RESEARCH NOTE — SUBMISSION TO PUBLIC CONSULTATION

# ALTO HSR 50-Year Lifecycle CO2 Budget: Parametric Analysis Across Nine Ridership and Grid Scenarios

*April 24, 2026 | Reviewed by Steven Moore and Andrew Hyett*

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| **Prepared by** | ALTO HSR Citizens Research Initiative |
| **Reviewed by** | Steven Moore and Andrew Hyett |
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## EXECUTIVE SUMMARY

This research note presents a 50-year lifecycle $CO_2$ budget for ALTO's proposed Toronto–Québec City corridor, integrating construction-phase and operational-phase carbon analyses into a 3×3 parametric matrix across three ridership scenarios (4M, 8M, 12M annual passengers) and three Ontario grid scenarios (clean 20 g/kWh, current 73.8 g/kWh, gas-expansion 130 g/kWh). Two previously uncosted categories, the cold-climate construction premium (2.30 Mt $CO_2e$ central) and the Leda clay ground treatment penalty (0.80 Mt central), are quantified here for the first time in any ALTO lifecycle analysis. Road severance permanent detour emissions (6,844 t/yr central) are included as a quantified operational category. Key finding: no scenario achieves carbon payback within any credible operating horizon at 4 million passengers once the EV fleet transition is accounted for. At 8M passengers on the current grid with an EV-transition fleet, payback requires approximately 101 years. Only the 12M / clean grid scenario achieves payback within ~32 years.

## Section 1 — Framework and Key Assumptions

This budget integrates two companion research notes into a consolidated 50-year lifecycle $CO_2$ analysis. Construction carbon is treated as a fixed one-time cost, independent of ridership or grid intensity; operational emissions divide into a fixed component (independent of ridership) and a variable traction component.

| Parameter | Value / Basis |
|---|---|
| **Average trip distance** | 650 km weighted (Toronto–Ottawa ~450 km; Toronto–Montréal ~540 km; Ottawa–Montréal ~190 km; Toronto–Québec City ~780 km) |
| **Annual passenger-km** | 4M: 2.60 billion pkm \| 8M: 5.20 billion pkm \| 12M: 7.80 billion pkm |
| **Ontario grid scenarios** | Clean: 20 g/kWh (post-nuclear refurbishment) \| Current: 73.8 g/kWh (2024 IESO actual) \| Gas-expansion: 130 g/kWh (IESO high-gas scenario) |
| **Fixed operational total** | 51,944 t $CO_2$e/yr (central) — includes cold-climate operational premium 13,600 t/yr and road severance detour emissions 6,844 t/yr |
| **Construction scenarios** | Optimistic: 6.87 Mt \| Central: 14.69 Mt \| Pessimistic: 29.60 Mt — all include cold-climate premium and Leda clay |
| **50-year window** | Optimistic opening 2040–2045; operating life to approximately 2090–2095 |

## Section 2 — Construction Carbon: Three Scenarios Including Previously Uncosted Categories

| Category | Optimistic | Central | Pessimistic | Notes |
|---|---|---|---|---|
| **Embodied carbon — materials (concrete, steel, track, electrification, fencing)** | 2.50 Mt | 5.40 Mt | 10.00 Mt | Largest category; 40–60% of base |
| **Heavy machinery / on-site construction (A5)** | 1.25 Mt | 2.10 Mt | 3.30 Mt | ~25% of base; HS2 benchmark |
| **Material transport to site (A4)** | 0.80 Mt | 1.70 Mt | 2.50 Mt | ~17% of base |
| **Tunnels** | 0.40 Mt | 1.25 Mt | 2.50 Mt | Critical undisclosed variable |
| **Bridges and elevated structures** | 0.25 Mt | 0.80 Mt | 1.70 Mt | Major river and terrain crossings |
| **Land clearing and deforestation** | 0.08 Mt | 0.17 Mt | 0.33 Mt | Frontenac Arch mature forest |
| **Debris and waste disposal** | 0.08 Mt | 0.17 Mt | 0.42 Mt | Rock excavation, demolition |
| **BASE CONSTRUCTION SUBTOTAL** | 5.36 Mt | 11.59 Mt | 20.75 Mt | Excl. cold-climate + Leda clay |
| **COLD-CLIMATE CONSTRUCTION PREMIUM (Harbin–Dalian precedent; 1,000 km full corridor)** | 1.21 Mt | 2.30 Mt | 4.35 Mt | NOT IN ANY ALTO DOCUMENT |
| **LEDA CLAY GROUND TREATMENT — Ottawa–Montréal segment (200 km quick clay)** | 0.30 Mt | 0.80 Mt | 4.50 Mt | NOT IN ANY ALTO DOCUMENT |
| **TOTAL CONSTRUCTION** | 6.87 Mt | 14.69 Mt | 29.60 Mt | — |

