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Abstract

Geological and ocean sequestration of carbon dioxide is a potential climate change mitigation option that is currently receiving an increasing level of attention within business, academic and policy communities. This paper presents a preliminary investigation of likely public reactions to the technologies under consideration. Using a focus group approach we consider the likely similarities between carbon storage technologies and analogous technologies that have generated strong reactions with the public. Initial results suggest that, in principle, carbon capture and storage may be seen as an acceptable approach as a bridging policy while other options are developed. However, concerns were raised regarding the safety of storage and trust in the ability of the various institutions to oversee the process in the long term. This analysis forms part of an on-going study which will continue to investigate the perceptions of a range of stakeholders.

Introduction

Options to store carbon dioxide in geological formations or in the deep oceans, are now receiving increasing attention from policy makers, industry and the scientific and engineering communities (Fujioka *et al.*, 1997; Grimston *et al.*, 2001; Herzog *et al.*, 1996; IEA GHG, 2000, 2001; Rau and Caldeira, 1999; Stevens & Gale, 2000). Attention from the NGO community is beginning to grow but the idea has barely entered the sphere of public debate (Lenstra & Engelenburg, 2000, ABC Environment News, 2001). The exception to this is perhaps deep ocean storage which has provoked significant opposition (Johnston *et al.* 1999; CNN, 1999), including the formation of the 'Coalition against CO₂ dumping' which is campaigning against ocean storage testing in the Pacific ocean.

The underlying principle is that CO₂ can be removed from fossil fuel combustion processes from where it is transported to a suitable storage site at which it can be stored potentially for many thousands of years. Storage sites include off-shore (and on-shore) geological reservoirs, such as depleted oil and gas fields and saline aquifers under the sea-bed; schemes to inject CO₂ directly into deep oceans have also been explored. The attractiveness of the option arises from the fact that such storage of carbon dioxide has the potential to permit continued use of fossil fuels whilst avoiding the risk of anthropogenic climate change. There are some major technical hurdles to overcome before the option can become cost-effective. The most significant of these is the capture of CO₂ from power station flue gases or combustion processes; however, the industry appears confident that technological innovation will bring down these costs.

Biological carbon sequestration – locking up CO₂ in forests and soils – has already received considerable attention and features in the Kyoto Protocol (IPCC, 2000). Geological sequestration, despite its potential for removing vastly more CO₂ from the atmosphere than biological sequestration, has received significantly less exposure to date. It is an opportune time, therefore, to investigate the potential public perceptions of physical carbon storage. Strong public opposition, and / or negative public perceptions which can be mobilised by organisations opposed to the principle of physical carbon storage, could very easily 'kill-off' the approach without the opportunity for open and calm debate over the relative desirability of this technology as part of a decarbonisation strategy. The effect of negative public perceptions has had profound effects upon the introduction of other new technologies - in particular Genetically Modified Organisms (GMOs) - as well as upon the viability of existing technological options - for example the introduction of new waste incinerators with

energy recovery or the sinking of the Brent Spa oil platform in the North Sea. A better understanding of public perceptions at an early stage, particularly before any political decisions are taken will, in our view, assist in the cultivation of a more robust public debate than witnessed with many recent technological changes.

Methodology

This study is part of a broader process in which we are exploring the issues surrounding various carbon sequestration options. This paper documents some preliminary research eliciting the views of a small sample of non-experts to the field.

We have adopted a focus group methodology which we considered to be appropriate in the context of such a new issue as carbon storage in which it is imperative that we understand *why* certain viewpoints are entertained (Burgess, et al., 1988, Harrison et al. 1996, Greenbaun, 1998, Krueger, 1998). A group discussion also allows individuals to interact and respond to one another - this is a useful feature when a new issue is being discussed because it stimulates mutual and creative exploration and analysis. We held two focus groups, the first of which consisted of 10 masters-level students from a Management School, and hence have a background in critical analysis, but not in environmental studies. They were all male and mostly in their mid 20s. Some of the MSc students had a first degree in engineering, and consequently had some quite specific technical frameworks available for assessing carbon sequestration. The second group consisted of 9 individuals, 7 of whom were male, and mostly in their late-20s to mid-30s (range from 20 to 35). None had degrees in science subjects and their occupations were generally public service (e.g. teacher, policeman), self-employed or working in a managerial role in small firms (e.g. wholesale carpet business, video editing).

