CCS Cost Estimation Methods in the Coal, Oil and Gas Sectors

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Capture Costs

- The cost of capture is generally expressed as:

Incremental cost to run for a given year / tonnes of CO$_2$ captured

Incremental cost is generally amortized incremental capital, O&M, fuel, etc required to capture CO$_2$
Incremental Cost in Power

Incremental cost can be established two ways:

1) By deriving the explicit costs to complete a CCS retrofit – Price out just the costs of the capture technology and the costs to run it (Works well for a retrofit) = Capex X CRF + O&M + Fuel per year

2) Compare the costs of a plant with CCS less the costs of a plant without CCS (Works well for a greenfield) = 
\[(\text{COE}_{\text{cap}} - \text{COE}_{\text{ref}}) \times \text{MWh}_{\text{cap}}\]
Capture Cost Equation for Power

\[(COE_{cap} - COE_{ref}) \times \text{MWh}_{cap} / \text{CO}_2 \text{ Captured}\]
Effect of Power Derate

Cash Cost of CCS =

\[
(\text{COE}_{\text{cap}} \times \text{MWh}_{\text{cap}} - \text{COE}_{\text{ref}} \times \text{MWh}_{\text{ref}}) / \text{CO}_2 \text{ Captured}
\]

• The numerator is the cash you would spend for both cases

However if the plant is derated society will replace this lost capacity without CCS

\[
(\text{MWh}_{\text{ref}} - \text{MWh}_{\text{cap}}) \times \text{COE}_{\text{ref}} / \text{CO}_2 \text{ Captured}
\]

• The numerator is the cost associated with replacing the lost capacity. The sum of the two equations above gives the standard capture cost formula
Avoided Cost Power

- Generally power and steam are taken from a plant to provide the energy required to capture CO₂.
- When a plant is derated, society must replace the lost capacity – CO₂ associated with it is not avoided.

\[
\text{CO₂ Captured} = (\text{Int}_{\text{ref}} \times \text{MWh}_{\text{ref}} - \text{Int}_{\text{cap}} \times \text{MWh}_{\text{cap}}) - (\text{MWh}_{\text{ref}} - \text{MWh}_{\text{cap}}) \times \text{Int}_{\text{ref}}
\]

Or Avoided Mass of CO₂ = \((\text{Int}_{\text{ref}} - \text{Int}_{\text{cap}}) \times \text{MWh}_{\text{cap}}\)

Avoided Cost =
\[
(\text{COE}_{\text{cap}} - \text{COE}_{\text{ref}}) \times \text{MWh}_{\text{cap}} / (\text{Int}_{\text{ref}} - \text{Int}_{\text{cap}}) \times \text{MWh}_{\text{cap}}
\]
# Oil and Gas Technologies

<table>
<thead>
<tr>
<th>Oil and Gas Processes</th>
<th>Capture Technologies</th>
</tr>
</thead>
<tbody>
<tr>
<td>OTSG</td>
<td>Solvent Scrubbing</td>
</tr>
<tr>
<td>Heaters and Boilers</td>
<td>Oxyfuel - CO2 Condensation</td>
</tr>
<tr>
<td>Fluid Cat Crackers</td>
<td>Fuel Cells (Molten Carbonate/SOFC)</td>
</tr>
<tr>
<td>Steam Methane Reformers</td>
<td>ATR – Low Carbon Fuel</td>
</tr>
<tr>
<td>NGCC / Cogens</td>
<td>Membranes (CO2, H2)</td>
</tr>
<tr>
<td></td>
<td>Cryogenic Separation</td>
</tr>
</tbody>
</table>
Energy Requirement Cases

Steam & Power

Power Plant

CCS

Steam & Power

O&G Complex

Process

CCS

Steam, Power & RFG

Steam & Power

Nat Gas

Energy Requirement Cases

Steam & Power

Power Plant

CCS

Steam & Power

O&G Complex

Process

CCS

Steam, Power & RFG

Steam & Power

Nat Gas
Issues with Oil and Gas

1) Establishing references for determining incremental cost can be hard
2) Estimating the incremental cost can be tricky
3) Determining the mass of CO$_2$ avoided can be difficult
4) Getting a good sense of how CCS will affect the cost of a product is difficult
5) Defining emission intensities for two commodities is complicated
1) References

A reference can be hard to establish for determining incremental cost and CO$_2$ emissions

• What is the reference for a polygen with CCS which produces both hydrogen and power?
  – A polygen without CCS
  – An SMR
  – An NGCC, SCPC etc

• What is the reference for an SOFC with CCS which produces power and steam?
  – An SOFC without CCS
  – An OTSG without CCS
Good References

- A good greenfield reference is generally the one you would build if you didn’t have to do CCS
- The cases with and without CCS should produce similar amounts of stuff to be comparable
- You may want to use more than one reference to complete the calculations
- However, many oil and gas studies assume a retrofit of an existing plant, so reference issues are not as important
2) Estimating Incremental Costs

Estimating the incremental cost can be tricky:

