PROCEEDINGS FROM THE 2013

CCS COST WORKSHOP

6–7 NOVEMBER 2013

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ORGANISED BY:

CONTENTS

AGENDA

Day 1	Wednesday, 6 November 2013
9:00–9:30	Opening session:
	Welcome Sean McCoy (IEA) and Didier Houssin (IEA)
9:30–11:00	Industrial capture cost: case studies
	Chair: John Davison, IEA-GHG Steel & CCS Jean-Pierre Birat (ESTEP) CO_2 Capture within Refining: Case Studies Rosa Maria Domenichini, Foster Wheeler Costs for CO2 Capture in Cement Manufacture Duncan Barker, Mott MacDonald
11:30–13:00	Industrial capture cost: estimation methods and metrics
	Chair: Simon Bennett, IEA - Introduction CCS Cost Estimation Methods in the Coal, Oil and Gas Sectors David Butler, David Butler and Associates Ltd Cost of Capturing CO2 from Industrial Sources Morgan Summers, National Energy Technology Laboratory CCS costs for industry: Considerations and collaboration Chris Hendriks, Ecofys
14:00–15:30	Power plant capture: case studies
	Chair: George Booras, EPRI – Introduction Summary Results of EPRI's Post-Combustion Capture Retrofit Studies Desmond Dillon (EPRI) From demonstrators to commercial CCS costs Wilfried Maas, Shell & Member UK CCS Cost Reduction Task Force) Perspectives on capture costs Max Ball, SaskPower
16:00–17:30	New and advanced capture technologies: cost estimation methods
	Chair: Howard Herzog, MIT Estimating the Cost of Novel (Pre-Commercial) Systems for CO2 Capture Ed Rubin, Carnegie-Mellon University Risk-Based Cost Methods David Engel, Pacific Northwest National Laboratory Estimating the cost of a CCS system Jean-François Léandri, Alstom
Day 2	Wednesday, 7 November 2013
9:00–11:00	Break-out discussion groups (parallel sessions)
	Industrial capture costs & power plant retrofit costs Estimating costs of novel technologies
11:30–12:30	Break-out groups report back
13:30–15:30	Forming an IEA-GHG CCS Costs Network
	Plenary discussion

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Ed Rubin	Carnegie Mellon University
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Morgan Summers	NETL
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Introduction

The International Energy Agency hosted the fourth meeting of the Expert Group on CCS costs on November 6-7 2013 in Paris.

The current knowledge regarding the costs of CCS applications – particularly for industry - were presented at the meeting and the agreed outcomes for the Group to take forward are included in these proceedings.

This work program consists of two streams of activities. The first stream, to improve the transparency of CCS cost calculations for industrial applications of CCS, included:

- Consideration of a number of case studies industrial applications and identification of the challenges that arose estimating costs.
- What types of methodologies are used to estimate costs for industrial applications and how do they differ from power cost estimation processes.
- Identification of costs in retrofit applications in the power sector, refinery, and demonstration plants currently under construction.

The second stream of activity focused on identifying and comparing the variety of methods used in cost estimation of new capture concepts and advanced technologies. Costs for this class of technology are the most uncertain, yet decisions on R&D priorities and scale-up of advanced process often depend on projections of future cost. Examples of approaches considered include:

- probabilistic methods in conjunctions with traditional engineering economics;
- 'learning curves' to project future costs;
- expert elicitations regarding future cost and performance;
- risk-based methods associated with technology readiness levels; and
- non-economic measure such as the projected energy penalty of alternative capture approaches

Finally, a plenary session on reforming the Expert Cost Group as a 'CCS Costs Network' under the IEA-GHG 'network' framework was held. This arrangement was agreed as the appropriate step forward.

The meeting was organized by a Steering Group including representatives from: Carnegie Mellon University (Ed Rubin), Electric Power Research Institute (Richard Rhudy), Global CCS Institute (Christopher Short), International Energy Agency (Sean McCoy), IEA Greenhouse Gas R&D Programme (John Davison), MIT Carbon Sequestration Initiative (Howard Herzog), Michael Matuszewski (National Energy Technology Laboratory) and Vattenfall (Clas Ekström).

Reporteurs for the two days were Howard Herzog, Michael Matuszewski and Christopher Short.

Presentation Summaries

Industrial capture costs

Introducing issues for industrial applications of CCS, John Davison (IEAGHG) noted three key challenges:

- A distinguishing feature compared to power is that CO_2 production in industrial sites is often an inherent part of the industrial process. For example, 60 per cent of the CO_2 released in cement production occurs in the calcination process.
- That there are a large variety of sources and technology applications in industrial processes, and often these plants are smaller in CO_2 'output' than a power plant. As a result, developing a standardized 'plant' to act as a baseline in a cost study is difficult.
- Many of the potential applications are located in non-OECD countries. Unfortunately, overall awareness of existing cost studies or exercises in non-OECD countries is more limited in the general CCS costing community.

