Report of a Recent CCS Cost Workshop: Part I

Audiences, Measures and Methods for CCS Costs

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Background

• In recent years, reported costs of CCS have increased. There’s been growing interest—and growing confusion—over the cost of CCS in different applications.

• This led to an ad hoc meeting of ~20 people last fall during GHGT-10 (organized by J. Davison and H. Herzog) to discuss interest in a network or workshop focused on CCS cost issues.

• The response was extremely positive. Seven people agreed to form a steering committee to plan a workshop in the March 2011 time frame, focused on CCS at power plants.

• The workshop was held on March 22-23 at the IEA offices in Paris. 40 invited participants attended.
Steering Committee

- John Davison, IEA GHG
- Clas Ekström, Vattenfall
- Matthias Finkenrath, IEA
- Howard Herzog, MIT
- Richard Rhudy, EPRI
- Ed Rubin, Carnegie Mellon
- Chris Short, GCCSI
Workshop Participants

- Experts from industry, government, academia, NGOs
  - Alstom Power, Amec, BG Group, Carnegie Mellon University, Clean Air Task Force, CSIRO, DOE/NETL, E.On gas storage, ENEL, EPRI, ExxonMobil, Foster Wheeler, gasNatural fenosa, GCCSI, IEA, IEAGHG, MIT, Panaware ab, RWE Power, Schlumberger, SFA Pacific, Shell, Southern Company, Statoil, Suncor, Teekay Shipping, Tel-Tek, Tsinghua University, University of Ulster, Vattenfall
- Experts from Europe, the Pacific, and North America
  - Australia, Canada, China, France, Germany, Italy, Netherlands, Norway, Spain, Sweden, UK, USA

Workshop Agenda – Day 1

**Keynote 1: Audiences and Uses for CCS Cost Estimates (Herzog)**
- Government, Industry, NGO respondents
- Open discussion

**Keynote 2: CCS Costing Methods and Measures (Rubin)**
- Vendor, Utility, R&D organization respondents
- Open discussion

**Keynote 3: Status of CO₂ Capture Costs (Finkenrath)**
- Europe, North America, Asia/Pacific respondents
- Open discussion

**Keynote 4: Status of CO₂ Transport Costs (Nilsson)**
**Keynote 5: Status of Geologic Storage Costs (Tombari)**
- Transport, Storage, Policy Expert respondents
- Open discussion
Workshop Agenda – Day 2

Breakout Session 1a: Capture Costs
Breakout Session 1b: Capture Costs
Breakout Session 2: Transport Costs
Breakout Session 3: Storage Costs
  - Further discussion of topics presented on Day 1
  - Need, role and agenda for a CCS cost network

Reports from Breakout Sessions

General Discussion:
  - Major conclusions/insights from the workshop
  - Recommendations/plans for follow-up action

Today’s Agenda

• I will summarize the keynote sessions on audiences, measures, and methods of CCS costing
• Howard Herzog will summarize sessions on the status of CCS costs, and the outcomes of the workshop
• Barry Jones and Stu Dalton will offer brief comments, followed by audience Q&A
• This afternoon in session 3-G we (plus John Tombari) will continue the discussion of CCS cost issues
Audiences for CCS Costs

Users (and Generators) of CCS Cost Estimates

Many people use cost estimates in many ways

**Government**
- Policymakers
- Analysts
- Regulators
- R&D Agencies

**Industry**
- Operators
- Vendors
- A&E Firms
- Venture Cap.
- Tech Developers
- R&D Orgs

**NGOs**
- Environmental
- Media
- Academia
- Foundations

Source: Howard Herzog / MIT Energy Initiative
Simplified View of the Uses of CCS Cost Estimates

Cost Estimates for CCS (and other technologies)

Technology Assessments
- R&D Priorities
- Capital Investments
- Marketing

Policy Assessments
- Legislation
- Regulation
- Advocacy

CCS in a Mitigation Portfolio

- Many users of CCS costs are also interested in how CCS compares to the cost of other CO₂ mitigation technologies or options
  - A desire for consistency across cost estimates for different technologies, but very difficult to achieve

- Different audiences also typically require (or get) different types and quality of cost information
  - Limited number of comprehensive independent studies vs. “derivative” studies
  - “Top down” vs. “bottom up” estimates
Measures of CCS cost

Common Measures of CCS Cost

- Cost of CO₂ avoided
- Cost of CO₂ captured
- Added cost of electricity
- Capital cost
Dollars per Ton

- This is the metric most commonly used in technical and policy forums to quantify the cost of CCS (as well as other methods of reducing carbon emissions)
- Also the measure that is most easily misunderstood and misapplied

Same Units, Different Meanings

- **Cost of CO\(_2\) Avoided (\$/t CO\(_2\))**
  \[ \frac{($/MWh)_{ccs} - ($/MWh)_{reference}}{(t\ CO_2/MWh)_{ref} - (t\ CO_2/MWh)_{ccs}} \]

