
Does 45Q Make CCUS Commercially Viable? A Discounted Cash Flow Analysis of the Phased Tax Credit Structure Across Industrial Sectors

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Abstract

This working paper quantifies the financial viability of carbon capture, utilization, and storage (CCUS) projects under the United States Section 45Q tax credit (Inflation Reduction Act, P.L. 117-169, as amended by P.L. 119-21) using a project-level discounted cash flow (DCF) model calibrated to publicly available cost data. Two representative project types are analysed: a high-purity point source (SMR/ammonia; cost of capture \approx \$30/t) and a low-purity industrial source (cement; cost of capture \approx \$100/t). The phased structure of 45Q — direct pay in Years 1–5 and transferability market access in Years 6–12 at an estimated 88-cent discount — does not consistently produce positive net present value (NPV) at a 10% hurdle rate across the modelled carbon price range of \$65–\$130/t. Full-lifecycle IRR for the high-purity case reaches the hurdle rate only when carbon prices exceed approximately \$170/t through Year 25. The cement case remains NPV-negative across all scenarios at current CAPEX levels. This paper introduces the concept of a **dual post-45Q threshold** — a short-run shutdown line and a long-run exit line — defining a “zombie zone” in which projects continue operating but cease attracting capital investment. The findings suggest that 45Q reduces investment losses without consistently generating commercial returns at modelled CAPEX levels, and that current project final investment decisions (FIDs) are likely driven by non-IRR strategic considerations.

1. Introduction

The US Section 45Q tax credit, substantially expanded under the Inflation Reduction Act of 2022 (IRA; P.L. 117-169) and preserved under the One Big Beautiful Bill Act of 2025 (OBBBA; P.L. 119-21), provides \$85 per tonne of CO₂ for geological storage and \$180 per tonne for direct air capture (DAC). The credit applies for 12 years from placement in service; qualifying construction must commence before January 1, 2033. The OBBBA further raised the 45Q credit for CO₂ used in enhanced oil recovery (EOR) or other specified commercial purposes to parity with geological storage at \$85/t for facilities placed in service after July 4, 2025, and introduced foreign entity of concern (FEOC) restrictions on credit eligibility and transferability.

A critical but underanalysed feature of 45Q is its phased payment structure. Years 1–5 allow direct pay — effectively a cash refund from the US Treasury irrespective of the entity's tax liability. Years 6–12 require either offsetting federal tax liability or selling credits via the transferability market established under IRA Section 6418. Market data indicate that transferability transactions occur at approximately 85–92 cents per dollar of credit face value (Cherry Bekaert LLP, 2025; Reunion Infrastructure, 2024), with the discount reflecting diligence risk, counterparty negotiation, and market supply-demand conditions.

This paper asks: given this phased structure, does the 45Q credit make CCUS projects commercially viable across representative industrial sectors? Commercial viability is defined here as achieving positive NPV at a 10% discount rate over a 25-year project life.

2. Methodology

2.1 Model Structure

A project-level unlevered DCF model is constructed with annual time steps over a 25-year operating life, preceded by a construction period (2 years for Case A; 3 years for Case B). Capital expenditure is distributed evenly over the construction period. Operating cash flows begin in Year 1.

Annual net cash flow is calculated as:

$$\text{Net CF} = (\text{Carbon revenue} + 45\text{Q credit}) - (\text{Fixed OPEX} + \text{Variable OPEX} + \text{T\&S cost}) - \text{Major maintenance}$$

The 45Q credit is applied as follows:

- Years 1–5: credit at full face value (\$85/t), received as direct pay
- Years 6–12: credit at 88% of face value (\$74.8/t), reflecting the transferability market discount
- Years 13–25: no 45Q credit

NPV is computed at a 10% discount rate applied from Year 1. Construction-period cash flows are discounted from their respective years relative to Year 1. IRR is computed using the `numpy_financial` library (Python).

2.2 Project Parameters

Cost data are drawn from Hughes and Zoelle (2023) (NETL DOE/NETL-2023/3907), adjusted from December 2018 USD to 2024 USD using the Chemical Engineering Plant Cost Index (CEPCI). The paper reports 2018-base CEPCI as approximately 603.1 and uses 941.0 for 2024, yielding an escalation factor of 1.560. Note that CEPCI values are proprietary and require a paid subscription to verify; readers are encouraged to check the most current annual average independently. All figures in Table 1 are in 2024 USD unless stated otherwise.