The presentations on costs for CCS applications to iron and steel, oil refineries and cement production highlighted the challenges of process and technology selection, the management of a variety of CO_2 sources within a single plant, and that costs remain high for iron, steel and refinery applications – but also varied significantly.

In addition, the addition of capture to these processes had much more complex impacts on the production process than for power generation. For example, JP Birat noted that the addition of capture to iron and steel production could, in some cases, reduce coke consumption – a benefit – but also reduce the availability of fuel gas – a drawback.

For cement cost studies Duncan Barker concurred but identified that there was a good platform of existing studies with both new build and retrofits considered.

All speakers emphasized the importance of transparency and that developing accurate cost estimates requires significant time and money. They cautioned that the current lack of published data on which cost estimates could be based means there is a danger of bias in current estimates of cost.

In discussing methodologies Simon Bennett (IEA) directed attention to the challenges in establishing the boundary and system conditions in an industrial site in a manner to permit cross-study comparisons, and whether there was a robust understanding of costing approaches.

David Butler and Morgan Summers identified specific challenges as:

- Identifying appropriate reference case for determining incremental cost is hard;

- The often multi-product output in industrial applications makes it determining a 'useful' $/unit cost challenging. Similarly, this also meant there were at least three ways of calculating avoid CO_2 costs.
  - Similarly, this presents challenges of getting energy and mass flows in an industrial plant.

In addition to the issues identified above, Chris Hendriks also noted that many industrial applications would be retrofits rather than greenfield applications with site specific issues for cost estimates. Comparing the market conditions to power, he noted that industrial application differences include:

- Higher risk, shorter payback periods and often low margins. This implies the appropriate return required was higher; and
- Industry is often exposed to global competition but CCS applications may affect product quality through changes in heat or power availability.

Cost Estimation Methods for New and Advanced Capture Technologies

In the session on the first day, three speakers addressed this topic.

The first speaker was Ed Rubin of Carnegie Mellon University. He described five approaches to costing new and advanced technologies:

1. Use conventional methodology but incorporate the correct process and project contingencies
2. Incorporate uncertainty into the costing analysis
3. Use learning curves (this approach is better for technologies that are already commercially deployed)
4. Use expert elicitations
5. Do not conduct a detailed cost analysis, but focus on the performance metrics of the process, such as energy penalty

The second speaker was David Engel from the Pacific Northwest National Laboratory. His methodology incorporated three of Ed's approaches – using conventional methodology plus uncertainty plus expert elicitations. Much of the talk focused on how one can relate the uncertainty of a process to its Technology Readiness Level (TRL). David is implementing this approach as part of DOE's Carbon Capture Simulation Initiative (CCSI) project.

The third speaker was by Jean-François Léandri of Alstom Power. Starting with today's processes, he showed how to project their costs over time by utilizing learning curves. A major theme was that the process has to be disaggregated the different components and the learning curves applied to the components, not the overall process.

Power Plant capture: case studies

The use of carbon capture to mitigate emissions in electricity production is the most widely studied application of CCS technologies. This brief session provided

an overview of recent studies on retrofits and the output of a recent CCS Cost Reduction Taskforce in the United Kingdom.

The first speaker, Des Dillon from EPRI, summarising five EPRI capture retrofit studies across various North American sties noted that:

- Despite the variances in base plants at the study site, there were no technical barriers to retrofitting the plants with post-combustion capture technologies targeting 90 per cent capture was possible;
- Both the capital investment and the operating costs varied significantly across plants, with future solvents currently in development offering opportunities to reduce the energy penalty by up to 2.5 per cent.
  - Though implicitly the studies assumed the plants had no further operating life in determining LCOE and avoid carbon costs;
- Lower unit costs for retrofits were reflected in:
  - Good initial base line plant efficiency
  - Lower age
  - Larger units offering economies of scale
  - Sufficient space available in the right plant areas

The second speaker, Wilfred Maas, noted a number of cost items can have a significant impact overall on costs for a large-scale demonstration plant including expected capacity factors, the cost of capital, operating life-time, network costs and fuel prices. The uncertainty relating to fuel prices, network costs and operating time (both average capacity factors and overall lifetime) also significantly affect the overall uncertainty for costs.

In discussing the nearly completed Boundary Dam CCS plant, Max Ball discussed that the long-term planning was effective with projected costs for the new build elements of the repowering of unit at Boundary Dam came in as expected. However, unexpected costs came in from dealing with issues relating to issues in the existing power plant. For example, discovery of asbestos in certain areas and that structural loads in the boiler house were no longer in compliance with modern structural codes. These 'unknown unkowns' had increased the overall plant cost.

With the knowledge gained during construction and the knowledge and learning derived from operation of the retrofitted unit for a 2-year period, it is anticipated that units 3 and 4 at Boundary Dam could be repowered without subsidy post-2016. Of course, other issues, such as gas prices, would affect any investment decision.

