

Produced by The Environment Council

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Contents

| | |
|---|----|
| Contents..... | 1 |
| Welcome..... | 3 |
| Meeting Objectives..... | 3 |
| Ground Rules..... | 3 |
| Programme..... | 3 |
| Day 1 - Setting the scene..... | 3 |
| Day 2 – Identifying the Issues..... | 3 |
| Introduction Presentation from Gardiner Hill..... | 4 |
| Questions on the presentation | 4 |
| Issues identification | 4 |
| Issues raised in first working session..... | 4 |
| The CCP project..... | 4 |
| Socio and political perspectives..... | 4 |
| Technical..... | 5 |
| HSE Risks and monitoring..... | 5 |
| Legal and regulatory..... | 5 |
| Economics..... | 5 |
| Perspectives Presentations..... | 6 |
| Climate Network Europe..... | 6 |
| Questions from perspective presentations..... | 6 |
| Project detail..... | 8 |
| Questions | 8 |
| Carousel process..... | 9 |
| Station 1 - Capture | 9 |
| Station 2 - Storage..... | 10 |
| Enhanced Oil Recovery questions..... | 10 |
| Station 3 - Monitoring and Verification..... | 12 |
| Post carousel plenary..... | 14 |
| Key issues for Afternoon discussion..... | 15 |
| Distribution..... | 15 |
| Technical and HSE risks..... | 16 |
| Further involvement in the project..... | 17 |
| Type of involvement..... | 17 |
| Data involvement..... | 17 |
| Workshops..... | 17 |
| Peer Review..... | 17 |
| Other..... | 17 |
| Areas of involvement..... | 17 |
| Ongoing input – plenary comments..... | 18 |
| Evaluation Report..... | 19 |

Attendees

| Name | | Organisation |
|-------------|-------------|---|
| Arnulf | Gruebler | International Institute for Applied Systems Analysis |
| Charles | Christopher | BP America |
| Claire | Gough | Tyndall Centre (North) |
| Coralie | Abbott | Earthwatch |
| Erik | Schmersal | VR0M |
| Eve | Sprunt | Chevron |
| Fokke | Rispens | Ministerie van Economische Zaker |
| Francesco | Ferrante | General Manager |
| Gardiner | Hill | BP |
| Georgia | Callahan | Texaco |
| Giovanni | Lozza | Politecnico di Milano-Dept. Energetica |
| Giuseppe | Iorio | ENI |
| Helen | Kerr | BP |
| Helge | Stiksrud | Norsk Hydro ASA |
| Jip | Lenstra | Ministry of Environment |
| John | Gale | IEA Greenhouse Gas R&D Programme |
| John | Lanchberry | Royal Society for Protection of Birds |
| Jos | Cozijnsen | Environmental Defense |
| Ken | Brown | Pan Canadian |
| Knut | Alfsen | Cicero |
| Lars Ingolf | Eide | Norsk Hydro ASA |
| Lynne | Clark | Climate Network Europe |
| Mike | Slovacek | Chevron Overseas Petroleum |
| Olav | Kaarstad | Statoil R&D Centre |
| Paul | Johnston | Greenpeace Int'l Science Unit |
| Peter | Gerling | Bundesanstalt fur Geowissenschaften und Rohstoffe (BGR) |
| Peter | Radgen | Fraunhofer Inst. For Systems and Innovation Research |
| Pierpaolo | Garibaldi | ENI Technologies |
| Rachel | Lewis | BP |
| Rob | Bradley | Climate Network Europe |
| Sybil | Schone | WWF-NL |
| Sam | Holloway | British Geological Survey |
| Tom | Brownscombe | Shell Chemical Co. |
| Wolf | Heidug | Shell Global Solutions |

Welcome

Bob Frith of Shell Global Solutions opened the workshop. He then handed the meeting over to the facilitators who ran through the draft meeting objectives, ground-rules and programme, which were agreed by the participants.

Meeting Objectives

- To enable stakeholders to consider the issues, options and possibilities around carbon capture
- To initiate a dialogue with stakeholders that can continue as the project continues

Ground Rules

- Everything will be reported, nothing will be attributed
- Be sensitive to language
- Discussion to focus on CO₂ capture and geologic storage in the context of global climate change
- Participation does not necessarily mean support for carbon capture and storage technologies
- This meeting is not to discuss individuals companies' policies on climate change
- No smoking
- Mobile phones off

Programme

Day 1 - Setting the scene

- Welcome and introductions
- What do you want to learn about carbon capture and storage to form a considered view on it as a technology and on its potential for CO₂ reduction
- Perspective presentations
- Project detail

5.30 Reception and speaker

Day 2 – Identifying the Issues

- Carousel process
 - Detailed questions and issues
- Emerging issues and way forward

4.30 End

Introduction Presentation from Gardiner Hill

Gardiner Hill the CCP chair gave a short presentation giving the background to the project. Below are the questions and answers raised following the presentation.

Questions on the presentation

Q How much were people selected for invitation to this meeting?

A We aimed for a cross section of sectors and countries, but attendance depended on who could make the dates.

Q Re ocean sequestration - to what extent will legal issues be addressed by the CCP?

A The project won't look at ocean storage - although it includes geologic storage under oceans. We will need to understand the legal issues.

Comment from the floor: Sub bed disposal is illegal under terms of the London Convention. This is an important issue to resolve for some NGOs who perceive that they are not being dealt with but are being 'fobbed off'. Suggest the industry address this explicitly; CO₂ capture is not just a technical issue.

Issues identification

Participants were asked to work in small groups to draw up a list of things they wanted to learn about CO₂ capture and storage to help them form a considered view about it as a technology.

The facilitators collected all the points and long list was created in plenary. The facilitators grouped the issues under a number of broad headings.

The section below is a list of all the points raised and as they were grouped by the facilitators.

