CENTRE FOR EUROPEAN REFORM

CARBON CAPTURE AND STORAGE
What the EU needs to do

Stephen Tindale with Simon Tilford

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Published by the Centre for European Reform (CER), 14 Great College Street, London, SW1P 3RX
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AUTHORS' ACKNOWLEDGEMENTS

The authors would like to thank all those who provided input and ideas for this report, in particular Jesse Scott, Craig Jones and Ben Caldecott, and also Kate Mullineux for layout and production. The views expressed in this publication, and any remaining errors, are those of the authors alone. The publication of this report would not have been possible without the sponsorship of ScottishPower.

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Foreword

As we enter a new decade, energy providers across Europe are finding themselves with three fundamental challenges: the need to maintain secure power supplies; the need to keep that power affordable for our domestic, commercial and industrial consumers; and the need to ensure that the energy we produce is both reliable and sustainable in the long term.

At ScottishPower we, alongside government, believe that the response to these three challenges lies in having a threefold solution. First, we need to move rapidly towards greater energy efficiency through smart meters and smart grids. Second, we need to continue to develop our portfolio of renewable energy sources such as wind and marine. And third, we need to develop reliable and flexible low carbon electricity generation which will include a fresh role for nuclear and a long-term future for coal.

In taking these steps towards our energy future, we have been at the forefront of carving out a new role for coal in the energy mix. Coal presents us all with a particular challenge. On the positive side, it is relatively cheap, it is abundant, and it can be easily extracted from most parts of the world. Set against that is its environmental price tag. It emits carbon dioxide when burned, which all the available science tells us is a key contributor to climate change. So, if we are to continue to be able to use it and meet the appropriately tough emissions reduction targets set for the end of this decade, then we have to tackle head on the CO_2 that this remarkable source of energy gives off.

We believe the answer lies with carbon capture and storage (CCS). We are committed to being among the first in the world to deliver a full-scale, commercially viable CCS system at our power station at Longannet in Fife, Scotland, by 2014. We have made great strides already, but know we aren't there yet. To take CCS out of the lab and make it an operational reality will take national and international support and collaboration.

This report is an eloquent argument for concerted European action to promote CCS. It paints a picture of uneven political focus in Brussels. It outlines too what could be achieved if politicians and energy providers all pull in the same direction. I am proud that we at ScottishPower have sponsored this insightful document. We support its findings and urge those who can make a difference on the European stage to act on the recommendations it makes without delay.

Nick Horler

Chief Executive, ScottishPower

1 Introduction

The global demand for electricity is set to boom. As people in China, India and other developing countries become wealthier, their use of electricity will rise dramatically, in spite of growing efforts to curb the use of energy. Electricity is already the main source of power for trains and will almost certainly replace oil as the power source for most road transport, as cars switch from internal combustion engines to batteries. Rising temperatures mean that electricity-hungry air conditioning will become more widespread. And heat for buildings will increasingly be provided by electricity rather than oil or gas boilers. Europe will be no exception to this global trend towards higher electricity consumption, notwithstanding its efforts to improve energy efficiency.

The challenge the world faces is to meet the burgeoning demand for electricity while delivering big cuts in emissions of greenhouse gases. Renewable energy will become an increasingly important source of electricity. The EU may well reach its target of meeting 20 per cent of its energy needs from renewable sources by 2020.[1] But it will not be until 2050 – and probably well beyond then – that energy in the EU or elsewhere could feasibly be fully renewable. In the meantime we must produce electricity in a way that involves pumping less carbon dioxide into the atmosphere.

[1] *Stephen Tindale, 'How to meet the EU's 2020 renewables target', CER policy brief, September 2009.*

At present, around half of the EU's electricity is produced by burning fossil fuels, of which two-thirds is accounted for by coal. EU countries are currently planning to build 50 large conventional coal-fired power stations, a move which would severely compromise Europe's efforts to reduce its emissions of greenhouse gases. Some people therefore argue that governments should leave coal aside and instead focus on an aggressive expansion of nuclear energy,

which is close to being carbon neutral. The tide is certainly turning in favour of nuclear across Europe. Italy is rethinking its ban on new nuclear capacity, Britain is gearing up for the construction of a large number of new plants, and France remains as committed as ever to nuclear energy. The recent election of a centre-right government in Germany could lead to that notoriously nuclear-sceptic country postponing the closure of its nuclear power plants and conceivably to it constructing new ones. But nuclear power stations will only ever be part of the solution to the energy challenge, because nuclear energy is very costly.

As a result, coal will continue to be the most important single source of electricity in Europe for decades to come. It will also be the dominant source globally, not least because most of the new energy capacity coming on stream in India and China will involve burning coal. The EU needs to burn coal and gas in a way that is less damaging to the environment.

The technology to do so does exist. Carbon capture and storage (CCS) involves capturing carbon dioxide from power stations and other major industrial users of coal and gas, compressing it, transporting it, and then storing it safely underground. Employing CCS does impose an 'energy penalty': a coal or gas-fired power station incorporating CCS technology will use more fuel to produce electricity and operate more expensively than a plant that simply releases the carbon dioxide into the air. The reason for this is that it requires extra energy to separate and capture the carbon dioxide. But the world is not short of coal. What is required is a way of using it to generate electricity in a less carbon-intensive fashion. Approximately 500 industrial facilities account for 25 per cent of the EU's emissions of carbon dioxide. Fitting CCS technology to them all would make a dramatic contribution to decarbonising the European economy.

The capture, compression, transport and storage of carbon dioxide have all been shown to work, but only on a small scale and not in

an integrated fashion. The world needs to see that CCS works just as well on a large scale, through each step of the process. Unfortunately, the EU has not yet put in place the policies to demonstrate the commercial viability of CCS and bring about its mass deployment. But if Europe fails to do so, it is very hard to see how it will be able to make the big cuts in emissions of carbon dioxide needed to meet its environmental targets. And Europe will fail to assume leadership of what promises to be a crucial 21st century technology.

The problem is money. Industrial emitters of carbon dioxide are not prepared to invest in CCS because they fear that they will be unable to recoup the investment. The costs of CCS are formidable. There is no agreement over how much it would cost to construct an integrated CCS demonstration project that captures, transports and stores carbon dioxide, and then there is the 'energy penalty' to consider. In theory, the EU's emissions trading scheme (ETS) should provide financial compensation for investment in CCS: from 2013 carbon dioxide captured and stored will not be counted as emitted under the ETS. The EU's carbon market caps the volume of carbon dioxide that heavy industry is allowed to emit and auctions emission permits to companies that need them. If utilities stored and captured carbon they would be freed from having to purchase carbon permits. But unfortunately carbon prices – around €13 per tonne in February 2010 – are too weak to provide sufficient financial incentives to invest in low-carbon technologies, such as CCS, and are likely to remain so for several years.

The construction of large demonstration projects will therefore require a lot of public financial support. The EU wants ten to 12 large-scale CCS demonstration projects to be in operation across the EU by 2015 and has made two sources of funding available for this purpose. First, in 2008 the European Commission set aside €1 billion from the EU's European Economic Recovery Plan (EERP), and has since allocated this to six CCS projects spread across the different member-states. Second, the revenues from the sale of 300

million emissions permits under the ETS will be put into the so-called New Entrant Reserve (NER) and used to fund investment in low carbon energy sources.[2] Unfortunately, the money from the EERP (even taking into account the need for member-states to provide matching funds) will not be enough to get the demonstration projects off the ground. And it is unclear how much money from the NER will be available for CCS because of uncertainty over the level of carbon prices. The UK government wants to introduce levies on electricity suppliers in order to help finance investment in CCS, but there appears little appetite for such an approach among other EU governments.

[2] The New Entrant Reserve comprises emissions allowances which have been set aside for new entrants to the EU ETS.