Break-out session discussions

Cost Estimation Methods for New and Advanced Capture Technologies

The breakout session discussing this topic was wide-ranging. There was uneasiness about trying to predict costs for a process in its early stages of development. There is just too little known about the process to make a credible estimate. However, costing exercises can be useful in process development. There was consensus around the following two statements:

- Process simulation (including costing) is an important tool to help development, not necessarily to predict absolute costs
- Early costing helps you understand if you are in the range needed for commercial systems, giving you a "cost potential"

However, there were some key questions that were hard to answer in the breakout. These were:

- At what level of development are we comfortable in making a detailed cost estimate?
- How do contingency factors change as a function of TRL?

These are questions that need to be explored more.

In terms of actual costing methodology, there was consensus that the approaches Ed Rubin set out in his presentation were valid if used properly. Further, it is not a case of choosing an approach, but the approaches could be combined. The following methodology was proposed:

- At a minimum, one needs a process design and credible performance metric. Without this, one cannot proceed.
- A process design and performance metrics allow one to do a conventional cost estimate. However, it is essential to use correct factors for project and process contingencies based on how mature the process is and how well defined the design is.
- At this point, one can add in uncertainty, as well as input from expert elicitations.

The cost estimate that results from this exercise gets you to the 'start of learning curve'. As commercial deployment starts, a reduction in costs can be expected.

General recommendation for moving forward included three suggestions for best-practice guidelines:

- Guidelines on when to do cost estimates
- Guidelines for conducting a cost estimate of emerging processes (as outlined in the previous paragraph). It should include:
  - Appropriate contingency factors

  - Checklists of what needs to be included

- Guidelines for moving applying learning curves

Industrial capture costs

This is a joint summary from the two break-out sessions

Initial discussion

There was a great deal of discussion regarding the unique characteristics of industrial type plants both within and across industrial platforms, resulting in three major themes of the immediate problem types that need to be addressed:

- Extreme diversity
- Many plant types
- Multiple industries

It was immediately evident that there are few, if any, accepted baseline plants for comparison. Furthermore, the unique product slate and associated specifications that need to be met in some cases (e.g. refineries, cement) generates great concern over how the balance of plant will be affected by integration of CCS technologies. Different candidate CCS technologies are also a critical consideration as they will affect different processes in different ways. Lastly, the captured cost allocation and reporting in markets with multiple products must be carefully defined in order to appropriately assign cost and allocate risk.

Methods of Addressing Identified Problems

The key areas for developing a methodology for industrial costing applications included:

- Industrial knowledge
- Applicable methods
- Consistency across applications

However, caution on using the term 'industrial sector' as a catch-all was repeatedly emphasized because of the large differences between industries such a iron and steel, oil refining or natural gas processing.

Once critical issues were identified, discussion focused on ways to assess captured costs by properly constructing a study that will objectively inform the industry while employing a consistent methodology for CCS cost comparisons. Critical elements of this type of study were not unlike those in the costing methodologies developed for power plants:

- Must be transparent
- Clear Baseline systems/subsystems to facilitate unbiased comparisons
- Clear economic calculations and key financial metrics
- Clear definition of capture system and relevant assumptions

It was agreed that concessions must be made more frequently in the industrial sector as opposed to the power sector when settling on a baseline plant and general methodologies for CCS cost comparisons since there are many more unique differences from plant to plant in the industrial sector. This should be done with the acknowledgement that a transparent study will allow straightforward, if not simplistic, reconciliation of differing assumptions.

The consideration around metrics – such as $/product or avoid cost – also present challenges in industrial settings due to the joint-product nature of many operations. Although $/product can often be a clear term for communicating the imact on an industry via changes in margins or the prices customers see, the accounting rules for cost allocation in joint products (eg th various outputs from a refinery, or a polygen plant) often represent arbitrary allocations to products reflecting where value is being determined in the individual product markets.

Recommendations and proposed follow-up actions

- Establish a task force to move the novel capture process cost estimation agenda forward.
  - Ed Rubin volunteered to lead the task force. Ed will reach out to people to join the task force, but contact Ed if you interested in participating.
- Establish a task force to develop a costing methodology to enable comparison CCS applications in industrial settings.
- Industry was invited to lead this work that would include:
  - Remaining cognizant of the purpose of cost estimates and the audiences they are prepared for;
  - Begin effort to establish accepted baseline plants and relevant subsystems
    - … Despite potential plant design differences existing in practice, consider how plant subcomponents might able to be standardized in costing studies.
  - Transparency and completeness of assumptions is paramount.
    - … Establish accepted product slate and requirements for production
    - … Establish accepted assumptions on product selling prices
    - … Clearly define scope of problem/analysis
  - Develop methodology for isolating captured/avoided cost
    - … ‘Before CCS vs. After CCS’
    - … Carefully assess appropriate metrics: $/product and $/tonne avoided
  - Develop sensitivity of key metrics to market based assumptions

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