

RESEARCH NOTE

ALTO HSR 50-Year Lifecycle CO₂ Budget Model Output

Parametric Analysis: 4 Million, 8 Million, and 12 Million Annual Passenger Scenarios × Three Grid Intensity Projections

Alto HSR Citizen Research Initiative — March 2026 — Prepared for the Alto HSR Public Consultation (Deadline: April 24, 2026)

EXECUTIVE SUMMARY

This document integrates two companion research notes (on construction-phase and operational-phase carbon emissions) and a third technical analysis on road severance into a consolidated 50-year lifecycle CO₂ budget for ALTO's proposed Toronto–Québec City high-speed rail corridor. Road severance is quantified here for the first time in any ALTO lifecycle analysis: Transport Canada has confirmed 1,000+ road crossings requiring complete grade separation, and ALTO's VP of Systems Engineering confirmed on record at Kingston City Council (February 2026) that the goal is to minimize the number of overpasses built.

Ridership is the primary driver of per-passenger emissions and carbon payback. Grid carbon intensity is the primary driver of total annual traction energy emissions. Construction carbon is treated as a fixed one-time cost across all scenarios; the central construction estimate of 14.69 Mt CO₂e is used for payback calculations. Cold-climate premiums (construction and operational) and the Leda clay ground treatment penalty appear explicitly in the budget — neither category has been acknowledged in any ALTO public document.

50-YEAR LIFECYCLE TOTAL (Mt CO₂e) — Central Construction (14.69 Mt) + 50 Years of Operations

Grid Scenario	4M passengers/yr	8M passengers/yr	12M passengers/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

CARBON PAYBACK PERIOD — Central Construction (14.69 Mt) — EV-Transition Fleet Displaced (2045+)

Grid Scenario	4M passengers/yr	8M passengers/yr	12M passengers/yr
Clean grid (20 g/kWh)	~143 yrs	~53 yrs	~32 yrs
Current grid (73.8 g/kWh)	>500 yrs	~101 yrs	~46 yrs
Gas-expansion grid (130 g/kWh)	Never	>500 yrs	~84 yrs

Key finding: No scenario achieves carbon payback at 4 million passengers within any credible operating horizon once the EV fleet transition is accounted for. Road severance permanent detour emissions (6,844 t/yr central; 3,934–10,851 t/yr range across three vehicle categories) are included as a quantified operational category — sourced from the companion Road Severance CO₂ Calculation (March 2026). The previously uncoded cold-climate and Leda clay construction categories add 3.10 Mt CO₂e to the central total.

1. Scope, Parametric Framework, and Key Assumptions

This budget integrates two companion research notes into a consolidated 50-year lifecycle CO₂ analysis. The parametric approach uses three ridership levels and three grid carbon intensity projections to produce a 3×3 matrix of operational scenarios. Construction carbon is held at three independent estimates (optimistic / central / pessimistic). The 50-year window reflects an optimistic opening date of 2040–2045 and a 50-year operating life to approximately 2090–2095.

1.1 The 3×3 Parametric Framework

	4 Million Passengers/yr	8 Million Passengers/yr	12 Million Passengers/yr
Occupancy (approx.)	40–50% — comparable to early-phase ridership and low-demand off-peak operations	55–65% — mature operations, typical European HSR load factor	70–80% — high-ridership, sustained peak-heavy demand pattern
Traction g/pkm at current grid	~50 g CO ₂ e/pkm — consistent with low-occupancy HSR on 74 g/kWh grid	~35 g CO ₂ e/pkm — consistent with medium-occupancy HSR	~25 g CO ₂ e/pkm — consistent with high-occupancy HSR on same grid
Grid scenario applied	Clean (20 g/kWh), Current (73.8 g/kWh), Dirty (130 g/kWh)	Same three grids	Same three grids