The focus groups began with a brief discussion regarding global climate change and the role that anthropogenic carbon emissions played in these changes. The discussion then moved on to debate whether carbon dioxide sequestration techniques were realistic policy options that should be explored more thoroughly. The groups then proceeded to attempt to expose possible public reactions to the proposed technologies. This discussion was initiated with the introduction of some examples of recent issues that have excited controversy with the aim of exploring their accuracy and relevance as potential analogues to carbon storage. The important role that the media would play in portraying and framing the issue and the consequences that this may have in determining the level of acceptance or opposition amongst the general public was also addressed.

The focus groups then moved to discuss the individual storage and disposal options, in order to ascertain whether initial levels of support and opposition varied with regard to the various options. There was then an attempt to determine why different storage solutions produced different reactions and perceptions among participants within the groups. The groups concluded by discussing some of the institutional and legal considerations that would need to be addressed in order to ensure that the integrity of sequestered CO₂ could be guaranteed for a suitable length of time.

The first focus group proved to be the most productive group in terms of the range of issues raised by the participants and the resulting discussion that emerged from these initial observations. The debate was spontaneous and lively, requiring little prompting from the moderator beyond ensuring it remained relevant to the topic and broadly followed a pre-determined list of issues. The level of interest and knowledge displayed by the first group is unlikely to be reflective of the general public at large but it does provide a useful first indication of how carbon storage policies might be perceived.

The second focus group proved more problematic than the first. This may have been in part because it was conducted in a less formal surrounding (in the moderator's own home), and the moderator was familiar with all the participants of the group. Another factor may have been that the composition of the second group differed markedly from the first. Participants generally had less scientific training than the members of the first group, with the result that there was less initial familiarity with the nature of the topic. The effects of these factors was compounded by the fact that the second focus group was held the day following the terrorist attack on the World Trade Centre (11/9/01), which meant that the minds of many of the participants were preoccupied.

The combined effect of these factors was that the role of moderator was much more demanding than in the previous group. The fact that the group did not have a scientific background meant that participants were not as forthcoming with opinions as the first group had been. This potential problem was overcome by implementing a more structured question route than had been required for the first group; this ensured that a full range of issues was discussed. There was also a requirement to address questions to individual participants to maintain the group discussion and to ensure that a range of views from the full complement of the group was received.

As a preliminary study within a broader programme of research, certain features should be born in mind when considering the results presented here. Each group met only once and, given that all the individuals concerned were unfamiliar with the topic, it is likely that participants either thought of new issues after the meeting had concluded, or that positions and viewpoints expressed within the groups might change after a period of reflection. However this research was primarily concerned with initial perceptions and the identification of some of the issues that might affect the social acceptability of carbon storage as an approach to climate change mitigation.

Focus Group Findings

Each of the following sections is designed to convey the major opinions and perceptions of the issues that were raised and include relevant direct quotations taken from participants in the discussion groups. At the end of each section there is a brief reiteration of the major points covered.

Carbon Sequestration Viability

On the whole, both groups were in agreement that global warming was a problem and that it was at least partly due to the industrial activities of humankind over the last century and a half. Only one member of the first focus group was not convinced by these claims, contending that the earth was currently in an interglacial period and that the changes in temperature were therefore predominantly a natural phenomenon.

On the subject of whether carbon sequestration and storage should be considered as a potential solution to the problem, or whether it was merely an unacceptable proposed technical fix to a problem, there was reasonable agreement that the proposals would, in principle, attract little public opposition:

Researcher Is it an acceptable solution, not merely a technical fix?

Paul It is a technical fix though.

Researcher Would it be rejected by the public on the grounds that it was a technical fix?

Alan On the grounds that the public can keep running their cars and get their electricity cheap it will be accepted.