Issues raised in first working session

The CCP project

- Where does the Carbon Capture Project (CCP) fit in a sustainable strategy?
- Is there public funding for the project?
- Concern about technology being in the future – how can the project help judge maturity?
- Is CCP concerned with removing CO₂ from power plants (pre/post)
- Why aren't coal and gas companies involved?
- What is the commitment of CCP companies on CO₂ reduction?
- Why is CCP more focussed on Northern hemisphere – need to include Southern too
- How does this fit with an oil industry strategy on climate change? (and the CCP group's)
- Need better feel for positions independent of industry
- Is there more info out there we should know about ie external to industry?

Socio and political perspectives

- Concern that sequestration creates a technological "lock-in"
- How to demonstrate appropriateness of applying the technology on a grand scale
- Is the project an end in itself? Is there potential for bridging to other technologies? Is storage an intermediate technology, which will become unnecessary in the long term?
- CCP should not inhibit the development of other technologies
- What is the link to a move towards the hydrogen economy and CO₂ capture?
- Can we get public support (from all stakeholders i.e. including govt and scientists) for this technology and how to achieve this?
- How smart an idea is this in relation to climate change from a policy and public funding perspective compared to alternatives e.g. cost effectiveness of energy efficiency
- To what extent is this compatible with moving to renewables and the more decentralised infrastructure it implies (energy supply)
- Who can take responsibility for CO₂ over the very long term (intergenerational)

- What can we learn from the NGO concerns?
- There is an implication that a technical fix removes need to make more fundamental changes

Technical

- Is there enough capacity in reservoirs?
- Geographical spread of reservoirs and how to connect sources and sinks
- In conventional gas reservoirs is it possible to use CO₂ as recovery mechanism?
- What safety issues are there around CO₂ transportation?
- To what extent will natural analogues on CO₂ reservoirs help understand storage in oil and gas reservoirs
- Could storage of CO₂ in neutral reservoirs stop replenishment of the gas?

HSE Risks and monitoring

- Is it safe and what are the environmental and ecological consequences?
- Understanding risk to storage from well penetration (caprock)
- Who has good info about long term storage and leaks....how much leakage...how long is long term...etc?
- How to monitor safety?
- Current knowledge on the Norwegian reservoir for the long term
- What chances of pollution of groundwater or other natural resources?

Legal and regulatory

- When reservoirs cross (international) boundaries, who gets the credits and how are credits and liabilities allocated?
- Clarify regulatory and legal framework (London, Ospar, EU Water framework Directive, EPA etc)

Economics

- Any idea how to make this cost effective in the long run
- What is the financial cost to individuals (the public) ie who will pay for this?

Perspectives Presentations

Following the issues identification exercise the participants heard three short presentations giving the view of CO₂ capture from the perspective of Academia, Industry and Environmental Non Government Organisations. The slides for the first two presentations will be available on the CCP website, the third presentation was made without slides and key points were captured by a facilitator and summarised below, the second part of the section are the questions, responses and discussion which followed the presentations.

Climate Network Europe

- CNE represents 83 NGOs in Europe
- There is not a single CNE position on CO₂ capture
- Likely to get broad reaction from NGOS, some will probably be positive others negative

Key concerns

Generic issues:

1. Integrity of sites
2. Types of sites
3. Ecological impacts

Concern that location of sources and sinks will be an issue, coal and saline aquifers will become needed and CO₂ will have to be transported large distances. There is a concern that 'we' are being asked to buy into small-scale projects but there is a sense that when it moves to the large scale there will be significant differences

There are also philosophical and societal objections to technical fixes based on underlying principles:

- Is sequestration bridging technology or an 'end game' solution over 50 - 100 years?
- It potentially does not answer the issues that NGOs have over fossil fuels
- Must not get in the way of other alternatives, renewables etc. Technological lock-in is a big danger and runs counter to new technologies such as renewable and a decentralised power infrastructure.
- The potential for decarbonisation pre-combustion is attractive to many NGOs because it provides a basis for a move to the hydrogen economy. And enables the decarbonisation of energy. Must ensure that 'we' (NGOS) don't see this, as a lockout technology the pre-combustion route may be a way.

Public money

- Must not be a distraction from investing in renewable and energy efficiency (some scope for transfer of support from fossil fuels)
- Burden of proof becomes more important, if it is just shareholder money you only have to give them value for money. If public funds are involved you have to demonstrate when applied on a grand scale that it will be cost effective. (Not necessarily convinced at the moment)

Questions from perspective presentations

Q to CNE - Is same criteria re public funding to be used for renewable?

A Yes, in fact questions and restrictions are tighter than for fossil fuels or nuclear.

Q How long will Statoil monitor?

A Don't know... have to keep discussion going with other parties e.g. government

Q Public money issue - What is 'cost effective' i.e. cost effective compared to another technology or in absolute - how to you make the assessment.

A Means options need to consider cost and effectiveness, how communities decide what to invest in depends on cost effectiveness but also other primary issues e.g. likely impacts

Q Decision process - Norwegian project went ahead after carbon tax came in, was this the main reason or were there other reasons (e.g. changed attitudes)

A Difficult to answer, CO₂ tax played a part but not just this, it was after Rio and Bruntland report.

Q What % of Norway's emissions is being dealt with?

A 2.5% of Norway's CO₂ emissions and 10% of offshore CO₂.

Q How many years can the CO₂ be injected for? (Norwegian example)

A Many years (over generations). There is a huge space but only a small % can be used for storage.

Q Aren't a range of technical solutions needed in context of differing approaches internationally e.g. developing and developed countries

A Yes, will need a range. The cost of technologies can be reduced by introducing them on a bigger scale, making them suit the widest possible range of conditions. . CO₂ storage may be less relevant compared to other options for developing countries (who need focus on things like infrastructure)

Project detail

Helen Kerr gave a detailed presentation explaining the areas of work the project was looking at and how it planned to develop. The next section summarises questions, responses and discussion around the presentation.