**PREVIOUSLY UNCOSTED: +3.10 MT $CO_2$E IN THE CENTRAL SCENARIO**

The cold-climate construction premium (2.30 Mt) and Leda clay ground treatment penalty (0.80 Mt) together add 3.10 Mt $CO_2$e to the central construction estimate, representing 21% of the base total (11.59 Mt). Neither category has been acknowledged in any ALTO public document. Eastern Ontario receives 3–5 times more annual snowfall than the Harbin–Dalian reference line, suggesting the cold-climate premium may be conservative.

## Section 3 — Fixed Operational Emissions: 51,944 t CO2e/yr (Central)

| Category | t/yr (Central) | Basis |
|---|---|---|
| **Station operations (HVAC, lighting, escalators, retail)** | 17,500 | Chinese and UK HSR station studies |
| **Track and infrastructure maintenance (base)** | 6,500 | LCA studies including HS2 and Beijing–Shanghai |
| **Rolling stock replacement (annualised over 20–30 yr fleet life)** | 3,000 | UIC fleet lifecycle data |
| **Vegetation management (diesel, herbicide, riparian control)** | 1,250 | Estimated; limited published data |
| **Waste handling and disposal** | 1,000 | Estimated |
| **Marketing, administration, and corporate operations** | 2,000 | Estimated |
| **Decommissioning (annualised over 80-year infrastructure lifecycle)** | 250 | LCA data; ~0.001% of total |
| **COLD-CLIMATE OPERATIONAL PREMIUM — 7 categories (switch heating, catenary de-icing, snow plough fleet, train pre-conditioning, de-icing chemical manufacture, frost maintenance, emergency diesel)** | 13,600 | Harbin–Dalian HSR precedent |
| **ROAD SEVERANCE — permanent vehicle detour emissions (350–700 road closures; light vehicles, school buses, farm machinery)** | 6,844 | Road Severance $CO_2$ Calculation (March 2026); Low 3,934–High 10,851 t/yr |
| **FIXED OPERATIONAL SUBTOTAL** | 51,944 | Applies to all nine scenarios; not sensitive to passenger volume |

# Section 4 — Nine-Scenario Matrix: Annual Operational Emissions and Per-Passenger Benchmarks

| Grid Scenario | 4M pax/yr | 8M pax/yr | 12M pax/yr |
|---|---|---|---|
| **Clean grid (20 g/kWh) — t/yr** | 87,304 t | 101,344 t | 104,984 t |
| **All-in g/pkm (clean)** | 33.6 g/pkm | 19.5 g/pkm | 13.5 g/pkm |
| **Per trip, 650 km avg (clean)** | 21.8 kg | 12.7 kg | 8.8 kg |
| **Current grid (73.8 g/kWh) — t/yr** | 181,944 t | 233,944 t | 246,944 t |
| **All-in g/pkm (current)** | 70.0 g/pkm | 45.0 g/pkm | 31.7 g/pkm |
| **Per trip, 650 km avg (current)** | 45.5 kg | 29.3 kg | 20.6 kg |
| **Gas-expansion grid (130 g/kWh) — t/yr** | 281,004 t | 372,784 t | 395,144 t |
| **All-in g/pkm (gas-expansion)** | 108.1 g/pkm | 71.7 g/pkm | 50.7 g/pkm |
| **Per trip, 650 km avg (gas-expansion)** | 70.3 kg | 46.6 kg | 33.0 kg |

**EV COUNTERFACTUAL — CRITICAL GAP IN ALTO'S ENVIRONMENTAL ANALYSIS**

At the current Ontario grid (73.8 g/kWh), an electric vehicle carrying 1.2 passengers emits approximately 10.2 g $CO_2e$/pkm — lower than ALTO HSR's all-in per-passenger emissions at every ridership level on the current grid (31.7–70.0 g/pkm). By 2040–2045 when ALTO opens, the EV advantage will be larger still. The 'carbon saving' from switching from a car trip to ALTO depends entirely on the assumption that the car is ICE-powered at the time of travel. VIA Rail diesel (~25 g $CO_2e$/pkm) is already lower than ALTO at 4M or 8M passengers on the current grid: passengers diverted from VIA Rail to ALTO produce no net carbon saving. A Beijing–Shanghai ex-post study found that HSR initially increased net emissions because it diverted passengers primarily from existing rail, not from cars and aircraft. ALTO has not published any EV counterfactual analysis.