Paul It's not a contentious issue, like, to take another scientific example, GM foods; there's not the same type of animosity towards it.

(exchange in group 1)

Both groups in general gave the overall impression that the potential dangers caused by global climate change, and the role that was played in this by anthropogenic carbon emissions, was such that carbon storage should at least be investigated as a possible solution to ameliorate the effects of global warming. However concerns were raised that levels of acceptability and opposition may vary between locations and the different methods of storage and disposal:

Steve The public in Germany are really well informed. They'll be like, 'oh no, they're dumping things in the sea'.

(group 1)

The groups were then asked about what other methods could be used to tackle the problem of carbon dioxide reduction. One of the participants in the second group suggested a reduction in deforestation and a move towards a policy of reforestation, a proposal that was met with widespread approval within the group. Given the levels of anthropogenic emissions and the relatively limited potential for biological sequestration (Royal Society, 2001), this indicates a certain lack of appreciation of the scale of the problem

There were a number of differences in perceptions of the viability of the process of capturing and storing CO₂ between the two groups. The second, less scientifically educated group, were content to accept the process was effective. The first group had a number of concerns regarding the effectiveness and potential dangers inherent in the process:

Tim Is it pure CO₂ or does it contain pollutants. Is it safe to put those underground?

Paul What percentage of the CO₂ will be captured in the power stations?

(exchange in group 1)

Renewable Sources and Energy Efficiency

One of the major objections to the proposal to store CO₂ either geologically or in the oceans is that it is not sustainable in the long term. Several participants suggested that rather than putting resources into unsustainable schemes such as this, more resources and research should be concentrated on methods that would either provide for increased use of renewable sources of energy or increases in energy efficiency. The consensus within the second group was that there would be a need to attempt to implement some form of energy efficiency alongside any sequestration policies that are adopted:

Sue It's a balance. You can't say we'll put the whole efficiency thing on hold and we'll just get rid of the CO₂, because people will see that we're still producing it.

(group 2)

The first group were concerned about the economic sense of building an infrastructure to support carbon sequestration technologies when the policy would be both unsustainable in the long term and rendered obsolete by advances in the technologies, such as clean coal technology and an increase in gas-fired power stations, which produce less CO₂. The group was not necessarily advocating increased investment in energy efficiency R&D; rather there was a feeling that within the near future technology would advance in such a way that increased energy efficiency and power stations with lower CO₂ emissions would occur 'naturally':

Alan In 30 years you would have power stations that run more efficiently, that burn better, that have filters. I'm worried about the initial outlay.

Tim Once you de-commission the old power stations, the process will occur naturally.

(exchange in group 1)

Potential problems and concerns were also identified concerning the costs associated not only with the collection of the CO₂, but also with the storage and transport of the CO₂, as well as any long term costs relating to the long term monitoring of the potential storage sites. Particular reference was made to the difficulties of transporting supercritical fluids and the cost that such an undertaking would entail.

One of the major concerns with waiting until technology progresses 'naturally' to more energy efficient technologies was alluded to by a participant in the second group:

Mark It's a case of the public seeing progress. You wouldn't see any initial progress [without intervention] because you are looking at thirty years from now and the public would say what about now?

(group 2)

Given that such a large percentage of the world's current energy needs are being met by fossil fuels (approximately 75% (IEA, 2000)) and that it would not be feasible to alter this situation overnight, each group was then asked whether CO₂ sequestration should be considered as a bridging policy to limit the effects on global climate change until increased energy efficiency and uptake of renewable sources of energy deliver more significant reductions. There was a widespread agreement within both groups on this approach:

Sean It's something emphasis should be put on to now, to stop the escalating problem of global warming.

(group 2)

Pete Maybe that's a better perception, as a temporary fix. The primary mode of government research could be for a long-term fix of renewable resources.