Table 1. Project Parameters

| Parameter | Case A: High-Purity (SMR/Ammonia) | Case B: Low-Purity (Cement) |
|----------------------------|-------------------------------------|---------------------------------------|
| Capture volume | 500 kt CO ₂ /yr (design) | 1,000 kt CO ₂ /yr (design) |
| Capacity factor | 85% → 425 kt/yr actual | 85% → 850 kt/yr actual |
| Total CAPEX | \$750M USD | \$1,200M USD |
| CAPEX per tpa capacity | \$1,500/tpa | \$1,200/tpa |
| Cost of capture (2024 USD) | \$29.6/t | \$100.3/t |
| Fixed OPEX per tonne | \$15.6/t | \$52.9/t |
| Variable OPEX per tonne | \$14.0/t | \$44.8/t |
| T&S OPEX | \$25.0/t | \$25.0/t |
| Construction period | 2 years | 3 years |
| Major maintenance | 15% CAPEX at Year 12 | 10% CAPEX at Years 10 and 20 |
| OPEX inflation | 2.5%/yr from Year 5 | 2.5%/yr from Year 5 |
| Primary NETL source | Ammonia (Table ES-2) | Cement 90% capture (Table ES-2) |

CAPEX calibration notes. For Case A, the Entropy Glacier Phase 2 project (Canada Growth Fund, 2023) provides a reference at approximately C\$200M investment for 185 kt/yr, equivalent to roughly USD 1,600/tpa at 2023 exchange rates; USD 1,500/tpa is used here as a conservative US onshore estimate. For Case B, the Heidelberg Materials Brevik project (Norway) cost approximately €400M for 400 kt/yr post-combustion cement capture (Heidelberg Materials, 2025), or roughly USD 1,100/tpa at 2025 rates. Scale-up to 1 Mt/yr using a 0.7 scaling exponent yields approximately USD 1,100–1,300/tpa; USD 1,200/tpa is used. Transport and storage (T&S) OPEX of \$25/t is consistent with US onshore geological storage estimates in the literature (Global CCS Institute, 2023; NETL range of approximately \$10–50/t depending on distance and reservoir quality). T&S CAPEX is excluded for parsimony; inclusion would reduce project returns further.

Important caveats on the Entropy Glacier reference. The Canada Growth Fund's C\$200M investment covers both the direct investment and the carbon credit offtake commitment structure; the actual capital expenditure attributable to the capture facility is not separately disclosed in public sources. The reported 185 kt/yr capacity is for carbon credits purchased under the offtake agreement, not necessarily the full capture design capacity. Readers should treat the Entropy-derived CAPEX benchmark as an order-of-magnitude calibration rather than a precise primary data point.

Important caveats on the Brevik reference. The €400M project cost for Brevik includes extensive Norwegian government co-funding under the Longship programme and offshore transport and storage infrastructure not representative of a standalone US facility. The unit cost is therefore not directly comparable to a US industrial greenfield estimate and is used here only as a directional cross-check.

2.3 Carbon Price Scenarios

The United States has no federal carbon price. The scenarios below represent the shadow carbon price — or credit revenue — a project would need to sustain positive cash flow, benchmarked against Canadian compliance carbon pricing for comparability. They are not US market forecasts.

Table 2. Carbon Price Scenarios

| Scenario | Carbon Price (USD/t) | Basis |
|----------|----------------------|--|
| Low | \$65/t | Canada federal carbon price, 2025 (C\$95/t × 0.74) |
| Mid | \$100/t | Canada federal trajectory 2030 (C\$170/t × 0.74) |
| High | \$130/t | Canada federal trajectory 2035 (illustrative) |

3. Key Results

3.1 Project NPV and IRR

Table 3. NPV and IRR Results (10% discount rate; 25-year project life; 2024 USD)

| Scenario | Case A IRR (45Q period) | Case A IRR (full lifecycle) | Case A NPV | Case B IRR (full lifecycle) | Case B NPV |
|----------|-------------------------|-----------------------------|------------|-----------------------------|------------|
| \$65/t | Negative | Negative | -\$514M | Negative | -\$1,303M |
| \$100/t | Negative | -4.5% | -\$379M | Negative | -\$1,033M |
| \$130/t | -7.1% | +1.2% | -\$264M | Negative | -\$802M |

At the base CAPEX assumption (\$1,500/tpa for Case A), full-lifecycle NPV is negative across all scenarios. The NPV-neutral CAPEX for Case A at a \$100/t carbon price is approximately \$816/tpa — within the lower bound of the published CCUS cost literature (\$500–1,500/tpa) but below the Entropy Glacier calibration point, and below the Brevik reference range. Case B remains NPV-negative at all scenarios, reflecting the substantially higher cost of capture from low-purity flue gas.