Questions

Q Why so much emphasis on flue gases?

A Large-scale emissions are coming from power stations so good place to start - also generators are not yet involved.

Q What is the proportion of energy lost in these processes?

A Approx 15 - 20 %

Q Does the CCP have a ballpark time for the options to get to market?

A To get to pilot scale in 5 years is a criteria for CCP options, then to be commercial in 10 years

Q Is the State of the Art report freely available?

A Some data is commercially sensitive, as much info as possible will be made available

Q Is Shell's project on fuel cells part of CCP?

A No, we try not to duplicate work.

Q Would you use profits from EOR to reduce public funding?

A Income from EOR clearly could reduce the extend of public funding, although by how much can only be evaluated on a case by case basis.

Q Are other fuels e.g. solid included?

A When we set work programmes they will be included in specs

Q Life cycle Analysis of processes?

A Looking at base models at present. We will look at environmental impacts as project evolves, with external review

Q High cost of equipment mentioned - how could you encourage manufacturers to improve?

A The 9 companies in CCP represent a big market and are also creating opportunity for even bigger market

Q Technology will have social and societal and environmental impacts - are these aspects being addressed?

A CCP focus is on the technology but will need to understand wider issues like these.

Q What is the system boundary for considering alternative technologies re environmental and economic assessment?

A We are developing base line models for emissions of power plant or field and comparisons across different scenarios

Q Any estimates of energy penalty (CO₂ penalty)?

A These are in the models: a range is assumed of 15 - 20%

Comment: Could also be negative balance - CO₂ penalties are of interest in practice in a downturn situation.

A Will try to get comments on this as part of the process, the aim is to minimise

Q How sure are you that you can get to the 50% and 75% reduction targets?

A Based on data on one or two of the technologies, others are a long way from development. 50% is probably doable, 75% more ambitious.

Q What is 'best' as in Best Available Technology?

A Off the shelf systems available today

Q Publicity of report ... most new technologies not in public domain so how can they be scrutinised and discussed?

A Results of CCP economic modelling will be available (except if competitive information - but will try to ensure this is not a barrier)

May not give technology details where there is a competitive factor, however, factors and criteria in calculations will be given.

Q Can you give us some baseline data to help us get a feel?

A We really don't have this in detail yet - did a rough sort at the start.

Comment EU came up with \$70 a ton estimate; such data is very useful for people outside industry to help assess the economic and environmental feasibility.

Carousel process

The second day started with a carousel process. This involved the participants dividing into three groups. There were three 'stations' set up around the edge of the room. Each station had a facilitator and an expert resource person. Station 1 dealt with capture, station 2 dealt with storage and station 3 dealt with monitoring and verification.

Each group went to one station and heard a short presentation from the resource person, the group were then able to raise questions and discuss issues around the subject. Points were captured by the facilitator. After around 30 minutes rotated to the next station. The process was repeated until all the groups had visited each station. The section below gives the points of discussion captured by the facilitator.

Station 1 - Capture

1. Pre combustion - possible basis for H₂ economy. What is the scale of this? How to transfer to renewables?
A Currently investigating different scales of reforming hydrocarbons – fuel cells to large scale H₂ plants.
2. This project could help create the 'supply' infrastructure for H₂.
3. H₂ transport is a problem, which needs to be addressed. There is already H₂ transport now but are there issues around large-scale application.
4. Amine residue disposal. Concern about how to address environmental impacts on a large scale. This is a current problem, partially being addressed through next generation amine solvents?
5. Power plants – post combustion applicable. How can we apply pre-combustion and oxyfuel to power plants? Can you use H₂ as a turbine fuel? For pre-combustion could use existing gas turbines, for oxyfuel require new technology.
A Issue with high temperatures, NO_x emissions
6. Question of cost – are these techniques realistic, the costs seem so high.
A Need to consider rebuilding completely vs retrofit costs.
Comment: Need to combine energy efficiency with these techniques, not address in isolation.
Approximate costs for 3 techniques ≈ \$60/t CO₂ for entire process \$40 – 45 capture, \$15 storage
7. What kind of test facilities are needed for these programmes?
A Projects are being run by universities, university contractors etc, currently bench scale
8. How do you relate/interact with electricity companies here? They are a single point source of CO₂ so an obvious candidate for these technologies. Distributed vs point source issues.
A Power generation within 9 participating companies. Power companies approached but not part of consortia at this point.
9. What legislative support do you need for this project to be successful
10. Efficiency penalty of steam reformer lower than a scrubber. Question around the reverse of this being true. Fuel cell development lowers efficiency penalty. What is the current amount of CO₂ produced from steam reformers as a % of world CO₂ production?
11. Energy market knockon effects pre vs post combustion. Can you improve efficiency of both or have we reached limit of post comb?
A Opportunities for both
12. Post-comb efficient in power plant (large scale). Pre-comb applicable to smaller scale. Post-comb not applicable for cars.
13. Issue with post comb for technology lock-in
A H₂ used already within refinery/chemicals, fuel source, generating power. Purpose of project to capture CO₂ from fuel.
14. Distribution costs should be considered - they are an important part of efficiency calculations. Is improving things like compressors, pipelines etc part of this project? Should lifecycle analysis be done for each of the projects?
15. Is there any existing infrastructure for transporting CO₂? Can you use existing infrastructure for this?

16. Pre-combustion: investigating coal and biomass as fuel sources as well as gas?
A Capture technologies could be applied to other fuels.
17. Have you done preliminary market potential studies for these options? Location of power plants.
A Not covered by CCP (use other studies such as IEA, DOE etc. for examples, in the USA – large % of sources within 100 miles of sink).
18. Have you decided which of the 3 options is best?
A Currently looking at all 3 – have range of advantages and disadvantages
Concern that all three options continue to be considered.
19. Discussion around using fuel cells on a large scale – no short/medium possibility at this stage.
20. Where is the main focus of CO₂ capture? Are you looking at real examples yet?
A Projects currently funded are research projects, actual experimentation not taking place.