(group 1)

However, there was also agreement within the two groups that a CO₂ storage policy devised as a short-term solution would reduce the impetus to devise more sustainable energy policies. Corporations and governments would be satisfied that the problem had been solved, at least for the duration of their life span, and consequently would not allocate the required resources necessary to develop alternatives. The perception that adequate research into alternative energy policies would not be undertaken,

following an introduction of carbon storage as an intended bridging policy, somewhat reduced enthusiasm for CO₂ sequestration and storage as a solution.

Relevance of Potential Analogues to Carbon Sequestration

Given that there is only one application of carbon sequestration technology (Statoil's Sleipner operations in the Norwegian sector of the North Sea (Herzog *et al.*, 2000)), public awareness of such approaches to decarbonisation is low. We sought, therefore, to identify potential 'analogues' in other fields and applications, which might be regarded as indicating the shape of public perceptions to physical / chemical carbon storage. We presented two analogues to the focus groups, namely the debates over: a) nuclear power and in particular, disposal of waste (Kitschelt, 1986, Turner, 1986, Welsh, 1993, Walsh *et al.* 1993); b) the proposed disposal of the Brent Spar oil platform in the North Sea (Grove-White, 1996, Shell, 2001).

With reference to the Brent Spar saga, there was some agreement that there were a number of similarities between this and proposals for carbon sequestration. Within both groups similar actors were identified as playing a major role, most notably the oil companies. There was also a general perception within each group that the Brent Spa was an example of a large company attempting to impose a quick technical fix for an environmental problem. However there were differences of opinion regarding whether the general public would view attempts to store CO₂ as more or less desirable than Shell's attempt to dispose of the Brent Spar oil platform in the North Sea:

Darren With Brent Spar, you had a big oilrig you wanted to stick in the sea. People would see it, it's visible. With this it's invisible, people won't see it.

Tim People think of CO₂ as an evil greenhouse gas, so I don't think they will be able to get away with it. It sounds wrong.

(exchange in group 1)

On the one hand, the physical sequestration of CO₂ was seen as 'invisible' compared to Brent Spa; on the other hand, disposal of CO₂ in this way could still be seen as irresponsible. There was, however, general agreement that the dangers posed by global climate change were severe and therefore any credible policy that could alleviate the problem should be seriously considered. However the second focus group voiced some concerns relating to both the amount of CO₂ that would have to be stored in this manner and the length of time it would be required to remain *in situ* for:

Alex The problem is a lot greater, but the scale of the amount of stuff you want to put down there is going to scare people.

Anne It's not a one-time thing like the Brent Spar, it's something we will have to live with.

(exchange in group 2)

The question of CO₂ capture and storage is similar to the debate that has occurred over nuclear power in a number of ways. Both were identified with the production of waste products that would have to be effectively managed for a period of centuries. However the nuclear industry was perceived as having an irreversibly bad reputation:

Researcher Do you think that nuclear energy is a good analogue?

Paul In many ways, but nuclear power already has a bad image. This is slightly different because it hasn't got an image. The concept hadn't entered my head until today.

Larry The thing with nuclear power is that if one thing does go wrong it's a big issue.

(exchange in group 1)

At this stage the groups were asked whether there were any other analogues they could identify which could give an indication of the outcome of debate regarding the acceptability of CO₂ capture and storage. The second group failed to suggest any alternatives, however the first group suggested the debate over genetically modified foods as a suitable example. The example of GM foods raised a number of interesting points regarding differing levels of acceptability throughout the world:

Pete With GM foods...in some countries they are accepted, in others they are not. It's a matter of who the public were influenced by.

Paul I know quite a bit about that and it's a joke the way that the media has presented it.

(exchange in group 1)

Formation of Opinions

This opened the potentially crucial debate regarding the factors that influence the formation of public opinion. One of the strongest early impressions that was created within both groups was that people were highly suspicious of the motivations of large corporations. Given the active role oil companies are playing in advocating and developing CO₂ storage technologies, this may affect general acceptance of these technologies. The oil companies were perceived in these focus groups to be motivated entirely by profit, more concerned with maintaining dependence on fossil fuels than promoting sound environmental policies:

Researcher Do you think public perceptions may be affected due to the active role played by the oil companies in promoting these policies.