- In some cases when you install CCS some pieces of equipment such as air blowers, compressors, etc are no longer useful. Their cost can be avoided on a greenfield basis but not on a retrofit basis. (Oxyfuel)
- If steam used for CCS is taken from other plant processes, is a cost attributed to it?
- If power used for CCS is taken from elsewhere in the plant, is a cost attributed to it?
- If extra RFG is used as a fuel, is a value attributed to it?
- If less fuel (RFG) is used, is a value attributed to it?
Incremental Costs (con’t)

- If the retrofitted process allows you to change feedstock, how do you account for this? (FCC)
- If the retrofitted process causes a decrease in output how do you account for this?
- For power the standard formula using COE accounts for the cost of derates. When using incremental costs for a CCS project, you may not know what the underlying plant costs is – so calculating the impact of a derate is not possible
3) Mass of CO$_2$ Avoided

What convention to use to determine mass of CO$_2$ Avoided?

- CO$_2$ Avoided = CO$_2$ Capture – CO$_2$ Power Used from Grid + CO$_2$ Credits for Power Produced – CO$_2$ from Extra Fuel Used (Steam) OR

- CO$_2$ Avoided = CO$_2$ in Ref Case – CO$_2$ Emissions – CO$_2$ Power Used from Grid + CO$_2$ Credits for Power Produced OR

- Change in COX / Change in GHG Emission Intensity (This one should only be used as a check, I do all three)
What Information Do You Have?

- If you are supplied with the incremental cost for completing CCS you might not know the CO$_2$ emissions for the reference case and therefore might not be able to use the second and third equation on the previous page.

- In order to use the first equation you will need to know how much extra fuel is used compared to the base case – This can be hard to figure out if you are only given the characteristics for the case with CCS.
Extra Fuel

- If a boiler is increased in size to provide additional steam required by the CCS process extra fuel will be used.
- The GHG emission associated with this extra fuel should be deducted from the CO$_2$ captured to determine the mass of CO$_2$ avoided.
- If a low carbon fuel is produced from natural gas, then extra fuel will be used – you will need to find a way to determine this.
Will CO$_2$ from Steam be Captured?

• If CO$_2$ produced from a boiler is not captured this mass of CO$_2$ should be deducted from the mass captured to determine the avoided mass of CO$_2$

• However, if say 90% of this CO$_2$ is captured from the boiler then effectively only 10% of the CO$_2$ generated by the boiler should be deducted to determine the mass of CO$_2$ avoided

• The previous formulae account for this - check to make sure you get the same results from several calculations
Use Appropriate Intensities

• If power is purchased from the grid for CCS then an emission intensity associated with the power produced should be used.

• An emission intensity for steam supplied to capture CCS should be used or else the explicit amount of CO$_2$ used to produced steam or the fuel consumption and emission intensity of the fuel used to produce steam should be supplied.

• The appropriate emission intensity for changes in fuel consumption should be used - natural gas is generally 0.05 t CO$_2$/GJ but not always.
Complications

• If you replace an OTSG with say a molten carbonate fuel cell you can displace power otherwise purchased by the OTSG from the grid and sell excess power from the grid
• Transmission charges for sales and purchases may not be the same
• If power is sold to the grid one must use the appropriate grid intensity factor
• Some oxyfuel processes end up being more efficient or providing more waste heat for steam production reducing fuel consumption for the underlying process
• Sometimes an existing air blower is no longer operating saving power (Oxyfuel)
Complications (con’t)

• How do you account for an increase or decreases in throughput?
• How do you account for potential changes in feedstock slate?
  – For scoping studies you note it and indicated whether it will have a small or large positive or negative impact
4) Impact on Cost of Products

- Generally CCS is placed on a process which makes an intermediate commodity (steam, heat) not an end product (gasoline, power sold to grid)
- If you are working with incremental costs you may not be able to figure out the % increase in cost for your commodity
- It can be difficult to get a sense for how CCS will impact the cost of an end product particularly if you don’t know how your intermediate product will be used
- It’s hard in some cases to get a feel for how much CCS will impact costs
Levelized Cost

The levelized cost of a commodities could be:

- $/m³ for steam produced by OTSG/boiler – can be translated into $/bbl but might not have other costs to produce oil
- For SMR could translate costs into $/tonne of hydrogen
- For FCC could potentially translate costs into barrels of output
- Not sure what to use for a heater. Could use GJ of heat supplied or on GJ of fuel supplied - Could translate CCS cost into a price increase of fuel
- Similar issue for defining intensities
5) Defining Emission Intensities

If your capture technology produces both steam and power (Cogen, IGCC, Fuel Cells) how do you determine the emission intensities for each commodity?

- Set the emission intensity for one commodity to 0 and solve for the emission intensity of the other and vise versa.
- Plot the values – the resulting line is the relationship between the two intensities.
- Compare to base case emission intensity without CCS.
- Sometimes it is not clear what commodity to use to define the intensity – Heaters?
Comment on Cement

• Many folks are planning to mineralize CO$_2$
• If they sell this mineral to the cement industry it will be calcined and all of the CO$_2$ stored in the mineral will be liberated!
• I have seen many projects pretending to store CO$_2$ this way
• Generally the economics don’t work if the mineral is landfilled
The End