The mass deployment of CCS will also need a clear regulatory signal. Without it, energy companies will instead invest in new conventional coal-fired power plants, or in more gas-fired generating capacity – which is less environmentally polluting than coal generation without CCS, but worse than coal with CCS. Unfortunately, the EU has not agreed a date after which all generators and intensive industrial users of fossil fuels will be required to incorporate CCS technology. The EU's 2009 Carbon Dioxide Geological Storage Directive does not make CCS mandatory; it simply requires member-states to ensure that the carbon can be legally and safely stored.[3]

[3] Directive 2009/31/EC of the European Parliament and of the European Council on the geological storage of carbon dioxide, European Commission, April 2009.

CCS must be a top priority for the new European Commission that took office in February 2010. The new commissioner for climate change, Connie Hedegaard, has primary responsibility for ensuring that the EU meets its emissions targets, and that the ETS functions effectively. The new energy commissioner, Günther Oettinger, has responsibility for bringing about the decarbonisation of EU energy supplies, while Janusz Potocnik, the environment commissioner, is charged with promoting eco-innovation and the adoption of new environmental technologies. All three commissioners and the

Commission president, José Manuel Barroso, must work closely together to ensure that CCS is demonstrated and deployed as fast as possible. The time for debate about which low-carbon technology is 'best' has passed. The EU needs to accept that in order to reduce carbon emissions far enough and fast enough to meet its targets, it will have to support a range of low-carbon technologies.

Chapter two of this report discusses the technology of CCS and the practical (as opposed to financial) obstacles to its use. Chapter three reviews what steps governments outside the EU are taking to accelerate the take-up of CCS, while the fourth chapter contrasts this with what EU governments are doing. Chapter five lays out the EU's current strategy for CCS and assesses its chances of success. The final chapter makes a series of recommendations to the EU. The report concludes that CCS is an invaluable bridge technology until countries can rely fully on renewables, but that much more needs to be done in the EU to secure its mass deployment.

2 The technology

The impact of CCS on carbon emissions

Carbon capture and storage will not make coal a fully sustainable fuel source, so the label 'clean coal' is not strictly accurate. But CCS has the potential to make coal a low-carbon fuel source. For example, according to the UK Energy Research Centre (a publicly-funded research institute looking at sustainable energy), a conventional coal plant releases 950 grams of carbon dioxide per kilowatt-hour of electricity generated. The same plant fitted with CCS would emit between 50 and 90 grams per kilowatt-hour. By way of comparison, a typical gas-fired power station produces 400 grams of CO_2 for every kilowatt-hour generated; a nuclear plant 120 grams; and a solar plant 110 grams. Only wind power does better than a coal plant incorporating CCS technology, producing just 25 grams per kilowatt-hour.

CCS is also required to reduce emissions from industrial sectors, such as the cement and petrochemicals industries. The International Energy Agency (IEA) announced in December 2009 that the cement sector could reduce its emissions by 18 per cent by 2050 (compared with the current level) by incorporating CCS and increasing the efficiency with which plants use energy. The IEA estimated that 20-33 per cent of the world's existing cement kilns will be replaced before 2020, rising to 40-45 per cent by 2050.[4] However, energy-intensive sectors such as cement and petrochemicals raise legitimate concerns about 'carbon leakage'. This refers to the relocation of industries from countries with tight environmental standards to those with lax ones. For example, if EU regulations requiring industrial plants to incorporate CCS

[4] Michael Taylor, 'Cement scenarios for 2030-2050: Energy technology perspectives', International Energy Agency, 2009.

technology were not replicated elsewhere, there would be a risk that industrial capacity would move from the EU to China or other emerging economies.

The currently available carbon capture technologies can be divided into three categories:

★ **Pre-combustion.** This approach involves capturing the carbon dioxide before the fuel is ignited and burning the remaining hydrogen-rich gas to produce power. The technology should reduce carbon emissions by 90 per cent. It is widely used in the production of fertiliser and hydrogen, and can be employed with 'integrated gasification combined cycle' (IGCC) power generation, which works by converting coal into gas. However, pre-combustion technology cannot be retrofitted to existing power stations.

★ **Oxyfuel.** This approach captures carbon dioxide during the combustion process. Prior to combustion air is separated into nitrogen and oxygen. Fuel is then burned in the oxygen, producing carbon dioxide and water vapour, which can easily be separated. This process should enable up to 90 per cent of the carbon dioxide emissions to be captured, although the initial process of separating the oxygen from air demands a lot of energy. The technology can be retrofitted to existing plants, whereas pre-combustion CCS cannot. The largest demonstration facilities operating in the EU use oxyfuel technology: a 40 megawatt test facility in Scotland, a 30 megawatt retrofitted gas plant in France and a 30 megawatt retrofitted coal plant in Germany.

★ **Post-combustion.** This technology is well understood and is already used in other industrial applications, though not at the level required for a large commercial power plant. It involves capturing the carbon dioxide after the fuel has been burnt. Post-combustion CCS can be added to existing coal or gas-fired power stations, but unlike the pre-combustion and oxyfuel approaches it does not necessarily cover the entire capacity of the plant.

All three technologies must be demonstrated at scale in order to assess which deliver the greatest climate benefits and which are most cost-effective. Oxyfuel is very promising because it can be fitted to existing plants. But it would be premature to focus all public subsidies for CCS on this technology, not least because its energy demands could reduce its attractiveness, especially in developing countries. Post-combustion technologies also need to be demonstrated: the rapid reduction of carbon emissions will require retrofitting coal plants in China, India and other developing economies, as well as in the developed world.

Transport and storage

Carbon dioxide must be transported from the power plant (or industrial facility) to a site where it can be safely stored underground. The most obvious answer to the transportation question is to move the gas by pipeline. This is a proven technology: it has been used since the 1970s to transport carbon dioxide in oil fields where it is used to enhance oil recovery. For example, the 225 kilometre Canyon Reef Carriers Pipeline in Texas has been in operation since 1972, and there are now approximately 5,800 kilometres of CO_2 pipeline in use across the United States. Carbon dioxide could also be moved by ship, in much the same way that liquefied natural gas is transported, although transporting large volumes by sea is likely to be much more costly than using pipelines, and would increase marine tanker traffic and hence emissions. CO_2 could also be carried by rail or road tankers, but this would be unlikely to be suitable for large-scale transportation for safety, cost and environmental reasons.

The need to identify secure ways to store the huge amount of carbon dioxide produced during the burning of coal or gas

arguably presents a bigger challenge than capturing it. Depleted oil and gas fields are one obvious option. As already mentioned, the Americans have been doing this since 1972, and the Norwegians started to do so in 1996. The Norwegians extract carbon dioxide from natural gas – they need to do this since Norwegian gas has a much higher CO_2 content than customers would accept – and then pump it into an aquifer. Since the natural gas stayed in these fields for millions of years, there is no obvious reason why carbon dioxide cannot also be stored in them for a very long time. The Intergovernmental Panel on Climate Change (IPCC) concludes that "the fraction [of carbon dioxide] retained in appropriately selected and managed geological reservoirs is very likely to be 99 per cent over 100 years and to exceed 99 per cent over 1,000 years."[5]

[5] Edward S. Rubin, 'Report on carbon dioxide and storage', IPCC, 2005.

The pumping of carbon dioxide into oil and gas fields reduces the net cost of storage because it leads to enhanced oil or gas recovery. However, it could also reduce the climate benefit if it leads to more fossil fuels being readily available from known and accessible fields, thus reducing pressure on governments to expand the use of renewable energy. Nevertheless, while oil and gas are being used – which they will be for the next three decades at least – it is better for the environment to extract oil from the North Sea than it is from the Canadian tar sands. It is also better in terms of energy security for the EU to use North Sea gas than, for example, to import more gas from Russia.

