuring that the power sector – currently the UK's biggest polluter – cleans up its act.

So does CCS have a role? In WWF's view the technology has considerable promise and may well play a role globally and in the UK. But many unanswered questions remain over the costs, safety and technical feasibility at industrial scale. These questions are best addressed by a well-coordinated EU demonstration programme before we commit to any new coal build in the UK or Europe.

The UK government is planning one modest 50MW CCS pilot project by 2014. Our fear is that this small demonstration will be used as a figleaf to justify a new coal-fired power station 30 times the size with no guarantees that full CCS will ever follow. With climate change, the stakes are now too high to allow that sort of gamble.

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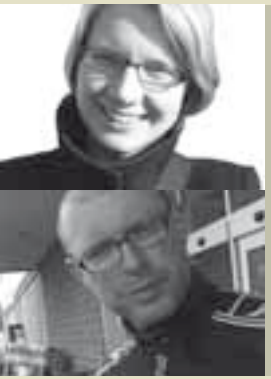
an emissions performance standard as the regulatory alternative to capture-readiness

Karla Hill & Tim Malloch, ClientEarth



> “ the scientific evidence on climate change is unequivocal and the regulatory response must be equally certain ”

As preeminent climate scientist James Hansen reminds us so powerfully, climate science now demands that we cease burning coal for electricity generation unless the carbon emissions are captured and permanently stored “if humanity wishes to preserve a planet similar to that on which civilization developed and to which life on Earth is adapted.” As part of the solution, it is imperative that CCS is demonstrated and deployed as quickly as possible.

The scientific evidence on climate change is unequivocal and the regulatory response must be equally certain. The California greenhouse gas emissions performance standard (EPS) provides a model for regulatory certainty in the transition to a low-carbon electricity system. In the UK and at European level, a similar regulatory approach is needed to avoid the regulatory uncertainty of a capture-ready approach and the risk of a power generation sector locked in to long-lived, high-carbon infrastructure.

The California EPS means that new investment in baseload power generation serving California consumers must be with power plants that have emissions no greater than those of a combined cycle gas turbine plant. (See further details of the California experience on page 38).

The California EPS is aimed at reducing the state’s carbon emissions, and is seen as an important interim step to protect the taxpayer and electricity consumers from the future costs of a carbon price in the current absence of a statewide cap on emissions. In the meantime, investors have certainty and can choose from a range of options that meet the standard.

For coal power, the immediate effect of the standard is that any new coal power plant would have to present a reasonable, economically and technically feasible plan that CCS will operate from the outset to meet the California EPS.

The capture-ready problem

The UK government is now consulting on whether it should allow a new generation of capture-ready coal power stations to be built in

the UK. The capture-ready definition is based on the European Commission's proposal to allow member states to consent to new coal power stations:

> "Member States shall ensure that all combustion plants with a capacity of 300 megawatts or more... have suitable space on the installation site for the equipment necessary to capture and compress CO_2 and that the availability of suitable storage sites, suitable transport facilities and the technical feasibility of retrofitting for CO_2 capture have been assessed."

This proposed Article 32 of the draft CCS directive is one of the most controversial provisions in the EU climate and energy package. A coal plant with CCS technology would capture and safely store the vast majority of its CO_2 emissions. But a capture-ready plant will not. It will emit millions of tonnes of CO_2 into the atmosphere until the expensive CCS technology is retrofitted.

Moreover, Article 32 proposes a very low and undemanding standard that requires energy companies to take no substantial action to reduce their CO_2 emissions or change their investment decisions. To be capture-ready a new coal power plant will only need to have empty space next to it for the CCS equipment to be fitted in the future, and to complete technical assessments of potential storage and transport and the technical feasibility of retrofitting carbon capture.

The concept of capture-readiness is inherently vague with no guarantee that CCS will ever be retrofitted. It also fails to account for the possibility that CCS will not work or be commercially viable with the risk of locking in a high-carbon system and its serious implications for climate goals, including the viability of maintaining the EU ETS and meeting emissions reductions targets at EU and UK levels. (See the contribution to this publication from Matthew Lockwood, IPPR).

The proposed provision for capture-readiness is part of a weak overall approach to CCS at the EU level, which will delay crucial demonstration of, and investment in, CCS technology. Only a combination of political and market conditions will ensure private sector investment in CCS technology. Energy companies and their backers will not voluntarily commit to expensive CCS technology on a large-scale as the carbon price established under the EU ETS in its current form is not enough to deliver CCS on its own. In the meantime, 50 more coal power stations are planned across Europe. The Stern review on the economics of climate change makes it clear that "carbon pricing on its own is not sufficient to reduce emissions on the scale and at the pace required", and "it is critical that governments consider how to avoid the risks of locking into a high-carbon infrastructure, including considering whether any additional measures may be justified to reduce the risks".