Station 2 - Storage

Enhanced Oil Recovery questions

EOR ⇒ (Inject with N₂)

(Inject with CO₂)

Q Why separate CO₂ and not just inject exhaust gas (made up of CO₂ and N₂)

- A** N₂ not miscible with the oil, need over 95% CO₂ and if too much N₂, it won't work
 → would also need very large reservoir if you inject N₂
 → would increase transport costs

Q How much do these other materials matter?

- A** Corrosive nature of O₂ - can't use N₂, anything else? Ie would it matter if purely for sequestration and not EOR?
 → no but would add to compression costs

Q Does some of the CO₂ come out?

- A** Yes, done a lot in Texas, have to buy CO₂ and use as little as possible
 Can recycle CO₂. In this case want to use as much CO₂ as possible

Q Are all wells suitable for recovery?

- A** No, depends on pressure and composition of oil and reservoir type.

Q Are there some suitable in the North Sea?

- A** Yes some are

Q Does removal of oil change structure of formation?

- A** Not significantly, does change pressure, if pressure changes formation could collapse (this is a possibility if left as it is now). With this process we want to keep pressure up.

Q What will be the impact on the micro-organisms? What is the impact if nothing is done? The same? Different?

- A** - All will be anaerobic – not sure of impact
 - certain organisms have been identified in saline aquifers
 - need to establish these potential impacts

Q If you pressure the reservoirs what do you do at the end? Assume you have to cap very well.

- A** Normally reservoir is left and pressure drops. Here we are trying to leave reservoir at same pressure as found it.

Q What about the numbers of holes going into one formation? Can't guarantee integrity by capping one well, could be many caps are needed? Is it not easier to monitor terrestrial wells? Long term fate of wells not understood.

- relationship between existing operations and old and abandoned operations
- duty of care is now required once you fill with CO₂
- long term behaviour over very long timeframes is a concern

Q What s the density?

- A** 0.8 – 1 (ie it is very heavy) so there are upward forces but not many

Q If you dissolve it in water is it an acid? Could it be corrosive?

- A** It doesn't dissolve limestone (but what about 1000 years time frame) – over that time may erode a bit but just create more space
 There is some value in having a reversible process

Q Re. risk – oil industry have a good understanding of formations with oil in them, but not same as deep coal bed and saline aquifers. These are different and need to be addressed? →Do you have experience of coal bed storage?

A Yes .History of disposal of waste in deep saline aquifers but little understanding of impacts, but are part of basin analysis. If put CO₂ in, will do analysis. (NEEDS to be done and done credibly)

Q If CO₂ is captured well over long period of time, do you have examples of CO₂ reservoirs and see what they do over time? ...→natural CO₂ reservoirs

A Yes in US

Q Saline aquifers – what will you do for monitoring?

A Monitoring

– most tools will be relatively short term (50 years) if its going to leak will do it soon

– also monitor at surface – available on terrestrial

Q Could you use wells to monitor what's happening?

A Try to avoid using wells because could effect the integrity of the reservoir

Q Any study of the groundwater above CO₂ reservoirs? What results?

Comment – How long do you need to store?

1. Doing it for climate change so how long is needed to deal with climate change? Answer is probably 1000 years

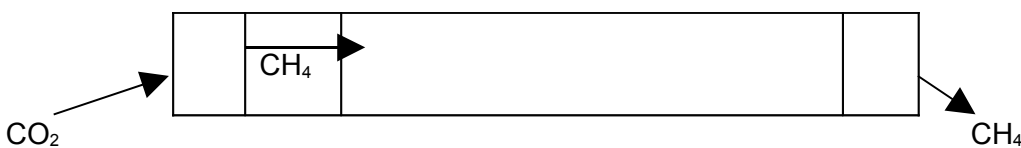
2. doing it because sliding to next ice-age will need to increase CO₂

3. is an ecological safety devise more to do with rate than time scales? (fluxflow)

Q If you have leakage problems at the surface is it not too late?

A Is this such a disaster? Will depend on local circumstances

Q Is it feasible to recover CH₄ by injecting N₂?



A Using CO₂ as recovery method for CH₄, yes but need a lot, complex process need to include N₂ Will take a long time to recover CH₄ in commercial amounts.

Inject CO₂ → coal bed CO₂ will be absorbed and has to saturate before CH₄ Can be extracted.

Q If you could rank the 4 storage processes, which is best?

A Can't answer in general sense – will depend on sites e.g. SE Asia CO₂ is vented to air as current practise, need to look for local reservoirs etc

- EOR has potential because close to lots of reservoirs

Q What about EGR (enhanced gas recovery)?

A Yes it is potential where gas stored in cavern.

Q EOR – advantage is an early opportunity – but what about breakthrough technology that is created to get rest (15-20% e.g. foam, polymers

A EOR is not uniform though reservoir. CO₂ flooding the zones you contact will enable recovery of all oil, oil you wont get is in zones you haven't flooded so plug zones you have already flooded

Comment – problem of getting CO₂ to react from inert state, would it be possible to add something to CO₂ to make it 'gel' in reservoir. Is possible – good idea (some work done CARE Japan)

Q Is it possible to get CO₂ out again if you want to e.g. decide impacting environment?