The obvious drawback with relying exclusively on offshore oil and gas fields to store carbon dioxide is that they are not evenly distributed around Europe. An elaborate pipeline infrastructure would be needed to connect the sources of carbon dioxide with the storage sites. Such a network would be costly to construct and would doubtless generate considerable opposition from affected communities. CO_2 can also be stored in fresh or salt-water underground aquifers, which are better distributed and have significantly greater storage capacity than oil and gas fields. The

storage of carbon dioxide in saline aquifers should be demonstrated on a large scale, particularly since these are likely to be the best option for storing the CO_2 from Chinese power stations. The Norwegians already capture carbon dioxide from the Snøhvit and Sleipner gas fields and store it in saline aquifers. By contrast, fresh water aquifers offer less potential as storage sites, as they are important sources of drinking water and used for irrigation, and are in any case being rapidly depleted in many countries.

Other storage options are also problematic. There is strong popular opposition in many EU countries to storing carbon dioxide underground in old onshore gas fields and coal mines. Carbon dioxide is not toxic, but it is heavier than air, so leakage carries the risk of suffocation. In March 2009, a Dutch council objected to Shell's plans to store CO_2 in depleted gas fields under the town of Barendrecht, near Rotterdam, following strong local opposition. In November 2009, the national government overruled the council, and announced that the project would be allowed to proceed, but only on the condition that strict safety conditions are met. There is also strong popular opposition to onshore storage of CO_2 in Germany. The carbon dioxide from the oxyfuel demonstration plant operated by Vattenfall in eastern Germany was to be stored in an old onshore gas field, but is now simply being released in the atmosphere.

The storage sites for carbon dioxide will need to be monitored accurately over very long periods of time. In order to demonstrate compliance with emissions reductions targets, and to maintain public support for CCS, there will have to be rigorous verification of the amounts of carbon dioxide being stored, plus regular testing for possible leakages.

3 Policy and practice outside the EU

The EU is far from being the global leader when it comes to the demonstration and deployment of CCS. As noted in the previous chapter, the US has been using carbon dioxide to enhance oil recovery for over 30 years, and Norway has been actively using CCS for 15 years. Indeed, carbon capture and storage is now being promoted all over the world: major economies such as China, the US, Canada and Australia are developing large demonstration plants with the benefit of substantial public subsidies. This is good news. It is unavoidable that coal will be burnt, so it is crucial that it is burnt in a way that limits the damage to the environment. But it is less good news for European businesses that hope to become world leaders in this technology. Unless Europe gets its act together it risks getting left behind.

The United States

The US is home to a quarter of the world's known coal reserves, and relies on coal for half of its electricity. Had the country ratified the UN's Kyoto protocol, its target would have been a 7 per cent reduction in emissions of greenhouse gases from their 1990 levels by 2012. By 2007, US emissions had risen by 17 per cent compared with 1990. The country will struggle to bring about rapid reductions in its emissions without the mass deployment of CCS.

During President George W Bush's second term of office, the US Department of Energy started a Regional Carbon Sequestration Partnership (RCSP). This is a joint government/industry initiative charged with determining the most suitable CCS technologies, and the regulations and infrastructure needed to bring about the

take-up of CCS in different parts of the country. Local variations in the use of fossil fuels and the distribution of potential storage sites across the United States mean that such a regional approach makes sense.

The incoming Obama administration moved quickly to provide more money for carbon capture and storage. The federal government allocated $2.4 billion (€1.8 billion) to CCS under the American Recovery and Reinvestment Act (ARRA), the economic stimulus package introduced in February 2009. This money is intended to promote the use of CCS in industrial plants and in the energy sector. The government has also made available an additional $2.3bn in tax credits to manufacturers of clean energy equipment. This covers not only CCS but also fuel cells, batteries, electric cars, advanced grid systems, solar, wind and other energy conservation technologies. In addition, the US also intends to set aside substantial funds – the bill before the senate proposes $1.1 billion a year – from the sale of carbon permits under a future federal emissions trading scheme for the research and development of CCS.

The American authorities have also made progress in selecting specific CCS schemes to spend money on. In July 2009, a project called the FutureGen Alliance, a public-private partnership, was awarded $1 billion from ARRA funds. FutureGen will now construct a 275 megawatt pre-combustion coal plant in Illinois. The private sector members of the Alliance have agreed to contribute $400-600 million. Hydrogen Energy International, a joint venture between BP and Rio Tinto, plans to build a 250 megawatt pre-combustion CCS plant in California. The estimated cost of the project is $2.3 billion: the Californian government has awarded $30 million and the Department of Energy $308 million. The carbon dioxide will be piped to local oil fields and used to enhance recovery, and the plant is due to enter operation in 2016. The Department of Energy has also provided $100 million to retrofit post-combustion technology to a 120 megawatt coal power station in North Dakota, which is due for completion in 2011.

In December 2009, the Energy Secretary, Steven Chu, also announced further awards totalling $1 billion to three more power stations to incorporate either pre- or post-combustion CCS. He also awarded $22 million each to 12 industrial facilities (such as cement and chemical plants, as well as major manufacturing facilities) to help finance the adoption of CCS technology.

Canada

Canada's Kyoto target is for a 6 per cent reduction in greenhouse gases by 2012. The country has no chance of meeting this target: by 2007 greenhouse emissions had increased by 55 per cent compared with 1990. Much of this rise reflected the impact of changes in land-use, such as the cultivation of more land for agriculture, and rising emissions from road transport, rather than from increased electricity generation.

Over half of Canadian electricity is produced by hydroelectric schemes; only 17 per cent is accounted for by coal and just 5 per cent by gas. Nevertheless, the Canadian government and private sector are investing heavily in CCS. Canada's Economic Action Plan, introduced in the aftermath of the financial crisis, created a C$1billion (€683 million) Clean Energy Fund. The government of the state of Alberta has also established a C$2 billion fund to support CCS.

Both Canada's federal and state governments have moved quickly to allocate the funds. TransAlta (a Canadian energy company) and Alstom (a French transport and energy conglomerate) will build a new coal-fired power station in Alberta, and then 'retrofit' post-combustion CCS. (They will build a new plant first and then fit post-combustion CCS, rather than retrofit the technology to an existing plant.) Some of the CO_2 will be used to enhance oil recovery while the remainder will be stored in saline aquifers. The Canadian government has awarded C$343 million (€233 million) to the project, while the government of Alberta has invested C$436 million.

In another scheme in Alberta, Shell, Chevron and Marathon Oil Sands will use CCS to reduce emissions from an existing plant to turn oil sands into petroleum. Around 40 per cent of the emissions will be captured and transported by pipeline to a nearby fresh water aquifer. The federal and Alberta governments announced in October 2009 that they would provide a total of C$865 million in public subsidy to this project. Finally, in Saskatchewan, SaskPower plans to retrofit a 100 megawatt plant with post-combustion technology, and have this fully operational by 2015. The Canadian government has provided C$240 million to this project, with the private sector expected to provide the remaining C$400 million. The CO_2 will be transported to a nearby oil-field and used to enhance oil recovery.

China

China now produces more carbon dioxide annually than any other country in the world. The country accounts for 46 per cent of global production of coal, and 20 per cent of global consumption, and relies on it for almost 80 per cent of its electricity. The Chinese have considerable domestic reserves of coal and intend to use them to produce electricity. According to the International Energy Agency (IEA), Chinese coal-fired generating capacity is set to expand from 350 gigawatt in 2006 to 950 in 2030.[6]

[6] *A gigawatt is equal to a thousand megawatt.*

The Chinese authorities are very concerned about climate change, not least because of desertification in northern China and because of the vulnerability of the country's low-lying coastal regions to rising sea levels. The country is engaged in a number of international CCS projects and programmes, such as the Carbon Sequestration Leadership Forum, and Chinese companies are working closely with foreign firms on CCS schemes in China.[7] A group of investors, including the US coal company Peabody Energy, five of China's largest power companies, two Chinese coal companies and the Chinese government, is

[7] *The Carbon Sequestration Leadership Forum is an international initiative to advance carbon capture and storage technology.*

constructing GreenGen, a 250 megawatt pre-combustion CCS plant that is due for completion in 2011. There are plans to expand this to 650 megawatt by 2016.

