Levelized Cost of Capture (LCOC) and Levelized Cost of CO_2 Avoided (LCOA) Approach

INTERNATIONAL CCS KNOWLEDGE CENTRE

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Calculator Documentation

Economic Assumptions

Assumptions about economic factors are used to convert from Total Overnight Cost (TOC) to Total As-Spent Cost (TASC). This accounts for escalation and the cost of capital during construction. **Escalation** + **Cost of Funding** is determined by the following formulas:

Where:

$$Escalation = \sum_{n=1}^{y} [(1 + i)^{(n-1)} * \%Capital_n]$$

$$Cost\ of\ Funding = \sum_{n=1}^{y} WACC * (y - n + 1) * (1 + i)^{(n-1)} * \%Capital_n$$

Where:

n = the year of capital expenditure
y = total number of years of capital expenditure
i = assumed escalation rate for capital during the expenditure period (nominal or real)
$\%Capital_n$ = percent of TOC expenditure for year n
WACC = weighted average cost of capital

*WACC = % Equity * % Return on Equity + % Debt * % Cost of Debt*

In a recent study [1] undertaken by the International CCS Knowledge Centre, a sensitivity analysis was done to determine the variables that most influenced the levelized cost of capture. It was determined that the discount rate had a significant impact on the final result, so it is important to use a discount rate for the assessment that is representative of the sector and for the size and type of project being considered.

The assumptions also determine the capital recovery factor (CRF), the fixed operations and maintenance levelized cost factor, variable operations and maintenance levelized cost factor and by-product revenue levelized cost factor.

The **capital recovery factor** (CRF) is determined using the following formula:

CRF = (WACC*(1+WACC)^y)/((1+WACC)^y-1)

Where WACC is the weighted average cost of capital (% equity * % return on equity + % debt * % cost of debt) and y is the total number of years of operating years.

The **fixed operations and maintenance levelized cost factor**, **variable operations and maintenance levelized cost factor** and **by-product revenue levelized cost factor** are found using the following formula:

Levelized Cost Factor = WACC*(1+WACC)^y/((1+WACC)^y-1)*(1-((1+i)/(1+WACC))^y)/(WACC-i)

Where WACC is the weighted average cost of capital, y is the total number of operating years, and i is the escalation rate.

Capital Cost, Operations and Maintenance Cost, and By-Product Revenue Inputs

The inputs for capital cost, operations and maintenance (O&M) cost, and by-product revenue are used with the factors determined above to calculate Total As-Spent Cost (TASC) and levelized costs. The next section, Capital and Operations and Maintenance costs, provides more details on the capital values to be considered.

TASC= TOC*(Escalation + Cost of Funding)

The levelized capital cost is found using the following formula:

Levelized Capital Cost = TASC*CRF

The levelized annual operations & maintenance expenses (LOM) is found using the following formula:

LOM = Annual Variable O&M Cost*Levelized Cost factor + Annual Fixed O&M*Levelized Cost Factor

The levelized by-product revenue is found using the following formula:

Levelized By-Product Revenue =By-Product Revenue* Levelized Cost Factor

Process Inputs

In the LCOC calculation "CO_2 captured" refers to the total CO_2 captured by the CCS facility. It includes CO_2 captured from the host facility and CO_2 captured from operation of systems used to support the capture, such as an auxiliary boiler or a combined heat and power plant.

In the LCOA calculation "CO_2 avoided" is the amount of CO_2 that is prevented from being released into the atmosphere compared to a baseline scenario and is calculated using the following formula:

CO_2 avoided = CO_2 emitted from host facility without CCS – CO_2 emitted after CCS

Applying the levelized cost and revenue values found previously to the annual CO_2 captured and CO_2 avoided volumes will provide the levelized $/tonne CO_2 using the following formulas:

$$\text{LCOC} = \frac{\text{Levelized Capital Cost + Levelized O\&M - Levelized By-Product Revenue}}{\text{Annual } CO_2 \text{ captured}}$$