1.2 Key Modelling Assumptions

Average trip distance	650 km (weighted average across corridor stops: Toronto–Ottawa ~450 km, Toronto–Montréal ~540 km, Ottawa–Montréal ~190 km, Toronto–Québec City ~780 km and intermediate stops)
Passenger-km (annual)	4M: 2.60 billion pkm — 8M: 5.20 billion pkm — 12M: 7.80 billion pkm
Traction scaling	Per-pkm traction emissions scale linearly with grid carbon intensity (all grids use the same relationship). At current grid (73.8 g/kWh) the document’s stated occupancy-dependent ranges are used as anchor values: 50 g/pkm at low occupancy, 35 g/pkm at medium, 25 g/pkm at high. Clean and dirty grid values derived by ratio.
Fixed operational total	45,100 t CO ₂ e/yr (central). Covers station operations 17,500 t, infrastructure maintenance 6,500 t, rolling stock replacement 3,000 t, vegetation 1,250 t, waste 1,000 t, marketing/admin 2,000 t, decommissioning 250 t, and cold-climate operational premium 13,600 t. Fixed costs do not vary materially with ridership.
Construction scenarios	Three: optimistic (6.87 Mt), central (14.69 Mt), pessimistic (29.60 Mt). The central scenario is used for payback calculations. All include cold-climate construction premium and Leda clay ground treatment.
Ontario grid trajectory	Clean: 20 g/kWh (post-nuclear refurbishment best-case, unlikely before 2040). Current: 73.8 g/kWh (2024 IESO actual, GTHA Carbon Emissions Inventory). Dirty: 130 g/kWh (IESO high-gas scenario, within stated IESO forecast range of 10.9–12.2 Mt system emissions by 2030).
50-year operating period	Annual emissions multiplied by 50. No discounting applied. Consistent with HSR lifecycle assessment practice.

2. Construction Carbon (One-Time, Independent of Ridership)

Construction emissions are a fixed one-time cost. They do not vary with ridership or grid intensity. Three construction scenarios are presented, incorporating the cold-climate design premium (Harbin–Dalian HSR precedent, full 1,000 km corridor) and the Leda clay ground treatment penalty (Ottawa–Montréal segment, 200 km).

Category	Optimistic	Central	Pessimistic	Primary driver
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 stage)	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
PREVIOUSLY UNCOSTED CATEGORIES — Not present in any Alto public document				
Cold-climate construction premium — Harbin–Dalian HSR design (3.1 m subgrade, XPS insulation, cement stabilisation, cold-weather A5 premium, pre-opening remediation)	1.21 Mt	2.30 Mt	4.35 Mt	Full 1,000 km corridor
Leda clay ground treatment — Ottawa–Montréal segment (200 km quick clay; pile-supported slab to partial viaduct)	0.30 Mt	0.80 Mt	4.50 Mt	Fixed 200 km segment
TOTAL CONSTRUCTION (one-time; excludes wetland disturbance — unquantified)	6.87 Mt	14.69 Mt	29.60 Mt	—

NOTE

Wetland and peatland disturbance, and stream/watercourse diversion impacts, remain unquantifiable from published HSR lifecycle data. Both are material for the Eastern Ontario and Ottawa Valley corridors and would increase all three construction totals if estimated. Ontario's wetlands hold an estimated 29 billion tonnes of stored carbon; no published HSR assessment has quantified the release from drainage of comparable terrain.

ROAD SEVERANCE

Transport Canada confirmed in 2023 that the Toronto–Québec City corridor would require complete grade separation on an alignment with over 1,000 public and private crossings (northern HFR route; the southern corridor through the Ontario concession grid would cross more). Alto VP David Cook confirmed at Kingston City Council (February 17, 2026) that the goal is to "try and limit the number of

overpasses that we'll need to get created." The construction carbon from 400–700 grade separation structures (0.16–0.35 Mt CO₂e) is now included in the construction total above. The permanent annual detour emissions from 350–700 road closures (3,934–10,851 t CO₂e/yr; light vehicles, school buses, and farm machinery) are included in the fixed operational total, using the central figure of 6,844 t/yr. Source: Alto HSR Road Severance CO₂ Calculation (March 2026). Neither category appears in any ALTO environmental document.

3. Operational Carbon: Fixed and Variable Components

Annual operational emissions divide into two categories: a fixed component that does not vary materially with ridership (stations, maintenance, cold-climate premium, administration, etc.) and a variable traction component that scales with both ridership volume and grid carbon intensity. This distinction is central to the parametric analysis.