- **Cost of CO\(_2\) Captured (\$/t CO\(_2\))**
  \[ \frac{($/MWh)_{ccs} - ($/MWh)_{reference}}{(t\ CO_2/MWh)_{ccs, produced} - (t\ CO_2/MWh)_{ccs}} \]

- **Cost of CO\(_2\) Abated (Reduced) (\$/t CO\(_2\))**
  \[ \frac{($ NPV)_{ccs} - ($ NPV)_{reference}}{(t\ CO_2)_{ref} - (t\ CO_2)_{ccs}} \]

*Use with caution!*
Methods for CCS

cost estimates

E. S. Rubin, Carnegie Mellon

A Hierarchy of Methods

• Ask an expert
• Use published values
• Modify published values
  • Derive new results from a model
  • Commission a detailed engineering study

E. S. Rubin, Carnegie Mellon
Current Status

- Individual organizations have developed detailed procedures and guidelines for calculating power plant costs (capital, O&M, COE) in a consistent fashion.

- However, there are significant differences in the costing methods used by different organizations concerned with CO₂ capture and storage.

Capital Cost Elements in Recent Studies

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<td>Process facilities capital</td>
<td>Bare erected cost (BEC)</td>
<td>Bare erected cost (BEC)</td>
<td>Civil Structural Material &amp; Installation</td>
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<td>Eng'g, home office, overhead &amp; fees</td>
<td>Project Contingency Cost</td>
<td>Project Contingency Cost</td>
<td>Electrical &amp; I&amp;C Supply &amp; Installation</td>
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<td>Contingencies – project and process</td>
<td>Process Contingency Cost</td>
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<td>Total plant cost (TPC)</td>
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<td>EPC Cost before Contingency and Fee</td>
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<td>APU/DC (interest &amp; escalation)</td>
<td>Pre-Production Costs</td>
<td>Fee and Contingency</td>
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<td>Total plant investment (TPI)</td>
<td>Inventory Capital</td>
<td>Total Project EPC</td>
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<td>Owner's costs: operation, preproduction costs, inventory capital, initial catalyst and chemicals, Land</td>
<td>Financing costs</td>
<td>Owner's Costs (excl. project finance)</td>
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<td>Other owner's costs</td>
<td>Total Project Cost (excl. finance)</td>
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<td>Total Capital Requirement (TCR)</td>
<td>Total overnight cost (TOC)</td>
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No consistent set of cost categories or nomenclature across studies.

- E.S. Rubin, Carnegie Mellon

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<td>Direct materials</td>
<td>EPC costs</td>
<td>Pre-licensing costs, Technical and design</td>
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<td>Labour and other site costs</td>
<td>Owner's costs</td>
<td>Regulatory + licensing + public enquiry</td>
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<td>Engineering fees</td>
<td>Total Investment</td>
<td>Eng'g, procurement &amp; construction (EPC)</td>
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<td>Contingencies</td>
<td>Infrastructure / connection costs</td>
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<td>Total Capital Cost (excluded IDC)</td>
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<td>Owner's costs</td>
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<td>Start-up costs</td>
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<td>Total Capital Requirement (TCR)</td>
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### O&M Cost Elements in Recent Studies

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<td>Operating labor</td>
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<td>Maintenance labor</td>
<td>Maintenance labor</td>
<td>Maintenance costs</td>
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<td>Admin. &amp; support labor</td>
<td>Admin. &amp; support labor</td>
<td>Property taxes and insurance</td>
<td>Overhead charges (admin &amp; support labor)</td>
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<td>Variable O&amp;M (excl. fuel)</td>
<td>Maintenance - material</td>
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<td>Maintenance costs</td>
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<td>Consumables (water, chemicals, etc.)</td>
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<td>Waste disposal</td>
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<td>Co- or by-product credit</td>
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<td>CO2 transport and storage</td>
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### Many Factors Affect CCS Costs

- Choice of Power Plant and CCS Technology
- Process Design and Operating Variables
- Economic and Financial Parameters
- Choice of System Boundaries; *e.g.*,
  - One facility vs. multi-plant system (regional, national, global)
  - GHG gases considered (CO₂ only vs. all GHGs)
  - Power plant only vs. partial or complete fuel cycle
- Time Frame of Interest
  - First-of-a-kind plant vs. *n*⁻th plant
  - Current technology vs. future systems
  - Consideration of technological “learning”
Uncertainty, Variability and Bias

- Cost methods can (in principle) account for variability and uncertainty, e.g., via parametric (sensitivity) analysis and/or probabilistic analysis

- Bias can arise in project design specifications and choice of parameters and values for cost estimates
  - Can be difficult to detect or prove
  - Independent (3rd party) evaluations can be helpful

The Devil is in the Details

- Need to improve the reporting and transparency of costing methods and assumptions to improve the understanding of CCS costs
Howard Herzog now will present Part II:

*Workshop reports on status of cost estimates for capture, transport and storage, with plans for follow-on activities*