Station 3 - Monitoring and Verification

- Q I am shocked that up to 15% H₂S is potential contaminant**
A It can be from 3-15%
- Q Why not cleaning with sulphur?**
A Depends on source of CO₂ – there will be some contamination in some cases
Comments – this is an important issue re waste disposal in different countries
Relates to sedentary basins – varies around the world
- Q Are most projects in North America?**
A No. About one third to one half are in US, some in Canada and rest in Europe
- Q Are you aware of other CO₂ projects**
A We have identified some and are trying to look at gaps
Comments – In Europe there are two projects – ‘Natural analogues for CO₂ leakage’ and ‘the CO₂ Net’.
EU has about 20 relevant projects and there are others too which need to be pulled together.
**Need for more communication and co-ordination
- A CCP may try to create a research website to help this. There is also some overlap of people in the various projects**
- Q Re ‘how safe is it?’ – when can you give first results?**
Comment – can’t say how safe it is as a generic process only on a project basis – varies
- A Its all about location e.g. the type of reservoir**
- Q What about monitoring aquifer storage?**
A (Refer to Storage presentation) Monitoring and Verification applies to all types: volumes and leakages
- Q Anything done on bio-activity e.g. bacteria reactions? If CO₂ leaks can see impacts in soil.**
A Trying not to duplicate existing work on this
- Q What is your view on very long term storage issues?**
A There are risks with CO₂ even though it is a natural product. It is less dangerous than nuclear but CCP is looking at what that industry has learnt
- Q Don’t Governments want you to give some assumptions/expertise re the potential?**
A There are some studies on the short term
- Q What is ‘long term’? In Germany we say this means 10,000 years**
Comments: Industry has experience of storing similar products
Penetration is the issue →risk
- Q What is the danger of CO₂ levels @ 3%?**
A It can interfere with the breathing regulation mechanism in humans. There are working limits e.g. in the food industry that the CCP will look at.
- Q What about ‘human analogues’? e.g. is there anywhere else where long term issues are longer than company and individual life including governments’?**
Comments – in UK British Coal had this liability, which was transferred to the Coal Authority
- What about the example of the chemical waste industry?
 - In the NL the Government takes this liability once certain conditions are fulfilled
 - Issue of concessions to government
 - Companies leave after 20-30 years
 - Need guarantees from companies for 50-100 years
 - Need to differentiate between different types of safety risks
- Q Is CO₂ a good solvent leading to leach of trace contaminants (in saline aquifer)? Will you consider this and look at other products than CO₂?**
- Q Is the Sleipner project being looked at?**
A Not included but trying to be aware of all work. There is also a transport project in CCP and a list of approx 15 other potential projects needing funding.
Comments on liability issue:
- the question governments should ask companies is ‘what are your storing?’ as this determines the risk
 - record keeping becomes a critical issue over long term
 - may be a need for body dedicate to this – potential project area?

- Q Will the project try to map legal issues e.g. conventions in different parts of the world? How to address these – what might governments need to address? Will this be funded?**
- Q Have you thought about social monitoring – how people respond to these sort of projects?**
A Interesting issue e.g. in Texas CO₂ has actually killed people so will be set of issues and perspectives. Need to get some consistency in social approach/transport planning etc
- Q Projects are small scale but there is need to project to large scale – how can this be done?**
A Many of the projects are large scale e.g. natural analogues and Canadian project
- Q How much stays in? (EOR)**
A 100 % of CO₂ stays in but uses energy to get it in there which creates more CO₂, so the net figure will be about 68%.
- Q How will you publish results?**
A By the end of the contract results will be public *i.e. 3 years. Some results will be published before – researcher keen to publish at end
- Q What about EGR (enhanced gas recovery)?**
A Some examples to look at – could be very beneficial use
- Q Can CO₂ be reused e.g. in greenhouses (NL example)**
- Q Are you in contact with independent (non industry) verification firms e.g. environmental monitoring firms? (cf. in Norway for CO₂ tax)**
A Generally yes – also have lots of established monitoring mechanisms in place
- Q What do you expect the main risks are?**
A Researchers will give their views – reluctant to give a view now re. worst case scenario as don't have good information to base it on. CO₂ not a hazardous chemical waste in itself but must consider what is with it e.g. H₂S
- Q Transport is most dangerous element in some countries – will you study this too?**
A Trying to look at all these issues
- Q Comments**
- Long term: have to keep CO₂ somewhere so have to monitor for ever
 - Be careful about language – there is a problem with CO₂, that's why we are here ie climate change impact through long term release to atmosphere
 - Can have immediate impact e.g. Cameroon lake example saw catastrophic impact
- A** Agree, also CO₂ not always pure so have to know what's with it
- Q Have there been any catastrophic releases from natural reservoirs?**
A Yes there have been 5 and we are studying them
- Comment** – how poisonous is CO₂? Above 4% starts to get dangerous and as it rises it gets more dangerous e.g. can kill humans at above 10% (
- Comment** - this depends on volume and exposure
- Q how can you study what happens to materials over millenniums?**
A One way is to heat it up – researchers will use this and other methods
- Comment** – Need to consider that society is unlikely to be in same state in the future re CO₂ emissions effect. Long term containment
- Q As there is more biological life under the earth than above – what do we know about this and how life will be effected (links to ecological questions)**
- Comments**
- Perhaps when we are beyond the carbon economy these issues will be similar to nuclear – likely that industry will disappear – then who will take care of ongoing monitoring.
 - Need for public involvement in the debate
 - Must also consider how to involve and if they want to be
 - From government perspective key is knowing that it is safe now ie 'even if something goes wrong it shouldn't go wrong', because long term control is problematic. Industry should focus on this

Post carousel plenary

Following the carousel process the participants had a discussion in plenary to draw out any general observations or gaps that emerged from the process. The next section records the discussion.