# Section 5 — 50-Year Lifecycle Totals (Central Construction: 14.69 Mt)

| Grid Scenario | 4M pax/yr | 8M pax/yr | 12M pax/yr |
|---|---|---|---|
| **Clean grid (20 g/kWh)** | 19.06 Mt | 19.76 Mt | 19.94 Mt |
| **Current grid (73.8 g/kWh)** | 23.79 Mt | 26.39 Mt | 27.04 Mt |
| **Gas-expansion grid (130 g/kWh)** | 28.74 Mt | 33.33 Mt | 34.45 Mt |

Construction scenario sensitivity at 12M pax / current grid: optimistic construction (6.87 Mt) → 19.22 Mt total; central (14.69 Mt) → 27.04 Mt total; pessimistic (29.60 Mt) → 41.95 Mt total. The 22.73 Mt construction range (optimistic to pessimistic) is larger than the full 50-year operational range across all grid scenarios at 12M passengers.

## Section 6 — Carbon Payback — EV-Transition Fleet Displaced (Most Policy-Relevant Scenario)

Carbon payback occurs when cumulative modal shift $CO_2$ savings equal the one-time construction carbon debt. The EV-transition scenario (approximately 50% of Canada's vehicle fleet electrified by 2040–2045) is the most policy-relevant, as it represents the fleet composition when ALTO opens. The weighted displaced-mode emission falls from ~100 g/pkm (current ICE fleet) to ~73 g/pkm (EV-transition fleet), materially narrowing or eliminating the annual saving per passenger.

| Grid Scenario | 4M pax/yr — annual saving | 4M pax/yr — payback | 8M pax/yr — annual saving | 8M pax/yr — payback | 12M pax/yr — annual saving | 12M pax/yr — payback |
|---|---|---|---|---|---|---|
| **Clean grid (20 g/kWh)** | 102 kt/yr | ~143 yrs | 278 kt/yr | ~53 yrs | 464 kt/yr | ~32 yrs |
| **Current grid (73.8 g/kWh)** | 8 kt/yr | >500 yrs | 146 kt/yr | ~101 yrs | 322 kt/yr | ~46 yrs |
| **Gas-expansion grid (130 g/kWh)** | Net increase | Never | 7 kt/yr | >500 yrs | 174 kt/yr | ~84 yrs |

**KEY FINDING: NO PAYBACK AT 4M PASSENGERS ON ANY CREDIBLE GRID SCENARIO**

At 4 million annual passengers (comparable to early-phase ridership): on a clean grid, payback requires ~143 years; on the current grid, >500 years; on a gas-expansion grid, never (net emitter). On the current grid with an EV-transition fleet at 4M passengers, ALTO's all-in per-pkm (70.0 g) exceeds the weighted displaced-mode emission (73 g) by only 3 g/pkm. The annual saving falls to just 8,000 tonnes, an implied payback of >500 years. Only the 12M / clean grid scenario achieves payback within ~32 years. The previously uncosted cold-climate premium and Leda clay penalty (3.10 Mt together) extend payback by approximately 21 additional years at 8M passengers on the current grid.

## Section 7 — Critical Gaps in ALTO's Environmental Disclosure

The following are required before any meaningful environmental assessment of the ALTO project is possible:

- Annual ridership projections for the first 10, 20, and 30 years of operation, subject to independent scrutiny
- Ontario grid carbon intensity assumptions for the 2040–2090 operating period, specifically addressing the IESO forecast of rising gas-fired generation emissions to 2030
- A lifecycle carbon assessment (LCA) using recognised standards (PAS 2080 or ISO 14040/14044) for both construction and operations
- The proportion of the corridor requiring tunnels, bridges, and elevated structures — the single most important undisclosed variable for construction carbon
- Any acknowledgement that cold-climate subgrade design requirements apply (3.1 m enhanced subgrade, XPS insulation, cement-stabilised surface layers, enhanced drainage per the Harbin–Dalian HSR precedent)
- Any acknowledgement that Leda clay underlies approximately 200 km of the Ottawa–Montréal segment and requires engineering treatment at 300 km/h
- A winter operations energy and emissions plan quantifying switch heating, catenary de-icing, snow plough fuel, train pre-conditioning, de-icing chemical consumption, and frost-accelerated maintenance
- An EV counterfactual analysis: at what level of vehicle fleet electrification does the per-passenger modal shift saving fall to zero, and when is that threshold expected to be crossed?
- Carbon costs of wetland drainage, peatland disturbance, and riparian corridor destruction along the Eastern Ontario and Ottawa Valley alignments
- A comparison of full lifecycle carbon between the northern and southern route options, using consistent methodology