Duke Energy, the third largest electricity producer in the US, is collaborating with the Chinese company Huaeng, which generates more than 10 per cent of the electricity consumed in China and is one of the firms behind GreenGen. Together with Duke, Huaeng is considering building a large CCS plant near Shanghai. The Australian government also worked with Huaeng to build a small post-combustion CCS demonstration plant near Beijing, which opened in July 2008.

By contrast, there is little in the way of EU-China co-operation to hasten the roll-out of CCS in China. In 2005, the EU and China agreed to build a large CCS demonstration plant in China, but the deadline for construction has been pushed steadily back, and it is not now expected to enter operation until 2020 at the earliest. Moreover, the European Commission has only agreed to provide €50 million of the estimated €550 million cost of constructing the plant. Private businesses will have to provide the rest, but have yet to commit to doing so, casting doubt on the likelihood of the plant ever being built.

Japan

Japan's Kyoto target is for a 6 per cent reduction in emissions of carbon dioxide between 1990 and 2012 – in 2007 emissions were 6 per cent up on their 1990 level. Japan may still meet the target, but only because of the severity of the country's economic recession, which has depressed energy consumption.

The country now produces three times as much electricity from burning coal as it did in 1988, but is wholly dependent on imports as it has no domestic coal reserves. A quarter of Japan's electricity is generated from coal, and a quarter from gas. The Japanese

authorities have invested heavily in R&D into CCS, including into how to store carbon dioxide in aquifers. Japanese firms such as Mitsubishi are also aiming to be world leaders in pre-combustion and oxyfuel technologies, for both coal and gas generation. A 250 megawatt coal gasification plant is operational in Japan, but the carbon is currently being released into the atmosphere rather than captured and stored. Field studies are underway to explore how it can be piped to and stored in offshore gas fields.

Australia

Australia only ratified the Kyoto treaty in 2008, following a change of government and the election of the country's Labor Party. Australia's Kyoto target is for an 8 per cent increase in emissions of greenhouse gases by 2012 (from 1990 levels), which it will meet. The prime minister, Kevin Rudd, has also set a target of a 25 per cent reduction in emissions by 2020, which poses a much stiffer challenge.

Nearly 80 per cent of Australia's electricity is generated by burning coal; a further 12 per cent is accounted for by gas. The country is working hard to foster the demonstration and deployment of CCS. The federal government has a A$500 million (€318 million) low emission technology demonstration fund, of which more than half has been allotted to four projects (the private sector has already committed to invest a total of A$1 billion in these), and an additional A$500 million has been made available through various regional programmes.

The most advanced plan is for a pre-combustion coal-fired power station called ZeroGen in Queensland. The project is supported by the state's government, the Australian Coal Association, Mitsubishi and Shell. Stage one of the scheme involves the building of an 80 megawatt coal gasification demonstration plant, with the carbon dioxide to be transported by lorry and stored in deep onshore underground geological formations. If this works as expected, the

capacity of the plant will be expanded to 300-500 megawatt. The aim is to have the plant operational by 2015.

Norway

Norway's Kyoto target is for a 1 per cent increase in emissions of carbon dioxide by 2012. By 2007 they were 11 per cent higher than in 1990, mainly due to increased road transport. The Norwegian government has set a target of making the country carbon neutral by 2030.

Norway relies for its electricity almost entirely on hydroelectric power stations. But it is the world's leader in CCS largely because it uses the technology to maximise gas extraction by pumping CO_2 into offshore gas fields. Norway has a public organisation called Gassnova, which is responsible for encouraging the take-up of CCS by the oil and gas industry as well as the electricity sector. In 1991 Norway introduced a carbon tax covering its substantial offshore oil and gas industry. The tax – levied at $50 (€37) per tonne – helped to encourage firms to store unwanted carbon dioxide under the sea bed. Firms extracting natural gas off the coast of Norway produce particularly large amounts of surplus carbon dioxide, because the gas contains far more CO_2 than is acceptable to customers. Statoil has separated and stored carbon dioxide from the Sleipner offshore gas field since 1996, while in 2007 the company began capturing the gas from the Snøhvit gas field and storing it in an offshore saline aquifer.

As a result of rising domestic demand for electricity, Norway plans to build a number of gas-fired power plants. The Norwegian government has announced that all of these new plants will be required to capture and store the carbon dioxide released through the burning of the gas. The Mongstad plant (on Norway's coast), which is due to enter operation in 2010, will burn gas to generate electricity and at the same time use the heat produced in the process for domestic heating. Another Norwegian scheme to deploy CCS is

at the existing Kårstø gas-fired power plant, one of the country's largest sources of CO_2. The Norwegian government postponed this CCS project in June 2009 because the plant had been out of operation for extensive periods since it opened in 2007. However, in its 2010 budget the government allocated Krona3.4 billion (€418 million) to CCS, which will be divided between the Mongstad and Kårstø projects.

4 Policy and practice in EU member-states

The European Commission wants ten to 12 large-scale CCS demonstration plants to be up and running by 2015. It also wants the mass deployment of carbon capture and storage by 2020 to make a major contribution to reducing EU emissions of greenhouse gases. As mentioned earlier, some EU member-states are making progress on demonstrating CCS, but only on a small scale; there are no large demonstration plants under construction anywhere in the EU. A brief survey of what individual EU countries are doing to foster the take-up of CCS illustrates that Europe is at risk of getting left behind.

United Kingdom

Britain's Kyoto target is for a 12.5 per cent reduction in emissions of greenhouses gases by 2012 (from their 1990 level). In 2007, emissions were 18 per cent below their 1990 levels, meaning the country will meet its target. The cut in UK emissions has largely stemmed from a switch away from burning coal (and oil) in favour of gas. In 1990, the UK derived 46 per cent of its electricity from coal and 10 per cent from gas. By 2008, gas accounted for 40 per cent of the total and coal for 32 per cent.

Successive British governments since the 1990s have talked up the potential of CCS, but have made little practical progress in rolling out the technology. In 2007 the government launched a competition for a substantial subsidy towards the construction of a large-scale post-combustion demonstration project. But a winner has yet to be announced, and none is expected before the country's next general election, which must be held by June 2010.

The UK's lack of urgency has led to the abandonment of many planned CCS projects, such as BP's plans to build a carbon capture and storage plant at Peterhead (Scotland) and Centrica's CCS project at Easton Grange in north-east England. This is a pity because the UK is very well placed to become a leader in the deployment of CCS: it has an established engineering base, a number of major firms with considerable experience of the relevant technologies, and a selection of available storage sites. A project to build a 900 megawatt pre-combustion coal gasification plant in Yorkshire, northern England, has been awarded €180 million EERP funding (see chapter five). However, a project of this size will require much greater public support than this, and the necessary private investment is yet to be secured.

The UK's Committee on Climate Change (CCC), which was established to advise the government on the best ways to curb the country's emissions of greenhouse gases, has argued that development of CCS must be accelerated. The CCC has called for three or four demonstration projects to be operational in the UK by 2015-16, and for the government to introduce a requirement for all coal-fired plants to incorporate CCS technology by the early 2020s. The government has accepted the CCC's proposals in principle, but has not announced a timetable for the selection of the additional demonstration plants. However, it has introduced an energy bill into Parliament, which includes a levy to raise funds from fuel consumers to finance subsidies for CCS. The opposition Conservative Party backs the bill because it favours the deployment of CCS on both climate and energy security grounds. With Conservative support, the bill may become law before the general election.

There has been some progress with small-scale projects, mainly in Scotland. In 2009, a consortium of companies including Doosan Babcock, Scottish and Southern Energy, ScottishPower, EDF, Vattenfall and E.ON opened a 40 megawatt oxyfuel test facility in Renfrew, Scotland. ScottishPower has also opened a small post-combustion CCS demonstration plant at its Longannet power

station in Fife, and it hopes to expand the capacity of this plant. Scotland's proximity to the oil and gas fields of the North Sea, and the existence of saline aquifers, make the country ideal territory for CCS. The Scottish government has published a joint industrial and academic study which concluded that all of the carbon dioxide produced by British coal-fired power stations over the next 200 years could be stored under the Scottish area of the North Sea.[8]

[8] *'Opportunities for CO_2 storage around Scotland', Proceedings of the National Academy of Sciences, 2009.*

Germany

Under the Kyoto treaty, Germany – Europe's largest emitter of greenhouse gases – must reduce its emissions by 21 per cent by 2012. By 2007 the they had fallen by 22 per cent compared with their 1990 level, although to a large extent this was the result of the closure of industrial capacity in the former-Communist eastern part of the country. Germany also has a domestic target to reduce CO_2 emissions by 40 per cent by 2020 (from 1990 levels).