Mike Yes, because oil companies themselves give an impression of lying to people.

Steve In Malaysia and South East Asia, what the big oil companies say goes. They own the entire region. If the oil companies want it to go ahead down there it will go ahead because the governments eat out of their hand.

(exchange in group 1)

There was also a degree of scepticism expressed in the support and research being undertaken on behalf of the United States government regarding carbon sequestration technologies. These concerns were based on the perception that the United States was unwilling to undertake any policy that would have adverse effects on its own domestic economy. In these circumstances CO₂ capture and subsequent storage was seen as a policy devised to allow industrialised countries to continue with current economic and industrial policies.

At this point we examined the influences that are important in presenting arguments to the public. A number of key actors were identified that would be involved in the framing of the issue for the general public, including the oil companies, environmental groups, national governments and the media.

There was a range of opinions regarding the level of interest that the general public had in relation to issues of environmental concern. The second focus group showed differences of opinion regarding the acceptability of contentious environmental policies by the general public:

Sue The public is so ill informed. It's naturally against anything, regardless of the facts or danger.

Martin I think it will be very much based upon...are you putting it in my back garden. No, right, I don't care.

(exchange in group 2)

The first group were more cynical about the interest that members of the public would have in the subject and consequently in the lengths that they would be prepared to go to in order to obtain information relevant to such proposals:

Paul If you ask the average man on the street what Kyoto is, he wouldn't have a clue.

Darren If you look at programmes like *Horizon* though.

Paul What are the audiences for these programmes though. People are not really interested. They like the idea of renewable resources, but they are not that bothered.

Alan They're all watching *Eastenders*.

(exchange in group 1)

These initial thoughts allowed the researchers to probe further in an attempt to discover perceptions on how to convey information on complex issues to a general public insufficiently motivated to seek out information. The media was considered to play a very important role in framing the issue. The way that the issue was presented would have a great bearing on the acceptability of any proposals, as illustrated for the environmental sphere in general (Gamson & Modigliani, 1990, Chapman, 1997, Social Learning Group, 2001). In the Brent Spar episode, Greenpeace was successful in convincing the media, and consequently the general public, that disposal at sea would incur unacceptable environmental risks (Grove-White, 1996). This was achieved despite scientific opinion, backed by many academics and the British government, which deemed the option of ocean disposal to be associated with the lowest environmental risk (Shell, 2001). The perception that the media play an important role in determining the acceptability of environmental policies was encapsulated within the second group:

Anne At the end of the day it's down to educating people about the subject. There are a lot of people out there who won't bother to find out and it's about how the media present it.

(group 2)

With regard to environmental groups, there was a range of opinions over whether or not they would support any proposed sequestration policies. Some participants felt that CO₂ storage would be rejected by environmental groups as it would allow the continued wide-scale use of fossil fuels, while environmental groups advocated an agenda that called for increased use of sustainable, renewable sources of energy. Others were of the impression that environment groups may be persuaded to support CO₂ storage proposals if they were presented as a bridging policy between fossil

fuels and greater reliance on renewable sources (which does appear to be a position likely to be adopted by some environmental groups).

There was a general agreement within the first focus group that geological sequestration may have a greater chance of being successfully accepted if it was seen to be part of an integrated policy designed to tackle the problem of carbon emissions, perhaps containing a more visible aspect that could be seen by the public:

Mike Could you not butter up the public by planting some trees as well, as they are cheap and visible. As part of a CO₂ reduction policy we are going to plant loads of trees...and put some under the sea. Put it in small print at the bottom.

(group 1)

One of the differences between the carbon sequestration issue and the other analogues is that in order for a carbon sequestration policy to be effective, it would be necessary for it to be adopted on a global stage. While individual countries can decide upon their own policy over issues like GM foods, the global nature of the effects of carbon emissions means that any effective policy to combat the problem must be implemented on a global scale. This introduces the question of which institutions or organisations will influence whether or not carbon sequestration is accepted and implemented on a global level. It was agreed that as the world's largest economy and producer of CO₂ emissions, the United States would have an important role to play in whether carbon sequestration became accepted. It was also felt that in the United States political lobbying would play an important part in influencing political decision-makers. Similarly in Europe, lobbying by the protagonists of both sides of the argument was considered to be important:

Pete In this it will be the same thing, who lobbies first and best, oil companies or the environmental groups...as I think happened in Europe with GM foods, who gets to the people first.