- *Gaps – nothing on distribution which is a key issue (siting, transport etc)
 - Discussion on capture went quickly into hydrogen economy discussion – important to consider getting ‘knock-on’ benefits (ie extra benefits) as criteria once looking at options
→ ultimate energy market effect needs to be considered
 - Project has a dilemma re full scientific assessment – is this feasible to try to do? Project should focus on its objectives but who will look at these wider issues?
 - I would be interested to know more about NGO positions on this area
 - There are diverse positions: some see it as a diversion from renewables, others as part of a multi faceted approach which includes renewables, energy efficiency etc
 - Paradigm shift – we used to think there was not enough energy now we think we can only use 1-2% of what is available
 - NGO’s usually only develop positions for specific international conventions etc. There isn’t yet a convention on this so NGOs haven’t developed positions
 - This will always mean a step to the hydrogen economy whereas if we only go for renewables the cost may be too high
 - Or does it mean this? – depends on the choices made
 - This discussion has only just started – NGO’s are interested in this discussion and the CCP.
 - *I am interested to know what the CCP team has learnt from today and what they will do about it
 - *How will non-industry be able to input into this process (CCP and wider)?
- * Indicates areas agreed for afternoon session to address

Key issues for Afternoon discussion

Before lunch the group agreed some of the areas they wanted to discuss in more detail in the afternoon. This enabled the facilitators to agree an agenda for the afternoon:

- distribution, transport and logistics – what and how
- technical HSE and risks – what else and how
- further involvement in the project
- CCP feedback and way forward

For the first two agenda items the participants took each subject and discussed them in small groups before discussing them in plenary. The plenary discussion was recorded by the facilitators and is transcribed below.

Distribution

(**S** indicates a suggestion or potential solution)

- How much transport is needed?
 - Where are the sites in relation to where generated
 - Knowledge gaps here
 - Keeping sequestration sites away from habitation
 - Need to know more about what is safe
- Technical/logistic issues fairly similar to natural gas so fairly straight forward
- Real issue is where pipelines run. Risk is of pipeline rupture and local impacts
 - Also the ecological risks e.g. pipelines through designated special sites
 - However, very, very few ruptures with natural gas
- Issues around catastrophic release e.g. if collects in low ground
- **S** Need to make it detectable in same way as natural gas
- Pipelines likely to be carrying liquid not gas
- Likely to have centralised system so need to look at it in an integrated way e.g. with renewable energy and energy efficiency
- Projects can be driven by economics – EOR driving way might proceed e.g. an option may pass standards but fail on economic hurdle
- **S** Risks of CO₂ and acid gas pipelines – suggest use current knowledge on existing pipelines
- Natural gas pipelines with hydrogen
- **S** Important to integrate transport with other parts
- What to do with rest of hydrogen – need process to deal with it on site
- How many control valves needed? Regulators interested in risk/cost assessment
- Economics of transport will effect site selection
- Pure hydrogen transport – what are the conditions?
- **S** In Europe there are already 2 networks for transporting hydrogen – also one in Texas – draw on this knowledge
- Many issues are location specific so need to do characteristic assessment and life cycle assessment (also re. scale up)
- Under sea sites may be seen as obvious solution because it avoids and risks BUT must remember ecological impacts

Technical and HSE risks

Suggestions:

- Extended peer review including social scientists from early stage
- Maximum leakage timeframe needed and rationale behind it from climate change perspective and local impacts perspective
- Want lots of research on ecosystems affected especially in saline aquifers under bedrock. Perhaps GESTCO could look at this?
- CO₂ capture in terms of transition issues – are we storing for 50 or 100 years etc. What are our assumptions? Does short terms imply its ok to leak more? Should always seek to be as safe as possible.
- Transition issues relates also to quantities projected (transition means CO₂ no longer being emitted to atmosphere)
- Learn from existing risk assessments of sites e.g. Statoil that are part of existing business
- Use natural gas (e.g. CO₂, CH₄) fields as a standard bench mark for what constitutes storage
- Pilot project could be scoped by learning from existing work and info: collecting info on deep well disposal of wastes, geological structures etc to create a better informed pilot
- Technical reports should be put on the web please
- Look at fingerprint of CO₂ so can trace leaks
- What about a field trip to Mammoth Mountain or Bravo Dome for stakeholders to learn! (NB need to remember these are specific ecosystems)
- Potential environmental impacts if this technology leads to more centralisation of energy production and types of energy (e.g. for cost reasons)
- Monitor pressure so not overloading reservoir/aquifer
- Monitoring timescale needs to link to quantity stored
- How to compensate for loss from storage (carbon insurance)
- Staging for permitting – first collect info when site chosen, then when it is operational, then for 50 years after (decommissioning) – with ‘go’s’ and ‘no- go’s’ and reparation conditions etc
- Need remedial options for if something goes wrong
- In transport and piping of CO₂, please avoid sites of special scientific interest

Further involvement in the project

Each participant was given two post-it notes they were able to write on one which part(s) of the how they would like to be involved in and on the other how they would like to be involved. These are recorded below in broad groups. If organisations included their name on the post-it they have been included in this section.

Type of involvement

Data involvement

- companies can share info – Jos Cozijnsen
- review of papers and distribution of project output – CICERO
- receiving reports/studies, follow project with workshop discussions – Fraunhofer ISI
- provide overview of information from Utrecht University (source to end trajectories)
- continuous and permanent information on how project evolves (via Web)-

Workshops

- watching brief at meetings such as these – John Lanchberry
- resource constraint, observation – CNE
- occasional consultation – setting priorities, identifying gaps – Coralie Abbott, Earthwatch
- continued participation in dialogue/meetings – Greenpeace
- workshops (like this), and research – Tyndall Centre

Peer Review

- Peer review and participation in market potential studies – Arnulf Gruebler
- Extended peer review involvement – Sybille van den Hove
- Extended peer review process/ social/institutional/political aspects – Tyndall Centre
- S Holloway BGS SMV: exchange of views, peer review

Other

- Facilitate (assist) co-operation between research activities internationally IEA GHG
- Have Climate Network Europe co-ordinate input from NGOs – S Schöne