Germany derived 48 per cent of its electricity from burning coal in 2006, and 12 per cent from gas. Many of the country's existing power stations use brown coal (lignite), which has a particularly high carbon content. Fortunately, the country's long-standing commitment to phase out nuclear power is now being reassessed following the formation of a centre-right government after the September 2009 election. Germany's nuclear generating capacity is 40 gigawatt, which is equivalent to around 40 large coal-fired power stations.

The previous German government – consisting of a grand coalition of the country's Christian Democrats (CDU/CSU) and Social Democrats (SPD) – promised to help finance the construction of two or three large-scale CCS demonstration plants. The country's leading energy utilities responded to this by presenting ambitious plans to invest heavily in CCS, on the assumption that the authorities would provide significant public subsidies. Unfortunately, the German

authorities have failed to make adequate money available, and a law specifying how carbon could safely and legally be stored was postponed because of the general election campaign.

In 2008, Vattenfall opened a 30 megawatt oxyfuel demonstration plant in Brandenburg, East Germany. The original aim was to bury the carbon dioxide three kilometres underground, in a depleted gas field (in the process enhancing gas recovery). But instead Vattenfall is being forced to pump the CO_2 into the atmosphere because of the absence of legislation allowing underground storage of carbon storage. There is strong domestic opposition to any change in the law, but the government supports it and Vattenfall expects to get a permit to begin storage sometime in 2010. The company has stated that it hopes to expand the capacity of this demonstration plant to 250-300 megawatt by 2015, and to 1,000 megawatt by 2020. Vattenfall has also been awarded €180 million in EERP funds for an oxyfuel CCS project in Jaenshwalde, eastern Germany.

Poland

Poland's share of the EU's Kyoto target is a 6 per cent reduction in emissions by 2012. By 2007 emissions had fallen by 29 per cent compared to 1990, largely as a result of the closure of inefficient Communist-era industry.

Poland remains highly dependent on coal, deriving 93 per cent of its electricity from it. The Polish government is supportive of CCS, not least because Poland has huge domestic reserves of coal. However, it lacks the funds to support demonstrations of CCS technology. The utility, Polska Grupa Energetyczna, has been awarded €180 million under the EU EERP to construct a post-combustion CCS at its Bełchatów power station – the biggest emitter of carbon dioxide in the EU. A second Polish energy company, Południowy Koncern Energetyczny, is planning to build a 288 megawatt pre-combustion coal-fired power station, at an estimated cost of €1.1 billion. Two thirds of the carbon dioxide would be stored over a kilometre

underground, and the rest used by the local chemical industry. This project would demonstrate pre-combustion CCS at large scale and promote combined heat and power technology.

The Netherlands

The Netherlands' Kyoto target is a 6 per cent reduction in greenhouse emissions between 1990 and 2012. By 2007 the country's emissions had fallen by 3 per cent and the target should be met. The Dutch government's 'Clean and Efficient' programme calls for a 30 per cent reduction in Dutch greenhouse gas emissions by 2020.

The Netherlands relies on coal for 27 per cent of its electricity and on gas for 58 per cent. The Dutch authorities were slow to see the potential of CCS but are now among the most active supporters of the technology in the EU. In November 2008, the Dutch government allocated €30 million each to two demonstration projects: one in the south of the country which will use the space under coal seams to store CO_2 from an ammonia plant; another – near Rotterdam – will store the gas produced by a Shell oil refinery in depleted onshore gas fields.

In March 2008, the government announced its aim to create large-scale CCS demonstration projects in the Rijnmond region (which includes Rotterdam), and set up a public-private taskforce to try to achieve this. Rotterdam is well-placed to become a hub for CCS. The city is located between possible storage sites on the continental shelf and large emitters of CO_2 in North-Western Europe. Local politicians and businesses are strongly supportive, and a demonstration of post-combustion CCS on a coal power station in Rotterdam was awarded €180 million of EERP funds in December 2009. A similar public-private partnership in the northern Netherlands also published an action plan in early 2009. The aim of this initiative is to demonstrate the full range of techniques for capturing CO_2 (pre-combustion, post-combustion and oxyfuel), as well as transport and storage.

Spain

Under the EU's Kyoto target, Spain is permitted to increase its emissions of greenhouse gases by 15 per cent by 2012. In reality, the country's emissions have ballooned and are now over 50 per cent higher than in 1990.

In 2006, 27 per cent of Spain's electricity was generated from coal (the country has substantial coal reserves), and 23 per cent from gas. The Spanish government has established a partnership with the utility Endesa to build a 30 megawatt oxyfuel pilot plant at Compostilla, north-western Spain, which is due to enter operation in 2010. Endesa hopes to expand the capacity of the plant to 500 megawatt, but it has not set a date for this. Endesa is set to fund 70 per cent of the construction costs, with the remaining 30 per cent coming from the public purse. The project at Compostilla has been allocated €180 million in EERP funds (which the Spanish government will match) but it will also need to receive NER funds if it is ever to reach full capacity.

Italy

Under the EU's Kyoto target, Italy is obliged to cut its emissions by 6.5 per cent by 2012, but by 2007 they were almost 7 per cent above 1990 levels. As a result, there is no chance the country will meet its target.

Italy has no significant fossil fuel reserves, but derives half of its electricity from gas, and a further 30 per cent from coal and oil. The current Italian government's main energy policy is to revive nuclear power; the country abandoned its nuclear power plants in the 1980s following a national referendum. Nevertheless, there is some official interest in carbon capture and storage, with the government funding R&D into the technology. Enel, the country's largest energy company, plans a post-combustion CCS demonstration project near Venice. The technology will be retrofitted to an existing coal station, and storage of the carbon dioxide will be in a saline aquifer. This

scheme was awarded €100 million under the EERP. Enel also has plans to build a 70 megawatt oxyfuel coal demonstration project, but has not announced a timetable for this.

France

France's Kyoto target is to hold emissions stable at 1990 levels; by 2007 they had fallen by 6 per cent. Almost 80 per cent of French electricity is produced by nuclear power stations, and 10.5 per cent from hydroelectric plants, with just 4.5 per cent deriving from coal and 4 per cent from gas. France has concentrated its CCS efforts on the gas-fired electricity sector. At Lacq, Total has retrofitted one of its plant's 30 megawatt gas-fired boilers with oxyfuel technology. The carbon dioxide from the plant is sent down an old pipeline that used to take natural gas from Rousse to Lacq, and injected into the depleted Rousse gas reservoir at a depth of around 4,500 metres. The Lacq project will run for two years, after which engineers will monitor the Rousse gas field to check that the carbon dioxide remains safely stored. The €60 million cost of the project is shared between the company and the French Petroleum Institute. There appears to have been little public opposition to the scheme.

5 EU performance

The EU has always been involved in coal policy. The precursor to the European Economic Community was the European Coal and Steel Community, established in 1951. The original Treaty of Rome gives Brussels substantial powers over energy policy via its market-opening provisions. The Commission has also acquired a role in energy policy through its powers to enforce anti-trust and state aid rules. The 1992 Maastricht treaty increased the EU's role in environmental policy, and gave it powers to improve cross-border energy infrastructure. The Lisbon treaty contains a specific chapter on the need to encourage new and renewable forms of energy. The result is that "Brussels has greater potential power to shape the energy market design of its member-states than Washington has over US states".[9]

[9] *David Buchan, 'Energy and climate change: Europe at the crossroads', OUP 2009.*

The EU has been funding research into CCS for the past 15 years. The Commission supported a project to demonstrate oxyfuel CCS as long ago as 1994-95, and helped finance the CASTOR (CO_2 from Capture to Storage) project. This small-scale initiative, which involved 11 member-states, focused on the technical obstacles to the use of CCS. The Commission also supported a €14 million project to inject CO_2 into a deep saline aquifer near Berlin. This started in 2004, and was scaled up significantly in 2008.