(group 1)

And as far as determining whether the policy has support on a global level:

Paul Certain countries will take the lead. Look at Kyoto. America's refusing to ratify, Japan, Australia... There are certain groups in the world who are the leaders. The G7, G8, whatever it is now. They will formulate the opinion of the smaller countries.

(group 1)

Storage Options

The members of the focus groups were introduced to several different storage options: namely depleted oil and gas reserves, storage in deep saline aquifers and direct ocean disposal and were asked to comment on the relative attractiveness of each option. The most contentious storage issue in both groups was ocean disposal of CO₂. There was some disagreement regarding the impact that the ocean disposal of sequestered CO₂ may have on the deep-sea environment:

Mike Will that not lead to an increase in sea acidity?...that could kill fish and cause more problems than you could solve.

Tim Were there not certain benefits with pumping CO₂ into the sea, including an increase in certain types of fishstocks?

(exchange in group 1)

The overall conclusion within both focus groups were that the introduction of anthropogenic CO₂ into the ocean may have unforeseen and unpredictable effects upon the entire oceanic food chain:

Pete There are deep-sea environments, once you disturb a portion of it...an ecological system is not isolated.

Mike It creates a ripple effect

Pete You don't know how certain micro-organisms on the sea floor affect larger organisms higher up.

Larry Plus there are a lot of unknown and unstudied sea creatures at that depth.

(exchange in group 1)

Both groups expressed concern over the uncertainties surrounding the behaviour of CO₂ underwater. However the nature of these worries varied between the two groups. The second focus group, having less scientific knowledge, struggled with the concept that the CO₂ would remain in a bubble for a substantial period of time. This concept was easier to accept by the first group, however they also had reservations regarding the integrity of the bubble, particularly after a substantial period of time:

Pete What happens after a couple of hundred years? Does it just stay as a bubble?

Alan What about seismic influences? If you get a tsunami in the sea, you would get a huge explosion of CO₂ all over the seabed...you don't know what is going to happen.

(exchange in group 1)

The option of storing the CO₂ geologically, either in depleted oil and gas reservoirs or under the seabed in saline aquifers, was received more positively by both of the focus groups. The perception was that the CO₂ would pose less of a threat if it were contained within some thing, in this case a theoretically impermeable rock formation. This feeling was echoed in both groups, with the first group also stating they would feel more confident in the solution if there were a barrier in place that would physically prevent the CO₂ from escaping and returning to the atmosphere. The second group thought that there would be an element of 'out of sight out of mind', particularly as there was a physical barrier in place to prevent the captured carbon from escaping. The favouring of geological storage over ocean disposal appeared to be based, within both groups, not primarily upon concerns for the deep-sea ecological environment. The primary concern appeared to be the lack of a visible barrier to prevent CO₂ escaping. Even given scientific research to show that the integrity of the CO₂ should be maintained within the ocean, participants felt more confident and secure with a solution that provided a visible physical barrier. Concerns about the use of geological reservoirs related predominantly to the integrity of the seal and the possibility that the CO₂ could escape:

Mike If you spend a lot of money putting it there and it just comes back you've wasted your money.

Tim What would be the result if all of it suddenly came out at once?

(exchange in group 1)

A further major issue was the integrity of the reservoir, particularly the effects that oil and gas exploration may have had upon the security of the cap. There were also

uncertainties about how the carbon dioxide would behave in the reservoir. There is no precedent for this as the CO₂ stored at the Sleipner test site has only been monitored over a very short timescale. There were also concerns regarding the effect that seismic activity, particularly earthquakes, may have upon the integrity of the cap seals. The possibility of a large-scale sudden release, and the potential catastrophic consequences of such an occurrence, was isolated as an area of concern. A slow release was regarded as less of a danger, and one which could still provide certain benefits:

Sue A slow release would surely put out less than if it had all been released at the start.