Areas of involvement

- Public acceptability – CNE
- The nature of the collaboration: between companies and between companies and stakeholders - Sybille van den Hove
- Jos Cozijnsen – start allocate CO₂ caps: no time and tight to pick or prefer CO₂ reduction cp bias
- BGS – specific interests; everything except capture
- Storage and monitoring – BGR
- Consultancy studies on related issues – how long is long? – IEA GHG
- Capture technologies and info dissemination – CICERO
- G. Lozza Politecnico MI, Italy –Research expertise in power plants, CO₂ capture ad hydrogen from fuels
- Link to the H₂ economy- Arnulf Gruebler
- Fraunhofer ISI – technical information, project economics, overall effect on energy infrastructure
- Proposal of attractive options (cost efficiency), systems analysis - Utrecht University
- Know-how transfer – BGR
- Aspect of project – leakage
- HSE risk and monitoring – Ferrante
- Coralie Abbott, Earthwatch – ecological impacts
- Greenpeace – ecological and legal information
- Dialogue on env/safety permitting – Min Env. NL

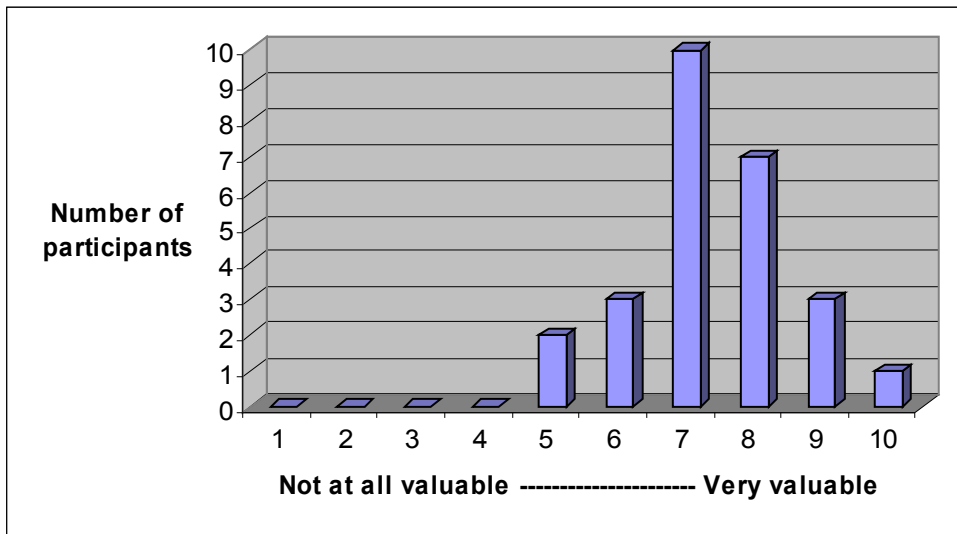
Ongoing input – plenary comments

- Likely to be interest in networks like CNE but resource intensive to represent all NGOs on this
- Some NGOs may not wish to be represented by others
- Could ask NL Government or other governments to help fund NGO co-ordination
- If there is a website for the project, please post notice of consultations and enable people to register interest in participation
- Website is a key tool to enable stakeholder involvement perhaps through restricted email list/internet consultation (but not a substitute for meetings)
- If NGOs broadly in favour of technology need to move to demos and then will need governments and NGOs to focus together on how to do permitting
- NGOs not yet at that point – just engaging with it as an issue and have some concern areas
- No bio-diversity specialists here – would need to involve them in discussion such as permitting
- Wider context – will CO₂ be capped? Where is CO₂ market now?
- So many CO₂ technologies needed now – don't have luxury of waiting for one ideal solutions – need this sort of project anyway

The meeting concluded with a summary from Gardiner Hill and evaluation from the participants. The results of the evaluation form are included in the appendices.

Evaluation Report

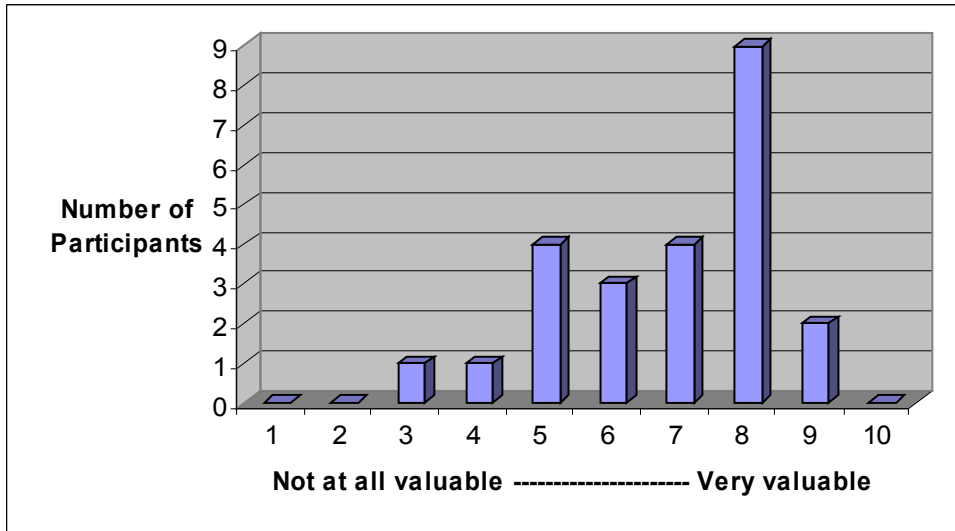
How valuable overall have you found the workshop for your own understanding?