# Section 8 — Formal Requests

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| 1 | **Publish a lifecycle carbon assessment using recognised standards before consultation closes**<br>ALTO must commission and publish a full lifecycle $CO_2$ assessment using PAS 2080 or ISO 14040/14044 for both construction and operational phases, covering all nine ridership×grid scenarios. The assessment must explicitly address cold-climate construction premiums, Leda clay ground treatment, winter operational energy, and the EV counterfactual. This is the minimum standard for a federally funded project of this scale. |
| 2 | **Disclose tunnel and elevated structure proportions before route selection**<br>The single most important undisclosed variable for construction carbon is the proportion of the corridor requiring tunnels, bridges, and elevated structures. ALTO must publish a preliminary infrastructure profile for each corridor option, with ranges for tunnel length, bridge/viaduct length, and at-grade section length, before the consultation closes. |
| 3 | **Acknowledge and quantify the cold-climate construction and operational carbon premiums**<br>ALTO must publicly acknowledge that the corridor's cold-climate operating environment requires design standards equivalent to or exceeding the Harbin–Dalian HSR precedent, and must quantify the additional construction carbon (estimated 2.30 Mt central) and operational emissions (estimated 13,600 t/yr central) from these requirements. |
| 4 | **Publish an EV counterfactual analysis**<br>ALTO must publish an analysis identifying at what level of vehicle fleet electrification the per-passenger modal shift saving from ALTO falls to zero or reverses, and when that threshold is projected to be reached. Given that ALTO is unlikely to open before 2040, and that fleet electrification will be substantially advanced by that date, this analysis is essential to the environmental case for the project. |
| 5 | **Compare full lifecycle carbon between northern and southern corridor options**<br>A comparison of full lifecycle carbon between the northern and southern corridor options, using consistent methodology and covering both construction and 50 years of operations, must be published before route selection. The southern corridor's greater agricultural land clearing, more extensive Frontenac Arch forest fragmentation, and more complex Napanee karst hydrogeology all affect construction carbon in ways that have not been assessed. |

## Key Sources


Harbin–Dalian HSR (HDPDL): Liu et al. (2016) Cold Regions Science and Technology; Miao and Niu (2020, ScienceDirect); XPS insulation engineering test (ResearchGate 2016); HDPDL operational cost overrun 25% (CN¥95B vs CN¥76B planned).

HS2: BBV Carbon Reduction Report (2024); HS2 Net Zero Carbon Plan; HS2 Environmental Statement (2013).

California HSR lifecycle: Chester and Horvath, UC Berkeley (2010); Chang and Kendall (2011, ScienceDirect). 71-year payback estimate.

Beijing–Shanghai HSR: Chang et al. (2019); CRH380BL 20-year lifecycle (ScienceDirect 2025). Ex-post study: HSR initially increased net emissions by diverting from existing rail.

Ontario grid: CER Provincial Energy Profiles (2022); GTHA Carbon Emissions Inventory (2024, 73.8 g $CO_2e$/kWh); IESO Annual Planning Outlook (high-gas scenario 10.9–12.2 Mt by 2030).

NRC Surficial Geology and Sensitive Marine Clay database; NRC Quick Clay research programme. Champlain Sea sensitive marine clay, 200 km Ottawa–Montréal segment.

Construction carbon factors: C40 concrete 371 kg $CO_2/m^3$ (PMC/NCBI Railway Construction Carbon Database); structural steel 1,900 kg $CO_2$/t (World Steel Association).

Road severance $CO_2$: Alto HSR Road Severance $CO_2$ Calculation (March 2026). Low 3,934–central 6,844–high 10,851 t/yr; 50-yr EV-adjusted range 97,567–277,720 t $CO_2e$.

UIC Carbon Footprint of High Speed Rail (2011); Carbon Footprint of Railway Infrastructure (2016).

IPCC 2014 Wetland Supplement (2023 updated factors); Ontario Nature carbon storage research.