Alex Half of it down there is better than none of it down there.

(exchange in group 2)

There was little distinction made by either group between the geological storage of CO₂ in onshore or offshore locations. This was slightly surprising given the possible dangers associated with a sudden release of CO₂ on life in the immediate area (Holloway, 1997). When the potentially catastrophic consequences of a sudden increase in the CO₂ concentration in the atmosphere were reiterated to the groups by the researcher, there was a reconsidering of opinion. Participants' viewpoints were slightly altered with a majority of people in each group now favouring geological storage at offshore locations, in order to minimise the risks for human populations. However, a minority in each group still considered the possibility of such a sudden release to be small, posing less of a threat to population centres than technologies such as nuclear power.

Future Concerns

The last section of the discussion groups dealt with some of the issues surrounding the implications of the decision to physically sequester CO₂. These related to whether or not it was acceptable to impose CO₂ storage onto future generations in this manner. The groups were also asked whether they considered that institutions would be in place that would be able to regulate and monitor storage sites and the ownership and responsibility for potential sites? This last point will be particularly salient if geological carbon sequestration technologies were ever to be included in a global policy to limit carbon emissions, as countries that possessed sites suitable for storage may be able to make monetary gain through emissions trading with other countries.

With reference to imposing the burden of regulating and monitoring the stored CO₂ on to future generations, it was felt that in principle this was acceptable. The view was held within both groups that sequestered CO₂ posed less of a long-term environmental risk than toxic waste. There was a general agreement that the potential benefits to the atmosphere outweighed the risks likely to be incurred through the storage process. There were a number of concerns raised regarding the cost and scale of the monitoring process that would be required to ensure that the storage sites were secure:

Alex How much maintenance would they require...or should they be pretty self-sufficient once they are in place?

(group 2)

Alan You may have to pay out so much money to monitor them, that you should have invested it elsewhere in the first place.

(group 1)

Interesting points were raised regarding the provision of institutions that could be guaranteed to monitor any stored CO₂ over a period of several centuries. Both focus groups pointed to the way that institutions had changed over the preceding centuries. In the last century alone there were two world wars, resulting in major political changes, highlighting the difficulties of establishing sufficiently robust and long-lived institutions. There was also a perception that long-term consequences would not be adequately considered. Governments are elected for approximately five-year terms while corporations are primarily motivated by short and medium term profit. In these circumstances the provision of institutions that would be equipped to monitor the sites in the long-term would not, it was felt, be a high priority.

There was also a lack of clarity over whose responsibility it should be to monitor the storage facilities: was it the corporations, individual governments or an institution with an international dimension? One solution to this problem was proposed by the first group, who referred to the example of Yucca Mountain in the United States. This is a proposed facility for the storage of nuclear waste. The criteria of the design are such that it would be necessary for the facility to continue to operate effectively in the event of a breakdown in the fabric of society. It was suggested that similar stringent criteria be proposed for potential CO₂ storage sites, in order to minimise the reliance on the existence of monitoring institutions in the future.

The ownership of storage sites was also covered by the discussion groups. This is particularly relevant in Europe, where there is a large aquifer situated under the bed of the North Sea. This aquifer alone could potentially sequester the total CO₂ produced by power stations across Europe for many years (Holloway, 1996). The researcher asked each group who should be held responsible for the aquifer. If carbon sequestration technologies such as those being discussed here were offset against emission levels, countries which had access to suitable storage sites could feasibly find a lucrative market trading their emission allowances with other countries. Should the aquifer be the property of Norway and the United Kingdom, as these are the countries whose territorial waters include the aquifer, or should it be a European resource?

The feelings of the discussion groups were that potential storage sites should be treated in the same way as any other natural resource, which would allow the country or countries in which the resource is situated to benefit from any revenue derived from that resource. An analogy was given between the location of these sites and the siting of precious metals and ores. These they are the property of the country in which they are located and the groups were in agreement there was little distinction between the two cases. However the point was made by the second group that global acceptance of geological storage of anthropogenic CO₂ could be affected if it was felt that some countries stood to benefit financially from its implementation.