Supplementing the EU ETS with a carbon EPS would provide energy companies with a clear investment signal that would stimulate investment in CCS technology. An EPS would work at the UK or EU level as part of an overall plan for decarbonising electricity and for deployment of CCS. Other measures, including increased financial support for CCS demonstration projects (discussed in section two), a stricter cap to ensure emissions reductions take place within the EU, and full power sector auctioning of EU ETS allowances, are also necessary to encourage energy companies to invest in CCS technology as part of a low-carbon portfolio.

Capture-readiness will not force energy companies to make important long-term investment decisions, and risks delaying the introduction of CCS in Europe and worldwide. The EU ETS needs to be supplemented with the clarity and certainty of a regulatory standard for electricity generation. The case for a carbon emissions performance standard as an alternative to the uncertainty of capture-readiness is compelling on both economic and environmental grounds.

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California's greenhouse gas performance standard for power plants

Sheryl Carter, Natural Resources Defense Council

" the regulatory certainty provided by the Californian EPS is already proving to be a driving force for reduced emissions and CCS in the USA "

On 27 September, 2006, Governor Arnold Schwarzenegger signed into law the Greenhouse Gas Emissions Performance Standard Act (Senate Bill 1368). The emissions performance standard (EPS) ensures that future long-term investment in electricity generation for California comes from sources that emit low amounts of carbon dioxide and other heat-trapping gases.

The development of SB 1368 was led by Senate President pro Tem Don Perata to protect California consumers from the significant financial and reliability risks of high greenhouse gas (GHG) emitting energy sources. It was known that California's utilities are planning to invest billion of dollars in energy generation over the next several years and that, depending on how those investments were made, they could generate GHG emissions for at least 60 years, contributing to global warming and the associated impacts on California's economy, environment, and public health.

Californians faced serious financial risks in committing to such long-term investments in carbon-intensive generation when the emergence of enforceable limits on emissions was only a matter of time. In fact, the first enforceable mandatory statewide limit in the United States on global warming pollution was also signed into law in California in September 2006. Assembly Bill 32 (AB32 or the Global Warming Solutions Act of 2006) requires the state to reduce GHG emissions to 1990 levels by 2020.

The EPS also specifically addressed the last critical element of the state's energy resource procurement priorities policy. California's energy agencies adopted the Energy Action Plan in May 2003, which established a blueprint for achieving the state's overall goal of adequate, reliable, and reasonably priced electrical power and natural gas supplies. This blueprint included a loading order of energy resources to guide procurement in California. The policy is to acquire all cost-effective energy efficiency and conservation first, to minimise increases in electricity and natural gas demand at lowest cost; renewable energy and clean and efficient distributed generation second; clean and efficient fossil generation to the extent that efficiency and renewable energy are not sufficient to

meet California's energy needs. By 2006, California legislation already required the acquisition of all cost-effective energy efficiency and a 20 per cent renewable portfolio standard (RPS) by 2010.

The EPS applies to any entity that provides electricity to Californian customers. All baseload generation resources seeking new, long-term California investments of five years or more are required to meet a GHG performance standard, which is set at a level of emissions equal to those of a combine-cycle natural gas plant on a per megawatt-hour basis (498kg CO_2/MWh). No blending or portfolio averaging is allowed and there are no exemptions or offsets.

"even governors of coal-producing western states have indicated their commitment to comply with the standard if they sell power to California"

The EPS is technology and fuel neutral, and applies equally to facilities both in and out of state. California currently imports almost a third of its electricity from neighbouring states, much of which comes from conventional coal-fired power plants, and several additional planned coal-fired power plants throughout the west originally aimed to sell their power to California to meet its growing demand for electricity.

Any facility that proposes to use carbon sequestration (injection in geological formations), must do so in a manner that prevents releases into the atmosphere, and in compliance with applicable laws and regulations. If they meet these criteria, then these emissions will not be counted as emissions of the power plant in determining compliance with the EPS. So while new investments in conventional unabated coal-fired power plants will clearly not meet the standard, coal plants using CCS could do so.

The effects of California's EPS

California's groundbreaking EPS has already inspired other western states to follow its lead. In May 2007, Washington State enacted a GHG performance standard (SB6001) modeled after SB 1368. Montana's similar constraints on regulatory approval of long-term generation investments in coal-fired power plants (HR 25) followed soon after. Oregon has introduced a bill similar to SB1368 and the US Congress is considering various emission performance standard designs.