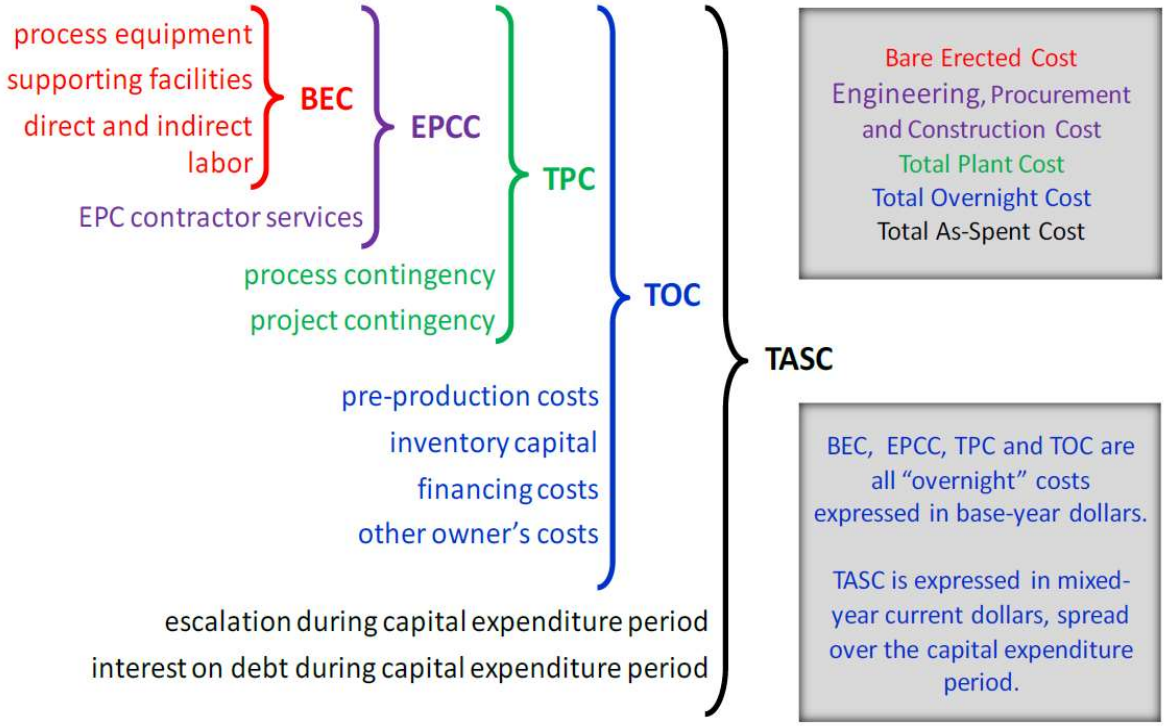
$$\text{LCOA} = \frac{\text{Levelized Capital Cost + Levelized O\&M - Levelized By-Product Revenue}}{\text{Annual } CO_2 \text{ avoided}}$$

Capital and Operations and Maintenance Costs

Capital Costs

Total overnight cost (TOC) is entered and is expressed in base-year dollars and does not include escalation during construction or construction financing costs.

The total overnight cost (TOC) is comprised of the components below:



Reference: "Quality Guidelines for Energy System Studies Cost Estimation Methodology for National Energy Technology Laboratory (NETL) Assessments of Power Plant Performance" [2] February 2021.

For a carbon capture facility, the following are suggested capital costs to include for the analysis.

CCS Facility Capital Cost (Transportation and Storage Capital)

- Upgrades for CCS Purpose
- Flue Gas Ducting
- Flue Gas Pretreatment
- Booster Fan
- All Equipment associated with CO_2 Capture
- CO_2 Compression and Dehydration
- Combined Heat and Power and/or Auxiliary Boiler
- Heat Rejection
- Other

Operations and Maintenance Costs

For a carbon capture facility, the following are suggested operations and maintenance costs to include for the analysis.

CCS Facility O&M Cost (Transportation and Storage O&M Cost)

- Utilities – steam power, natural gas, etc.
- Chemical Costs – solvent, caustic, etc.
- Makeup Water
- Demineralized Water
- Water Treatment
- Operating Labour and Maintenance
- Waste Removal
- Other

References

[1] The International CCS Knowledge Centre, "Lessons Learned from 11 Industrial FEED Studies," *Emissions Reduction Alberta*, Oct. 2024, [Online]. Available: https://www.eralberta.ca/wp-content/uploads/2024/11/Lessons-Learned-from-11-Industrial-CCS-Feed-Studies.pdf

[2] J. Theis, "Quality Guidelines for Energy Systems Studies: Cost Estimation Methodology for NETL Assessments of Power Plant Performance," Feb. 2021. doi: 10.2172/1567736.