The concept of imposing stored CO₂ on future generations was not considered to be unacceptable. It was perceived to pose less of a danger to future generations than failure to act to prevent further global warming. There were however some concerns that long-term monitoring costs could offset short-term benefits, in which case an alternative solution to the problem of global warming should be sought.

Conclusions

The findings in this paper are preliminary given that they represent the views of only two focus groups, one of which was composed of postgraduate students with a scientific background. There was no existing knowledge of physical carbon

sequestration within the groups and therefore no prior opinions or pre-conceptions. We found that there was limited opposition in the groups to the principle of capturing and storing anthropogenic CO₂ from power stations. A major reason for the lack of opposition seemed to be the level of concern expressed over the problem of anthropogenic climate change. The seriousness of the problem was felt to demand action from the leading industrial countries. Some level of risk taking in mitigation was deemed to be acceptable because carbon storage would reduce a much greater risk, that of climate change. For this reason the groups distinguished between the risks arising from carbon sequestration and the risks of Genetically Modified Organisms (GMOs): in the latter case a new risk is being created but without an associated reduction in risk elsewhere.

Concerns were raised, however, concerning the safety of carbon storage, in particular the integrity of the storage reservoirs and the security of the stored gas. There were also economic objections based on the fact that such a policy would be rendered unnecessary by improvements and advances that would occur in power generation technologies in the near future. There was a consensus, however, that carbon sequestration would be an acceptable 'bridging policy' until such technological improvements could be implemented. The concern was voiced that once CO₂ storage policies had become widely adopted and accepted, the resources required to develop alternative strategies would not be made available.

Whilst there were no pre-formed opinions of geological sequestration, the same cannot be said in relation to some of the agencies who wish to implement sequestration. Oil companies are suspected as being primarily concerned with ensuring the continued use of fossil fuels to protect their current business interests. It is envisaged that the media will be highly important in framing the debate on sequestration for the general public. The disposal of the Brent Spa oil platform was discussed as a potential 'analogue' for the perception of physical carbon sequestration, yet was regarded as a much 'smaller' or 'isolated' issue, being concerned with just one oil platform, whereas carbon sequestration is a much bigger and longer-term proposal. Nuclear waste was seen as a good analogue, particularly with respect to the need for long-lived institutions to conduct thorough monitoring and security.

There were differing levels of support regarding the potential storage options. Ocean disposal was deemed to be undesirable for a variety of reasons. One of these were the impacts such a policy could have on the poorly understood deep marine ecological system and the ramifications any disruption could have throughout marine ecosystem. However the main objection to this potential storage solution was that many participants were unconvinced by the scientific theory that the CO₂ would remain in the deep ocean for a sufficient period of time. For this reason, geological storage was perceived to be a more acceptable solution and proposal as there was a 'visible' physical barrier to reassure the public that the CO₂ could not escape. Because of the potential risk of CO₂ escaping, the importance of monitoring was reiterated in the focus group discussions.

The findings presented here provide some useful indications to the policy community on the potential public perception of physical carbon sequestration. The assumption that off-shore and contained hydrocarbon reservoirs and aquifers will be more readily accepted than other storage options is given credence here. More specific information about the monitoring of physical carbon sequestration and its costs needs to be provided to inform public debate. There is a good basis for believing that the public will distinguish between risks in relation to disposal of the Brent Spa oil platform, nuclear waste, GMOs and carbon sequestration. Although, an element of risk

associated with carbon sequestration may be considered acceptable in return for a reduction in the greater risk of anthropogenic climate change, there is a general scepticism of the motives of petrochemical companies, and acceptance of physical carbon sequestration might become dependent upon the demonstration that renewable energy sources to replace dependency upon fossil fuels are being actively developed. Our groups were also anxious to point out that the media would have a crucial role in shaping public opinion, and that the skill of proponents and opponents in conveying the appropriate messages through the media would, therefore, be crucial.

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