California's EPS is also sending a clear signal to energy markets and power plant developers, that low GHG-emitting generating technologies are the future of California energy. Dozens of conventional coal plant proposals throughout the west have been withdrawn since the bill was passed, or replaced with proposals that include CCS. Even governors of coal-producing western states, such as Montana and Wyoming, have indicated their commitment to comply with the standard if they sell power to California.

While there is a lot of activity in this area, most efforts to develop projects that deploy CCS are in the early planning stages. However, at least two have been publicly announced. The first is an integrated gasification combined cycle project with pre-combustion CO_2 capture by BP at its refinery in Carson, California. The other is Tenaska's proposal for the Trailblazer Energy Center in Texas, which plans to capture and deliver to the enhanced oil recovery markets 90 per cent of the CO_2 produced.

The regulatory certainty provided by the Californian EPS is already proving to be a driving force for reduced emissions and CCS in the USA. Efforts are underway to extend this approach to the federal level, but this will take time to bring about. If a similar approach were to be put in place by the European Union it would significantly strengthen the calls for federal action and greatly facilitate the USA's positive re-engagement with global partners on tackling climate change.

contributor biographies

Rt Hon Margaret Beckett MP
member of parliament

Margaret Beckett is the Labour MP for Derby South and chairs the UK Intelligence and Security Committee. Mrs Beckett was a cabinet member of the British government from 1997-2007. She was foreign Secretary from 2006-07, secretary of state for the environment from 2001-06, and secretary of state for trade and industry from 1997-98. While foreign secretary, Mrs Beckett chaired the first meeting of the UN Security Council on the security implications of climate change. She was the chief EU and UK negotiator at the Climate Change Convention Meeting in Montreal in 2005 at which the basis for negotiations on the Kyoto Protocol after 2012 was agreed. She chaired both the Agriculture and Environment Council throughout the UK's presidency of the EU in 2005.

Stephen Hale
director
Green Alliance

Stephen Hale joined Green Alliance as director in July 2006. He was previously special adviser at the Department of Environment, Food & Rural Affairs from 2002-06, to secretary of state Margaret Beckett MP from 2003-06 and prior to that to environment minister Michael Meacher MP. He worked from 1997 – 2002 as an adviser to businesses on social and environmental issues. He was chair of SERA (the environmental group affiliated to the Labour Party) in 2001-02 and vice-chair from 1999-2001. He is a trustee of the development charity Christian Aid.

Dr Jon Gibbins
senior lecturer, Energy Technology for Sustainable Development Group
Imperial College London

Jon Gibbins has worked on coal and biomass gasification and combustion for over 25 years, at Foster Wheeler and then Imperial College, London, where he now teaches Sustainable Energy Engineering. He is the principal investigator for the UK Carbon Capture and Storage Consortium (www.ukccsc.co.uk) and is also involved in a number of other academic, industrial and government initiatives on CCS and low carbon electricity in the UK and overseas, including the UK/China Near Zero Emissions Coal project (www.nzec.info) and membership of the UK BERR Advisory Committee on Carbon Abatement Technology.

Hannah Chalmers
research assistant, Energy Technology for Sustainable Development Group
Imperial College London

Hannah has been working on CCS since May 2003. Her main research interests are in technical and economic aspects of CO_2 capture for power plants, including improving understanding of various approaches for incentivising CCS deployment. She played an active role in kicking-off the UK Carbon Capture and Storage Consortium (www.ukccsc.co.uk) and has also been involved with projects on retrofitting CCS to existing plants and capture-ready principles. She is currently the Imperial College lead for a Technology Strategy Board project on transient behaviour of oxyfuel power plants.

David G Hawkins
director, Climate Programs
Natural Resources Defense Council

David G. Hawkins built on his work on public interest law at Colombia University when he joined the Natural Resources Defense Council's Washington, DC office in 1971. In 1990, he became director of NRDC's Air and Energy Program, and in 2008 he became the director of NRDC's Climate Programs. David is recognised as an expert on advanced coal technologies and CCS. He participated in the Intergovernmental Panel on Climate Change's Special Report on CCS and in the IPCC's Fourth Assessment Report on climate change.

Dr Graeme Sweeney
executive vice president, Future Fuels & CO_2
Shell International Petroleum Company Ltd.