During the past three years, the EU's focus has switched from financing research into CCS to the demonstration of the technology. In March 2007, national governments agreed that ten to 12 large (meaning at least 250 megawatt) CCS demonstration plants should receive European funding and enter operation by 2015. But almost three years after the original agreement, not

nearly enough practical progress has been made. This is bad news in terms of the EU's ability to bring about big structural reductions in carbon emissions, but it also means that Europe risks losing out economically. Investment in low-carbon energy supplies could provide a strong source of economic growth and demand for skilled labour at a time when European economies will be struggling with high levels of indebtedness and intensifying international competition. A concerted drive to bring about the take-up of CCS would help European firms to develop expertise in the design, development and manufacture of the technology, and hence to capture a share of what is destined to be a huge market.

Funding

The EU has made two sources of funding available to help finance CCS demonstration projects. At its December 2008 summit, the EU announced a €200 billion European Economic Recovery Plan (EERP), aimed mainly at boosting confidence and spending following the financial crisis. Although the vast majority of this money comprises expenditure by national governments, the EU did provide some new money for longer-term objectives, such as upgrading skills and meeting the EU's environmental policy objectives. Of this additional money, €1 billion was set aside to fund CCS demonstration projects.

In December 2009, the Commission announced the six projects which will receive funding under the EERP. EU financial support is conditional on national governments providing matching funds (so-called co-financing). The requirement that the member-states match funds received from the EU is standard practice. However, co-financing could be a sticking point for some of the poorer EU governments, such as Poland, which argues that it cannot afford to provide such support.

The following five projects will receive €180 million each:

★ A 500 megawatt, pre-combustion coal-fired plant in Germany. The CO_2 will be stored in a saline aquifer.

★ Post-combustion CCS on a 250 megawatt of coal-fired plant under construction in the Netherlands. The carbon dioxide will be transported to depleted off-shore gas fields.

★ Post-combustion CCS on 250 megawatt of a coal-fired pant under construction in Poland. The CO_2 will be stored in a saline aquifer.

★ A 500 megawatt oxyfuel coal power station in Spain. The CO_2 will be stored in a saline aquifer.

★ A 900 megawatt pre-combustion coal-fired power station in Yorkshire, UK. The storage sites for the carbon dioxide are yet to be chosen.

The remaining project will receive €100 million:

★ Post-combustion CCS covering 250 megawatt of an existing coal-fired plant in Italy.

The construction of these projects would be a significant step forward in the drive to establish CCS as a viable low-carbon energy technology. They would demonstrate at large scale both pre- and post-combustion techniques as well as oxyfuel. But the funds allocated under the EERP are unlikely to be enough to ensure that any of these projects actually gets built. Even when the member-state's equivalent funding is added, the total public subsidy per plant is not enough.

The second source of EU funding will come from the EU's emissions trading scheme (ETS). In April 2009, the EU announced that the revenue from the auctioning of 300 million permits under the ETS would be placed in a so-called New Entrant Reserve (NER). Like the

EERP funds, the money distributed from the NER must be matched by member-state governments.

The Commission estimated in the summer of 2009 that the 300 million emission allowances could be worth €7 billion, but the figure is likely to be much lower than this. A total of €7 billion implies an average carbon price of €23 per tonne. At a carbon price of €13 per tonne (the level in February 2010), the NER would be worth around €4 billion. There is no guarantee that the carbon price will recover much by 2013, when the permits will be auctioned. The value of ETS allowances is not fixed: there is no floor price for carbon, and the Commission has no power to reduce the number of emissions allowances issued to the industries covered by the scheme without the unanimous consent of the member-states. The economic downturn has cut emissions of greenhouse gases and with it the carbon price. The emissions caps for the carbon market were set with reference to a forecast for economic growth (and hence emissions of greenhouse gases) that is now far too high.

However, at the beginning of February 2010, EU governments did back the Commission's proposal to ring-fence a proportion of the NER for CCS. National governments will each submit a shortlist of potential projects to the Commission, which will then together with the European Investment Bank (EIB) select eight CCS projects for financial support and an equivalent number of renewable energy schemes. Up to three projects can receive funding in any particular member-state. In order to ensure that the three principle CCS technologies are demonstrated, pre-combustion, post combustion and oxyfuel must be covered by a minimum of one and a maximum of three of the eight CCS projects. Moreover, three of the CCS schemes must demonstrate storage in oil and gas or coal fields and three in saline aquifers. This agreement came as a welcome surprise, given what had been known about the negotiating positions of the various governments ahead of the meeting. A number had argued that member-states should be allocated shares of the money according to their size,

and then be free to choose which project should receive the funds. Meanwhile, others had opposed setting aside a proportion of the NER fund for CCS.

The Commission is working on a fairly ambitious timetable for the award of the NER money. It hopes to call for proposals in the spring 2010 and to draw up a shortlist by the summer. The projects chosen for funding could then be announced in mid-2011. The Commission will allocate two-thirds of the NER to the selected projects by the end of 2011 and the final third by the end of 2013. The deadline for spending any money awarded under the first tranche would be the end of 2015, and the end of 2017 for the second tranche. As a result, the revenue from the auctioning of the final 100 million permits will not contribute to meeting the 2015 deadline for the construction of the demonstrations. Moreover, the Commission has indicated that it might postpone the auctioning of permits until 2013, having previously indicated that the process would begin in 2011. This could delay the date when money is actually made available, unless the EIB provides the money upfront, and then receives it back once the auctions have taken place.

Even if NER generates substantial sums of money for CCS and the timetable for distributing the money is kept, more public financial support for the demonstration and deployment of the technology will be required. EU governments could introduce levies on electricity suppliers in order to help finance investment in CCS. The UK is already pursuing this avenue. The Energy Bill currently being considered by its Parliament will place a levy on electricity suppliers to help fund up to four commercial-scale CCS demonstrations on coal power stations. The British government estimates that the levy could raise £9.5 billion (€10.8 billion) over the next ten years. Electricity suppliers will pass on the cost to consumers, adding an estimated 2-3 per cent to average bills. Levies have the advantage of providing secure and predictable flows of finance – a number of EU governments, notably Germany and Spain, have successfully used them to encourage investment in renewables.

Market signals and regulation

Public money is needed for the construction of CCS demonstration plants, but strong regulatory and market signals will be required to ensure mass deployment of the technology. Firms will only invest in new low-carbon technologies such as CCS if they are confident that carbon prices will be high enough to justify the cost. In early February 2010, the EU ETS carbon price stood at €13 per tonne. Although this represented an improvement on the low of €10 reached in February 2009, prices are not high enough to make such investment worthwhile.

There are cyclical and structural reasons for the current weakness of carbon prices. The cyclical reason is the decline of Europe's industrial activity, and hence energy use, since the middle of 2008. With the supply of carbon allowances fixed and emissions of carbon dioxide declining, carbon prices have inevitably fallen. The EU economy shrank by around 4 per cent in 2009. The release of carbon dioxide by industries covered by the carbon market will have declined by as much as 10 per cent. Moreover, the economic recovery will be slow to gain momentum, with economic growth (and hence energy consumption) set to remain weak for several years. In short, the EU economy will not grow anywhere near as fast between 2008 and 2020 as was assumed when the emissions caps were set, which means that emissions will be considerably lower than forecast. Economic growth is more likely to be around 1-1.5 per cent a year over the next ten years rather than the 2-2.5 per cent originally assumed by the Commission. The cumulative impact of this on emissions will be huge.