3.2 Post-45Q Thresholds and the Zombie Zone

After 45Q expires at Year 12, project viability is governed by two distinct economic thresholds derived from standard industrial economics:

Table 4. Post-45Q Operating Thresholds

| Threshold | Definition | Case A | Case B |
|-------------------------|---|--------|---------|
| Short-run shutdown line | Carbon price < variable OPEX + T&S (avoidable costs only) | \$39/t | \$70/t |
| Long-run exit line | Carbon price < full COC + T&S (includes capital recovery) | \$55/t | \$125/t |

Between these thresholds lies the "zombie zone": projects that continue operating because avoidable (variable) costs are covered, but that will not attract new capital investment or major maintenance spending. As equipment ages without capital renewal, effective capture volume is expected to decline. This pattern is consistent with EIA projections of post-45Q capture volume reduction in modelled scenarios.

4. Discussion

4.1 Limitations

- CAPEX estimates are derived from a small number of reference projects. They may not reflect US-specific site conditions, permitting costs, labour rates, or supply chain constraints.
- The transferability discount of 88% is a market estimate. Actual transaction prices vary by credit type, counterparty creditworthiness, documentation quality, and market conditions. Industry sources report a range of approximately 85–95 cents per dollar for well-documented credits (Cherry Bekaert LLP, 2025; Reunion Infrastructure, 2024).
- T&S CAPEX is excluded from the model. Its inclusion would reduce project returns.
- The model uses the 88% discount as a proxy for the tax offset pathway in Years 6–12. Corporate tax rate effects and the specific mechanics of tax credit monetisation are not explicitly modelled.
- No revenue from CO₂ utilisation (EOR, industrial use) is modelled. Projects with EOR revenue or alternative offtake would show different economics.
- OPEX inflation is applied uniformly from Year 5. Real inflation trajectories will differ.
- The CEPCI 2024 annual average value used (941.0) is sourced from third-party summaries, as the primary CEPCI data require a paid subscription. A mid-2025 estimate from one aggregated source places the index near 800, suggesting the figure may reflect a specific monthly observation rather than a confirmed 2024 annual average. Readers should independently verify the escalation factor against the primary Chemical Engineering magazine data.

4.2 Why Projects Receive FID Despite Negative NPV

The finding that 45Q does not consistently generate positive NPV at a 10% hurdle rate does not contradict observed project activity. Several non-IRR drivers can justify FID:

- Corporate decarbonisation mandates and Scope 1 reduction commitments
- ESG disclosure requirements and investor relations considerations
- Regulatory pre-compliance in anticipation of future carbon pricing or emission standards
- Strategic optionality: establishing capture infrastructure ahead of anticipated carbon market development
- Offtake agreements with counterparties that value the carbon credit independently of project-level IRR

Distinguishing IRR-driven from mandate-driven investment motivation is important for policy design. If 45Q is intended to mobilise private capital on commercial terms, the results of this model suggest it is insufficient at current CAPEX levels and the carbon price range examined. Complementary instruments — including loan guarantees, revenue support contracts (carbon contracts for difference, CCfDs), or capital grants — may be necessary.

5. Data and Code Availability

All model code (Python) and project parameter assumptions will be made available at:

- GitHub repository: [to be added upon publication]
- Zenodo DOI: 10.5281/zenodo.20819173

Primary data sources are listed in the reference list below.

6. Disclaimer

This is a preliminary working paper produced for academic and professional development purposes. It has not undergone peer review. It does not represent the views of any employer or institution. It is not financial or legal advice. The author is employed by the Government of Alberta; this analysis is based solely on publicly available data and US federal policy and does not address Alberta-specific regulatory frameworks. All opinions are the author's own.

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