Graeme Sweeney joined the Royal Dutch Shell Group in 1976 and in 1984 he became a UK senior strategy consultant for Shell International. In 2002 he became president of Shell Global Solutions in the USA shortly before becoming vice president Manufacturing Supply and Distribution for Shell Europe Oil Products. In 2005, Dr Sweeney was the executive vice president of Renewables, Hydrogen, CO_2 & Power. He is now the executive vice president of the Future Fuels & CO_2 organisation for Shell. Dr Sweeney chairs the Advisory Council of the European Technology Platform for Zero Emission Fossil Fuels Power Plants and the Advisory Board of the UK Energy Research Centre (UKERC).

Jules Kortenhorst
chief executive officer
European Climate Foundation

Jules Kortenhorst is the chief executive officer of the European Climate Foundation. Before joining the ECF, he served as a member of the Dutch parliament for the Christian Democratic Party, CDA. His career also includes serving as CEO for International Operations of ClientLogic Corporation, as the president and CEO at CORDENA, and as the managing director of Shell Bulgaria. Graduating a Baker Scholar from Harvard Business School and holding a master's degree in economics from Erasmus University in The Netherlands, he began his career as an analyst at McKinsey & Company in Amsterdam.

Linda McAvan MEP
member of the European parliament
Yorkshire and the Humber

Linda McAvan was first elected as an MEP in 1998. She was re-elected in 1999 and again in 2004 as head of Labour's regional list for Yorkshire and the Humber. She is Labour's spokesperson in the European Parliament on the Environment and Public Health and is a member of the Environment, Public Health and Food Safety Committee. She has been a member of the PSE Group Bureau since 2004, and was recently elected as a vice president. Her "Quality of Life" portfolio oversees policy on the environment, climate change, agriculture, regional affairs and fisheries.

Alain F Berger
VP European Affairs
Alstom

Alain F Berger has formally assumed the position of VP European Affairs and Head of the Brussels' office since 2008. Mr Berger's career spanned numerous positions within Alstom since 1999 when Mr Berger joined Alstom as senior vice president, International Operations, Latin America. In early 2001 he took on the role of senior vice president, Commercial & Sales of Hydro Power Business of Alstom worldwide. From June 2003 to December 2007 he was president of Alstom China in Beijing.

Dr Ruud Lubbers
chairman
Rotterdam Climate Initiative

Ruud Lubbers was prime minister of the Netherlands from 1982 until 1994, having previously been a member of parliament from 1978 until 1982, during which time he was instrumental in merging Protestant and Catholic parties into the Christian Democratic Alliance (1980). In 1994 he retired from politics and became professor of globalisation, in addition to holding many ancillary positions including as international president of WWF. From 2001 until 2005, he was UN high commissioner for refugees. During those years, he continued his membership of the Earth Charter Commission. At present, he devotes a lot of time to chairing the Energy Research Centre in the Netherlands, which provides a focus for energy saving, renewable energy, and Atoms for Peace, as well as to the Rotterdam Climate Initiative.

Frances O'Grady
deputy general secretary
Trades Union Congress

Frances became TUC deputy general secretary in January 2003, the first woman ever to hold this post. Frances has lead responsibility for a wide range of key areas of policy development across the TUC's work including trade union recruitment and organisation, inter-union relations and TUC services to members. Frances was a member of the Commission on Environmental Markets and Economic Performance, and has played a leading part in the development of TUC energy and climate change policy. She sits on the board of the think tank IPPR and is joint vice chair of the Learning and Skills National Council.

Dr J Mike Farley
chair, TUC Clean Coal Task Group;
director of Technology Policy Liaison, Doosan Babcock Energy Limited

Mike Farley currently represents Doosan Babcock on the Advanced Power Generation Technology Forum. Mike is a member of the government's advisory committee on carbon abatement technology and also of the energy research partnership. Through membership of the Coal Forum, chairmanship of the TUC Clean Coal Task Group and his chairmanship of the IPA (Industrial and Power Association in Scotland) he has strongly promoted clean coal and carbon capture. He is a vice president of the European Power Plant Suppliers' Association and a member of the Advisory Committee of the European Technology Platform for Zero-Emissions Fossil Fuel Power Plant.

Dr Matthew Lockwood
senior research fellow, Climate Change
IPPR

Matthew Lockwood is currently the senior research fellow at IPPR on the climate change team. In 2008 he authored the report *After the Coal Rush: Assessing policy options for coal-fired electricity generation*. He has a history of working on global development issues with a focus on Africa, first as an academic at Cambridge and Sussex Universities, and then in the NGO sector. He was head of international policy at Christian Aid and head of policy and campaigns at Actionaid UK. He has also worked for Save the Children UK and for the Department for International Development. In 2004 he started working on climate change policy. He has been an advisor on climate change to the deputy mayor of London and worked for the London Climate Change Agency.