The ferocity of the economic downturn has also highlighted two underlying weaknesses in Europe's carbon market. First, the EU fixed the supply of carbon allowances until 2020. This was done for good reasons. Investors needed to be convinced that the cap on emissions would be sufficiently tight to ensure consistently high carbon prices, and that the emissions caps would not be altered under pressure from governments. However, the lack of a

mechanism to amend the emissions allocations in the light of changed economic circumstances threatens the efficacy of the scheme. The EU carbon market was created to meet specific public policy objectives – greater investment in low-carbon technologies and improved energy efficiency. If firms believe carbon prices will remain low for a prolonged period because economic growth (and hence emissions) are much weaker than anticipated, they will have a much weaker incentive to invest in new technology. In short, it matters why emissions of carbon dioxide fall. A structural fall requires investment in new technologies, such as carbon capture and storage. A cyclical fall will simply be reversed once the economy rebounds.

Second, the method of distributing the allowances is exacerbating the weakness of carbon prices. In phase two of the ETS (which runs from 2008 to 2012), the vast majority of allowances will be allocated for free. In phase three of the scheme (2013 to 2020) energy generators will have to purchase them through auctions. But auctioning will only be introduced gradually for the other industries covered by the market. The upshot is that very few businesses are actually paying to emit carbon dioxide at present. And it has become apparent that emissions will remain weaker than projected for a number of years, so businesses will be able to put off buying allowances until well into phase three. If all businesses had to pay to emit carbon dioxide now (or at least from 2013), prices would not be as weak as they are at present.

An energy tax would arguably have been a more effective way of providing an incentive for firms to invest in CCS than an emissions trading scheme. Norway's tax on offshore carbon emissions has certainly contributed to the economic viability of CCS projects in that country. Despite the Swedish government arguing that it would promote a carbon tax during its presidency of the European Council in the second half of 2009, it made little headway. And it seems unlikely that progress on the introduction of an EU carbon or energy tax will be made soon enough to make a significant contribution to

the deployment of CCS. Of course, member-states have the power to introduce their own carbon taxes. France has announced that it will do so, but it will not cover the electricity sector and so will not provide an incentive to invest in CCS.

In addition to a robust market signal, it is imperative that the EU puts in place a regulation requiring that CCS be incorporated into any new coal-fired power station or industrial plant. A report produced by a number of environmental non-governmental organisations (NGOs) including the Worldwide Fund for Nature (WWF), Bellona Europa, ClientEarth, E3G and the Green Alliance, argues that Europe could cut two-thirds of the greenhouse gases emitted by large power plants by 2020 if binding emission caps are introduced.[10] The EU's CCS directive requires the harmonisation of the member-states' regulatory frameworks for CCS, but only in regard to how the carbon should be transported and stored; the directive does not make CCS mandatory.[11] The Commission considered setting a future date for making CCS compulsory on all new power stations, but backed down in the face of opposition from national governments, who argued that such a requirement would breach the EU's subsidiarity principle.

[10] *Sina Wartmann, Piotr Jaworski, Sebastian Klaus, Catharina Beyer, 'Scenarios on the introduction of CO_2 emissions performance standards for the EU power sector', Ecofys, January 2009.*

[11] *Directive 2009/31/EC of the European Parliament and of the European Council on the geological storage of carbon dioxide, European Commission, April 2009.*

The EU is currently updating the Integrated Pollution Prevention and Control Directive (IPPC), and integrating six other, more specific directives into what will be called the Industrial Emissions Directive (IED). However, this will only cover pollutants, such as sulphur dioxide, nitrogen oxides and not emissions of greenhouse gases, such as carbon dioxide. If the EU were to include CO_2 in the IED, all new coal-fired plants would have to be built with CCS and existing plants retrofitted with CCS or closed down. The European Commission maintains that including carbon dioxide in the IED would undermine the ETS, which must remain the principle

mechanism for addressing the emissions of industrial plants. In March 2009, a group of MEPs unsuccessfully attempted to insert carbon dioxide into the proposed IED, but the European Parliament's environment committee has ruled out the inclusion of any further amendments before the second parliamentary reading of the draft in March.

If the IED does not set maximum CO_2 limits for power stations and other industrial plants, an alternative would be for national EU governments to set their own limits. However, under the proposed directive, member-states would be prevented from doing so. The Commission justifies its opposition on the grounds that it would distort competition between energy providers in different European countries. However, it is unclear whether this is legal. For example, the WWF has argued that it is inconsistent with article 176 of the Treaty of Rome, which allows member-states to take "more stringent" environmental protection measures as long as these are compatible with the treaty.

6 Recommendations

Carbon capture and storage is not an untried, speculative technology. There is no doubt that it works. The problem is that it is very costly, and that it will not be deployed in the absence of substantial public subsidy. The EU needs to do a host of things if it is to meet its target of ten to 12 large CCS demonstration plants being in operation by 2015, and bring about the mass deployment of the technology by 2020:

★ The demonstration plants must cover the portfolio of potential CCS technologies.

★ Market incentives must be strong enough.

★ EU money must be used efficiently and there must be no delay in making funds available.

★ CCS needs to be mandatory by a specified time.

★ There should be geographical clusters of CCS projects.

★ There must be full knowledge-sharing between all of the projects.

(i) **Technology:** The six projects that have already been selected for funding under the EERP provide a good mix of CCS technologies: pre-combustion, oxyfuel and post-combustion, with storage in oil and gas fields and in saline aquifers. However, none of the projects allocated EERP funds are gas-fired plants. Gas is less damaging to the climate than coal, but still produces significant amounts of carbon dioxide. A gas-fired power station emits only 40 per cent as

much carbon dioxide as a conventional coal-fired power station, but at least four times as much as a coal plant fitted with CCS. Another 'dash for gas' would not produce the almost complete decarbonisation of the EU's electricity sector that is needed. Some of the ETS's New Entrant Reserve (NER) should be used to promote the use of CCS in gas-fired industrial facilities.

The EU's agreement reached in February 2010 was positive for a number of reasons: any project receiving NER funds will have to implement the full CCS chain (capture, transport, storage), and have a capacity of at least 250 megawatt whether it is pre-combustion, post-combustion or oxyfuel; the Commission will retain responsibility for ensuring that the full range of potential CCS technologies are allocated funds from the NER; the member-states will submit shortlists of projects, and the Commission will then decide which will receive funding in conjunction with the EIB. The Commission has performed well in selecting six EERP projects, while the participation of the EIB would inject rigour and impartiality into the process. The inclusion of the EIB has the additional advantage that it could make the NER funds available immediately, without waiting for the revenue from the emission allowances to be auctioned.

(ii) **Stronger market signals:** Public subsidy alone will not be enough to secure the take-off of CCS. Carbon prices will need to rise quickly if the ETS is to provide sufficiently strong market incentives to encourage private sector investment in the technology. Given the poor outlook for the EU economy, the Commission may have to intervene in the carbon market to ensure this happens. One argument against intervention is essentially ideological, that it would interfere with the working of the market. Another argument is that intervention would create uncertainty: investors would come to fear that the Commission would interfere in the market whenever it was unhappy about the price of carbon. Both fears are exaggerated. The carbon market, like many others, is the product of regulation, so altering the

framework for that regulation in the light of changed circumstances should not be considered problematic.

The Commission should tighten the ETS's post-2020 (phase four) emissions cap, which is not yet set in stone. Given that emitters can retain allowances from phases two and three (2008-12 and 2013-20) of the scheme for use in phase four, reducing the number of allowances available in the post-2020 period would help to prevent further falls in carbon prices. But this alone will not be enough to ensure that prices rise rapidly. The Commission should also announce that from 2013 auctions will be subject to minimum carbon prices of €30 per tonne. Those allowances that do not meet the reserve price would then be withdrawn from the market. Such a move would increase carbon prices and reassure firms that prices will remain high enough to warrant investment in CCS.