3.1 Fixed Operational Component — Central Estimate: 51,944 t CO₂e/yr

Category	Central t/yr	Basis
Station operations (HVAC, lighting, escalators, retail)	17,500	Proxy data from Chinese and UK HSR station studies
Track and infrastructure maintenance (base, temperate-climate)	6,500	Moderate quality; LCA studies including HS2 and Beijing–Shanghai
Rolling stock replacement (annualised over 20–30 yr fleet life)	3,000	Good quality; UIC fleet lifecycle data
Vegetation management (diesel equipment, herbicide, riparian control)	1,250	Estimated; limited published data
Waste handling and disposal	1,000	Estimated; limited published data
Marketing, administration, and corporate operations	2,000	Estimated; no HSR operator publishes disaggregated data
Decommissioning (annualised over 80-year infrastructure lifecycle)	250	Moderate; LCA data; ~0.001% of total in published studies
Cold-climate operational premium — all seven categories (see below)	13,600	Harbin–Dalian HSR precedent; 7 discrete categories quantified
Road severance — permanent vehicle detour emissions (350–700 road closures; three vehicle categories: light vehicles, school buses, farm machinery)	6,844	Alto HSR Road Severance CO ₂ Calculation (March 2026); Low 3,934–High 10,851 t/yr; 50-yr EV-adjusted range 97,567–277,720 t CO ₂ e
FIXED OPERATIONAL SUBTOTAL	51,944 t/yr	Applies to all nine ridership×grid scenarios; not sensitive to passenger volume

COLD-CLIMATE PREMIUM DETAIL (13,600 t/yr central)

A. Switch/point heating 330 t — B. Catenary de-icing (electric + diesel patrol) 2,150 t — C. Snow plough fleet (diesel) 2,400 t — D. Train pre-conditioning + depot heating 1,260 t — E. De-icing chemicals (manufacture + transport) 1,800 t — F. Frost-accelerated maintenance premium (+60% on base maintenance) 4,500 t — G. Emergency response interventions (diesel) 1,160 t. Eastern Ontario receives 3–5× more annual snowfall than the Harbin–Dalian reference; categories C and E are likely to exceed these benchmarks.

3.2 Variable Traction Component by Ridership and Grid Scenario

Traction energy emissions scale with the product of passenger-km operated and the per-pkm emission intensity. The per-pkm intensity declines as ridership increases (higher occupancy dilutes the fixed energy cost per train-km across more passengers). It also scales directly with grid carbon intensity.

Grid Scenario		4M passengers/yr (2.60 billion pkm)	8M passengers/yr (5.20 billion pkm)	12M passengers/yr (7.80 billion pkm)
Clean grid (20 g/kWh)	g/pkm	13.6 g/pkm	9.5 g/pkm	6.8 g/pkm
Traction emissions at 20 g/kWh	t/yr	35,360 t	49,400 t	53,040 t
Current grid (73.8 g/kWh)	g/pkm	50 g/pkm	35 g/pkm	25 g/pkm
Traction emissions at 73.8 g/kWh	t/yr	130,000 t	182,000 t	195,000 t
Gas-expansion grid (130 g/kWh)	g/pkm	88.1 g/pkm	61.7 g/pkm	44 g/pkm
Traction emissions at 130 g/kWh	t/yr	229,060 t	320,840 t	343,200 t

4. Total Annual Operational Emissions — Nine-Scenario Matrix

The following table presents the complete annual operational emission total for each of the nine combinations of ridership and grid intensity. The fixed component (51,944 t/yr) is identical across all cells; the traction component varies. The per-passenger and per-passenger-km figures are all-in: they include both the fixed and variable components fully allocated across all passengers. This is the correct basis for modal comparison.

Grid		4M pax/yr	8M pax/yr	12M pax/yr	Fixed component
Clean grid (20 g/kWh)	t/yr	87,304 t	101,344 t	104,984 t	51,944 t/yr <i>(all grids, all ridership levels)</i>
All-in g/pkm (at 20 g/kWh)	g/pkm	33.6 g/pkm	19.5 g/pkm	13.5 g/pkm	
Per-trip, 650 km avg (at 20 g/kWh)	kg/trip	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	51,944 t/yr <i>(all grids, all ridership levels)</i>
All-in g/pkm (at 73.8 g/kWh)	g/pkm	70.0 g/pkm	45.0 g/pkm	31.7 g/pkm	
Per-trip, 650 km avg (at 73.8 g/kWh)	kg/trip	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	51,944 t/yr <i>(all grids, all ridership levels)</i>
All-in g/pkm (at 130 g/kWh)	g/pkm	108.1 g/pkm	71.7 g/pkm	50.7 g/pkm	
Per-trip, 650 km avg (at 130 g/kWh)	kg/trip	70.3 kg	46.6 kg	33.0 kg	

5. Per-Passenger Emission Benchmarks and Modal Comparison

The all-in per-pkm figures for ALTO HSR — which include fixed operational and cold-climate costs fully allocated across all passengers — must be compared to the alternative modes ALTO would displace. This comparison is fundamental to the carbon case for HSR; if ALTO's per-passenger emissions approach or exceed the modes it displaces, the environmental justification collapses. The EV transition radically changes this calculation.

