Decarbonizing Alberta's Oil Sands: Integrating Electrothermal Energy Storage and Renewable Energy to Reduce Greenhouse Gas Emissions from Steam Production

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Abstract

Electrothermal energy storage (ETES) offers a promising pathway to decarbonize steam production in Alberta's oil sands. Modelling across five electricity supply scenarios shows ETES can cut greenhouse gas emissions from steam-assisted gravity drainage by up to 91.8% with 100% renewable electricity. Although capital costs are higher, ETES becomes cost-competitive when carbon credits from Alberta's TIER system and Canada's Clean Fuel Regulations are applied. Wind and solar assessments confirm strong potential for private-wire ETES in key oil sands regions. However, policy gaps, notably capped carbon pricing and the absence of ETES-specific protocols, remain barriers. ETES is thus technically viable and strategically aligned for industrial decarbonization.

Objectives

01 Assess the technical feasibility of ETES in oil sands steam applications

02 Assess the renewable energy generation potential of oil sand development areas for onsite charging of ETES

03 Quantify emissions reduction potential under alternative electricity scenarios

04 Evaluate economic and policy conditions affecting ETES deployment

05 Identify strategic barriers and opportunities in Alberta's energy transition

Methodology

Research Design

Interdisciplinary & Scenario-Based Approach

Scenario Design

- Alberta Grid (2023)
- 50/50 Natural Gas & Renewables
- 100% Renewables
- Private Wire
- Low-Carbon Grid Charging
- Baseline: Natural Gas Boilers

Data Sources

- Secondary data
- Peer-reviewed literature
- Industry reports
- Public datasets

Analytical Framework

- Technical
- Emissions
- Economic
- Regulatory and Policy Analysis

Key Results

Technical Feasibility of ETES

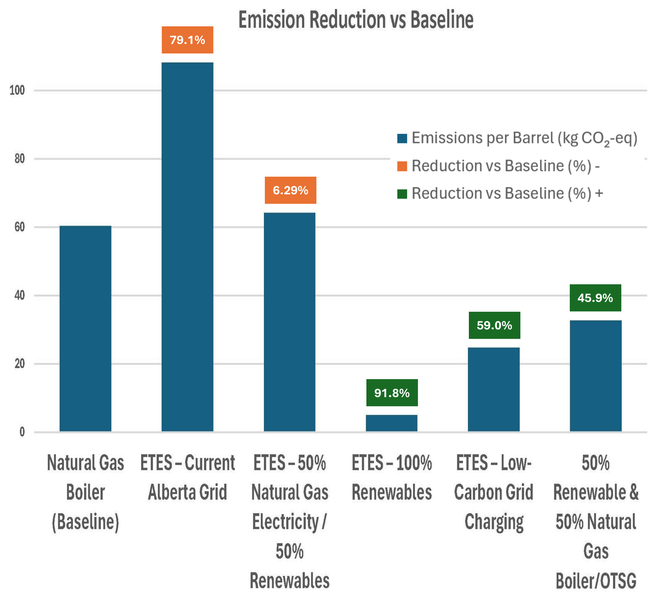
Performance	Deliver required steam temperature (300–1,200°C) for SAGD
Scalability & Durability	Durable, non-toxic materials with a lifespan exceeding 20 years.
Storage & Efficiency	High electrical-to-thermal efficiencies (85–97%) and long storage duration
Grid & Renewable Integration	Charges during periods of surplus wind/solar or low-cost electricity

Emissions Reduction Potential

- Grid matters: ETES emissions depend on the electricity mix: 2023 Alberta grid intensity (438 g CO_2-eq/kWh) made ETES dirtier than natural gas boilers.
- Post-coal advantage: Alberta's 2024 coal phase-out lowers grid intensity, improving ETES feasibility and aligning performance with ~50% renewables scenarios.

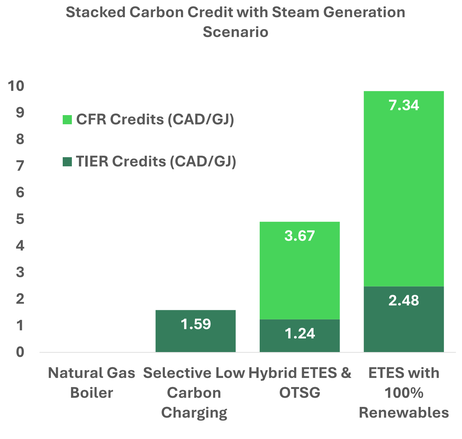
Path to net-zero

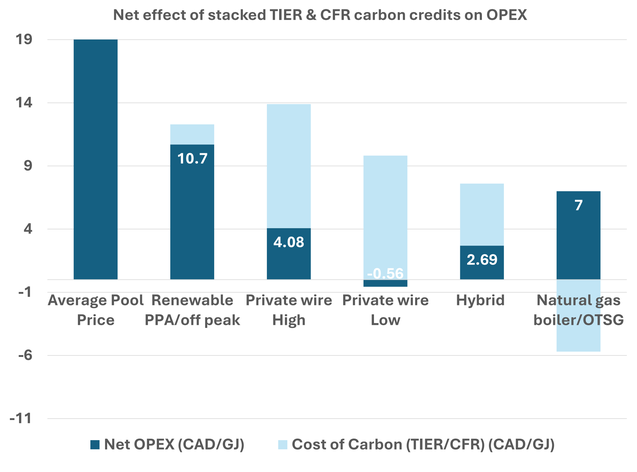
- Best case: 100% renewables → *91.8% emissions reduction*
- Smart charging: Aligning ETES with renewable surpluses → 59% reduction



Economic Considerations

- Renewable-powered ETES can earn up to $9.82/GJ in stacked TIER & CFR carbon credit offsets.
- Without carbon credits, ETES is not cost-competitive.
- ETES economics are less favourable with fossil-heavy grid electricity.
- Renewable-powered ETES + strong carbon credits: The most robust option for long-term cost and emissions wins





Wind & solar Resource Assessment

- Resources align with oil sands hubs (Athabasca, Cold Lake, Peace River).
- Enables private-wire ETES projects with reliable low-carbon steam

Policy & Regulatory Insights

Carbon Pricing Gaps

- Alberta's TIER capped at *$95/tonne*, while credits trade at *$35–50/tonne*.
- Weak investment signals without ETES-specific crediting protocols.

Credit Stacking Potential

- TIER + CFR credits ≈ *$9.8/GJ* with 100% renewables.

Conclusion

01 Technical Feasibility

Viable and can integrate into oil sands SAGD/CSS operations.

02 Emissions Reduction

Contingent on the electricity source. Achieves up to 92 100% renewables, Selective low carbon charging and hybrid configurations

ETES

03 Economics Viability

- Higher CAPEX, OPEX.
- Can generate up to 9.82 CAD/GJ in stacked carbon credit under TIER/CFR.

04 Policy & Regulatory Alignment

- Uncertainty around CFR eligibility and lack of recognition in the TIER protocol.
- Policy misalignment

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