(iii) **Public money:** There needs to be greater certainty about the scale and timing of public funding. Even including matching funds from EU governments, the EERP money of €180 million per project will not be enough to guarantee that they get built. The February 2010 agreement states that projects which have received EERP funds should not be given precedence when it comes to allocating money from the NER. This is a mistake. In order to prevent EU money from being spread too thinly, the Commission should give priority to projects chosen under EERP when distributing NER funds, so long as this does not exclude more advanced schemes.

There must be no delay in making the NER funds available, and the EU needs to set a deadline of the end of 2015 for it to be spent. The Commission has said that it aims to make NER awards in mid-2011. All EU institutions must ensure that the Commission's timetable for doing this is met, so that in the spring of 2010 the Commission can call for proposals from national governments, and make the awards by the middle of 2011. The second tranche of NER funds should be made available in 2012, rather than in 2013 as currently planned. Making extra money available only in 2013

would make it unlikely that the ten to 12 plants would be operational by 2015. Finally, the EIB also needs to make the NER funds available in advance of the auctioning of permits, in order to prevent a prolonged delay in the funds being awarded. A mechanism could be put in place to allow the EIB to claw back the money if a project failed to get the go-ahead.

However, even if the Commission persuades EU governments to set a minimum carbon price of €30 per tonne and makes sure that substantial funds are made available under the NER for investment in CCS, much more public support will still be required. With most EU governments facing acute fiscal pressures, there is scant chance of them finding additional funds from state coffers. Instead, they should introduce levies on electricity suppliers and use the revenues to help finance investment in CCS.

(**iv**) **Deployment:** In addition to substantial public subsidy, a much stronger regulatory signal is required. The EU's 2009 CCS Directive on the storage of carbon dioxide does not make CCS mandatory; it simply includes regulations to ensure that the carbon is safely stored. Once CCS has been proven on a large scale, coal and gas-fired industrial plants should be required to retrofit CCS or to close down. The Commission was wrong to rule out including carbon dioxide in the EU's forthcoming Industrial Emissions Directive (IED). Its argument that the inclusion of CO_2 in the IED would undermine the effectiveness of the carbon market is unconvincing. First, it is far from clear that the ETS will work as desired; in the absence of intervention in the market it is just as likely that carbon prices will remain too low to have any impact on investment in CCS. Second, it is unclear why setting emissions standards for industrial plants would undermine the ETS, whereas the EU's existing targets for renewable electricity apparently do not. The Commission's opposition to member-states going it alone and setting more stringent emissions standards for industrial plants on the grounds that it would distort competition is similarly problematic. It makes no sense that California has the right to set an Emissions

Performance Standard but an individual EU member-state does not. EU governments need to challenge the legality of this.

(**v**) **Clusters:** The need to allocate money fairly between member-states must not mean that the advantages of connecting CCS demonstration projects in clusters get overlooked. The creation of such clusters would reduce the unit cost of constructing each plant as well as the cost of transporting the carbon dioxide. One obvious location for such a cluster is Rotterdam, which is situated between major sources of CO_2 in the Netherlands and Germany, and the depleted oil and gas fields and saline aquifers of the North Sea. The Rotterdam Climate Initiative (RCI) estimates that the cost of constructing and operating the network of pipelines needed to connect a cluster of plants fitted with CCS technology with the storage sites (along with the monitoring of the storage sites themselves) would be anything between €13 and €38 per tonne of carbon stored.

The governments surrounding the North Sea and the European Commission should also promote the idea of a broader CCS cluster spanning the North Sea. This would involve the construction of a network of pipelines to transport carbon dioxide to depleted oil and gas fields and saline aquifers. Such cross-border co-operation is essential in order to lower costs and make the most rational use of potential storage sites. The North Sea would be turned from a source of oil and gas into a location for carbon storage, in the process safeguarding employment in the off-shore oil and gas industry. All the relevant governments have voiced support for the initiative (although none has yet committed to providing any financial backing). However, the Commission has not yet decided whether to support the proposal, simply stating that it will give it consideration during 2010. The Commission should state immediately that it backs the establishment of a North Sea hub, and work with the relevant governments to identify the necessary finance.

(**vi**) **Knowledge sharing:** The EU's CCS demonstration programme will only fulfil its potential if there is adequate knowledge sharing

between all the projects receiving EU funds. There is no justification for restrictions on the sharing of experience gained through the participation in publicly-funded demonstrations. The exchange of knowledge on environmental performance, cost and public health issues must therefore be made a condition of any project receiving EERP or NER money.

7 Conclusion

Carbon capture and storage (CCS) does not convert coal into a renewable energy. Coal will never be entirely clean, since some carbon dioxide and other air pollutants will still be emitted. But a coal-fired power station incorporating CCS technology produces only around 10 per cent of the carbon dioxide emitted by a conventional coal-fired power plant, and only a quarter as much as a conventional gas-fired power station. As such, CCS (like nuclear power) must be regarded as an essential bridge technology until that time when countries are able to rely fully on renewable sources of energy. The ultimate aim must be for all energy to be generated renewably. But it will be a long time before the world can feasibly rely 100 per cent on renewables for electricity, heat and transport. The roll-out of CCS would not be a retrograde step environmentally. Moreover, it would increase the EU's energy security by reducing the need to import gas from politically unreliable countries.

Companies will not build large-scale CCS plants unless governments provide substantial public support; there is just too much uncertainty over the cost of construction and some doubt over whether the public will accept the use of such a technology. Unfortunately, individual EU member-states have done far too little to bring about the demonstration of CCS, let alone its deployment. As a result, Europe is getting left behind. Public funding for the demonstration of CCS is insufficient and uncertain, while the long-term financial and regulatory framework needed to ensure mass roll-out has not been put in place.

The European Commission has accepted that large demonstration projects will require public money, but the sums so far agreed compare unfavourably with the amount of support provided by the

US government, and proportionally, by a number of other industrialised countries. Rapid demonstration and deployment of CCS must therefore be a top priority for the new Commission. To make significant progress and meet its target of having ten to 12 large scale demonstration plants operational by 2015, the EU must make sure that there is no delay in making funds available and that these are not spread too thinly. For their part, member-state governments will not only need to match the EU's contribution, but also provide very substantial additional funds.

The EU must also ensure that it moves as rapidly as possible from demonstration to widespread deployment. This will require further public financial support. But it will also require a strong market signal. The carbon price set by the EU's ETS must be much higher. The European Commission needs to intervene in the ETS to establish a floor price for carbon and to lower the volume of emissions permits by cutting the emissions caps for phase four of the scheme, which starts in 2020. As soon as the technology is proven at scale, the EU will have to set a date by which CCS will become mandatory for new and existing plants. Without it, there is a risk that energy companies will build conventional power stations or more gas-fired power plants – which is better in carbon terms than coal without CCS, but worse than coal with CCS. In the absence of EU-wide regulation requiring the use of CCS, member-state governments should push ahead with their own national rules.

On current trends, CCS will be slow to take off in the EU. As a result, the EU will struggle to assume leadership of this crucial new technology. The rest of the world is not standing still. China, the US, Canada and Australia are all now actively pursuing CCS, making substantial public funds available, and the new Japanese government plans to do the same. The potential prize is considerable – a huge global market for equipment and expertise. But if Europe wants to secure business benefits, it will have to move fast.

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CARBON CAPTURE AND STORAGE
What the EU needs to do

Stephen Tindale with Simon Tilford

Coal will be the biggest single source of electricity for decades to come. Yet the EU is doing far too little to encourage the take-up of carbon capture and storage, a technology which could make coal a low-carbon fuel. This failure threatens not only Europe's leadership of global climate change policy but also its ability to profit from the emergence of a huge global market for equipment and expertise. Stephen Tindale and Simon Tilford argue that more public money is needed for the construction of demonstration projects, while regulation and strong market signals will be required to ensure mass deployment of the technology.

Stephen Tindale is the co-founder of Climate Answers and **Simon Tilford** is chief economist at the Centre for European Reform.

ISBN 978 1 901229 95 0 ★ £10/€16