Comments

- The point of view of companies and NGOs has become clear. I didn't know very much about that, being an academic.
- I learned something about industries and NGOs perspectives
- It was interesting to hear perspectives other than those of geologist
- I'd prefer deeper technical assessment rather than general views
- A huge amount of technical details but well positioned for the audience
- It should have been good to provide some information (technical, economic, ... before the workshop)
- I only participated on June 13th
- Very helpful, especially given my low level of initial understanding
- A lot of repetition of issues covered in other fora.
- I was well informed already
- A lot of info, but for most aspect no real xxx (too early to tell)
- Good exchange of information and perspectives
- Some excellent presentations and conversations have given me great insight - the structure of the workshop was good way to facilitate this
- Very good exchange with NGOs
- Better understanding of technical issues involved

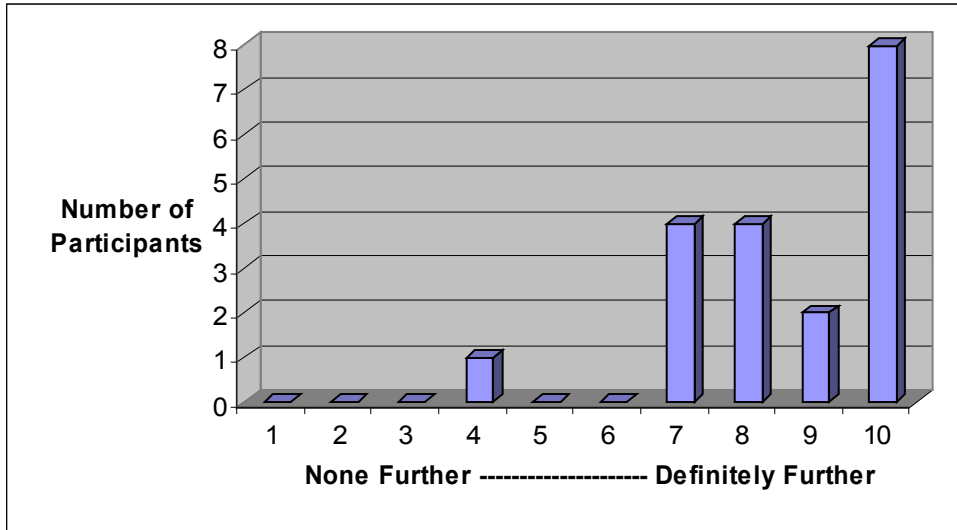
How valuable do you think the workshop was for the project team and the development of this work?



Comments

- Hope they understood the need to step back from the project and consider public and environmental acceptability
- 'Thin' feedback from the project team
- Quite useful to see level of inducement of Greenpeace CNE etc, some good actionable suggestions
- Some more than others
- NGOs seems to start thinking in a constructive way
- Not much evidence of project teams awareness of other debates
- Not sure, as I am not a project team member
- Maybe too many ideas and suggestions
- It might be difficult to address the broad field of questions in the project alone
- Although as a first meeting it was good to have a lot of people from the project a broader participation of non industry would be good.
- Very useful feedback from a wide variety of stakeholders. How does the project address the 'non technical' aspects of the work - ie policy implications
- I cannot estimate, it is just a guess
- Very valuable in engaging stakeholders
- You should communicate with external projects
- I think this workshop fits well into the work scheme of the CCP. The next one will be very important, because the issues mentioned this time should be seriously developed

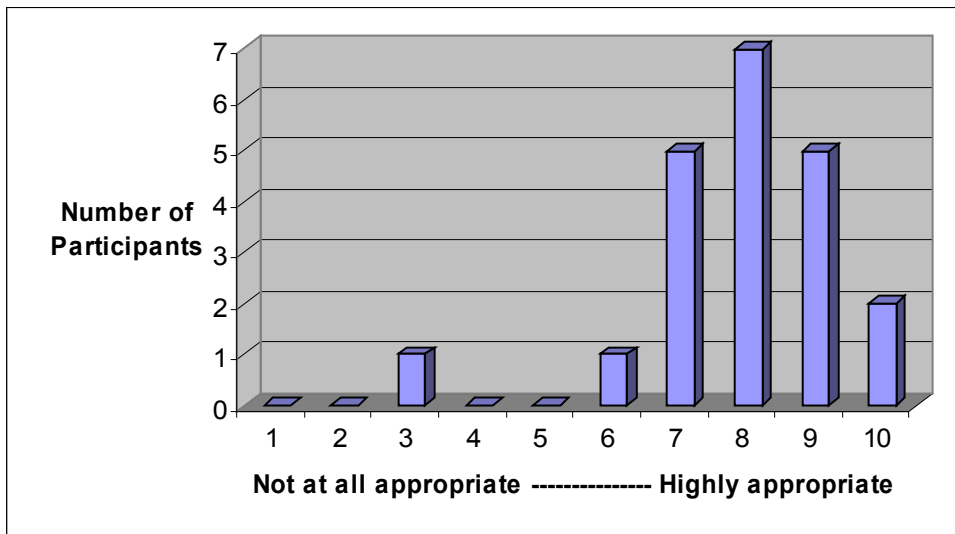
Do you wish to remain involved in inputting into the project as it develops?



Comments

- It is a very interesting project and very useful for me, but I'm not sure if I can be involved very much. For PhD students time is an issues (I will check the web site often!)
- I am interested in storage, monitoring and verification
- Things going on are of high relevance
- Some independent non-industry research activity would be good - so maybe formal and specific activity of outside institutions would be good.
- Discussion and information exchange very valuable to everyone
- Resources may be a constraint, but yes in principle
- Yes very much so
- We need to be undated
- Occasionally contribute an outside perspective and be aware of progress
- Obvious resource constraints
- If resources allow definitely need NGO input into emerging project

How appropriate do you feel the format and process were for the workshop?



Comments

- Too much on the 'question' side . Some more answers would have been got from the technical experience of the audience
- The workshop could have been reduced to 2 half day session
- Good quality organisation format he coordinators
- Well run
- It would be good to promise at the start to answer all questions in a report that would be reviewed and objective.
- Perhaps a bit over-structured and overstylized
- Good mix
- Worked well with technical issues but difficult to step outside it. Quickly drawn into technical debates rather than larger issues - social / environmental

Any further comments

- Very good facilitation
- Pippa and Rachel and Rebecca and the meeting convener did a great job
- Good input for project team. Challenge will be to apply input appropriately. Good facilitation
- Useful
- Good atmosphere!
- Good location for the workshop. To get the travel / expenses paid by the project is very helpful for the involvement of NGOs
- I enjoyed the meeting immensely and learned a lot
- Thanks for the invitation