Ben Caldecott
research director and head of environment unit
Policy Exchange

Ben Caldecott is currently research director and head of the environment unit at Policy Exchange. He was previously director of the East Asia Section at The Henry Jackson Society. Ben read economics and specialised in China at Cambridge, Peking and London universities. Ben has worked in parliament and for a number of different UK government departments and international organisations, including the United Nations Environment Programme (UNEP) and Foreign & Commonwealth Office (FCO).

Thomas Sweetman
environment research fellow
Policy Exchange

Thomas Sweetman is a research fellow at Policy Exchange. Having studied both arts and sciences at Durham University he has since worked as both consultant and researcher in a major city firm as well as several leading think tanks. Specialising in environment policy he has also conducted research on issues from gang crime to health and finance. His most recent reports include *Green Dreams – a decade of missed targets*, *Six Thousand Feet Under – Burying the Carbon Problem* and *Is Britain Ready for Carbon Capture and Storage?*.

Dr Keith Allott
head of climate change programme
WWF-UK

Keith Allott is head of WWF-UK's climate change programme, a team which works on issues including the climate change bill, UK energy policy, emissions trading, climate change adaptation, international climate change negotiations, aviation and publications including *Evading capture – is the UK ready for carbon capture and storage?*. Before joining WWF, Keith spent most of his career working as deputy editor at ENDS, the leading publisher of information and analysis on UK and EU environmental policy. He also worked for the Royal Commission on Environmental Pollution and contributed to its 2000 report on Energy & Environment, the source of the government's current target to reduce the UK's CO_2 emissions by 60 per cent by 2050.

Karla Hill
climate & energy lawyer
ClientEarth

Karla Hill joined ClientEarth in October 2008 to develop a work programme on climate and energy law, regulation and policy and to examine aspects of the energy bill, the climate change bill and the EU climate and energy package. In previous roles Karla worked on sustainable energy policy issues with the Sustainable Development Commission, and before coming to the UK, she practised environment, planning and public law in New Zealand where she was admitted as a barrister and solicitor of the High Court in 2001.

Tim Malloch
climate & energy lawyer
ClientEarth

Tim Malloch focuses on evaluating the UK government's plans to allow a new generation of coal power stations to be built. Tim is qualified as a solicitor in England and Wales and was previously a senior associate with an international law firm, advising on a wide range of dispute resolution, environment and regulatory law matters.

Sheryl Carter
co-director of energy program
Natural Resources Defense Council

Sheryl Carter plays a leading role in NRDC's energy program, promoting the increased development of energy efficiency, renewables and other environmentally sound and cost-effective energy resources. She has advocated before the California Energy Commission, Northwest Power Planning Council, Minnesota Department of Public Service, and before the California, Oregon, Washington, and Minnesota state legislatures. Her current board memberships include the Clean Power Campaign, the California Foundation on Environment and the Economy, the Renewable Northwest Project, and Women's Energy Associates.

Green Alliance

Green Alliance is an independent charity. Our mission is to promote sustainable development by ensuring that environmental solutions are a priority in British politics. We work with representatives from the three main political parties, government, business and the NGO sector to encourage new ideas, facilitate dialogue and develop constructive solutions to environmental challenges.

Green Alliance
36 Buckingham Palace Road, London SW1W oRE
tel: 020 7233 7433 fax: 020 7233 9033
email: ga@green-alliance.org.uk
website: www.green-alliance.org.uk

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a last chance for coal: making carbon capture and storage a reality

In this collection of viewpoints, Green Alliance reveals the growing support for carbon capture and storage (CCS) as a means of tackling the twin challenges of climate change and energy security. CCS technology appears to be ready, but it must be demonstrated urgently at commercial scale if it is to be deployed more widely in the coming decades.

These essays come from a variety of perspectives – politics, economics, business, unions, academia, think tanks and NGOs – but some important common themes emerge. First among these is that the demonstration of CCS requires dedicated public funding for a programme of different technologies. This is a strategically important undertaking, which must be funded and carried out at European level if it is to succeed. By doing so, the European Union can deliver on its international leadership ambitions, unlocking the potential for action by China and the USA.

But financial support to kick-start a new CCS industry is not in itself sufficient. Europe must reduce carbon emissions and cannot risk the construction of new unabated coal plants while CCS is being demonstrated. This collection therefore also looks in depth at how Europe can follow California's experience with emissions performance standards. Such an approach would provide regulatory certainty for CCS and secure the future of the EU emissions trading scheme.

Green Alliance argues that funding for CCS demonstrations and the introduction of emissions performance standards must go together. The time is now for the EU and its member states to act. In our carbon-constrained world CCS provides 'a last chance for coal'.