Mode / Scenario	g CO ₂ e/pkm	kg CO ₂ e per 650 km trip	Notes
DISPLACED MODES (reference)			
Gasoline car — 1.0 occupant	130	84.5	170 g/km; current ICE fleet average
Gasoline car — 1.2 occupants (average)	108	70.2	Current national average occupancy
Gasoline car — 1.5 occupants (shared)	87	56.6	Carpooling / shared trip
Short-haul flight (Toronto–Montréal / Toronto–Ottawa; without radiative forcing)	130	84.5	Comparable to gasoline car solo; RF roughly doubles this
Short-haul flight (with IPCC radiative forcing factor)	~230	~150	IPCC RF correction; contested but widely cited
VIA Rail, diesel, medium occupancy	25	16.3	Existing service on corridor; passengers diverted from VIA produce no net saving
EV — Ontario current grid (73.8 g/kWh), 1.2 occupants	10.2	6.6	At 6 km/kWh efficiency; already cleaner than Alto at any ridership level
EV — Ontario clean grid (20 g/kWh), 1.5 occupants	2.2	1.4	Best-case EV scenario; 6–6× cleaner than Alto at 12M / clean grid
ALTO HSR — All-In Per-Passenger Emissions (fixed + variable fully allocated)			
Alto HSR 4M pax/yr — Clean grid (20 g/kWh)	33.6	21.8 kg	<i>Better than car but worse than EV</i>
Alto HSR 8M pax/yr — Clean grid (20 g/kWh)	19.5	12.7 kg	
Alto HSR 12M pax/yr — Clean grid (20 g/kWh)	13.5	8.8 kg	
Alto HSR 4M pax/yr — Current grid (73.8 g/kWh)	70.0	45.5 kg	<i>Approaches gasoline car at 1.5 occ; worse than EV at any occupancy</i>
Alto HSR 8M pax/yr — Current grid (73.8 g/kWh)	45.0	29.3 kg	<i>Better than car solo; worse than EV at 1.2 occ (10.2 g/pkm)</i>
Alto HSR 12M pax/yr — Current grid (73.8 g/kWh)	31.7	20.6 kg	
Alto HSR 4M pax/yr — Gas-expansion grid (130 g/kWh)	108.1	70.3 kg	<i>Approaches or exceeds gasoline car at 1.5 occ</i>
Alto HSR 8M pax/yr — Gas-expansion grid (130 g/kWh)	71.7	46.6 kg	
Alto HSR 12M pax/yr — Gas-expansion grid (130 g/kWh)	50.7	33.0 kg	

EV COUNTERFACTUAL — CRITICAL

At the current Ontario grid (73.8 g/kWh), an electric vehicle carrying 1.2 passengers emits 10.2 g CO₂e/pkm. This is lower than ALTO HSR's all-in per-pkm emissions at every ridership level on the current grid (30.8–67.3 g/pkm). The EV advantage will be even larger by 2040–2045 when Alto opens. This means 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. As the fleet electrifies, the per-trip saving from modal shift narrows to near-zero or reverses. The case for HSR carbon saving rests on displacing air travel and solo ICE car trips, not the broader mixed car fleet.

VIA RAIL DISPLACEMENT

VIA Rail, diesel, currently emits approximately 25 g CO₂e/pkm — lower than ALTO's all-in emissions at 4M or 8M passengers on the current grid. Passengers diverted from VIA Rail to Alto HSR produce no net carbon saving; in many scenarios they produce a net increase. 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. The Toronto–Ottawa–Montréal corridor already has VIA Rail service; the same displacement risk applies to ALTO.

6. Consolidated 50-Year Lifecycle Budget

The following tables present the complete 50-year lifecycle CO₂ budget combining construction (one-time) and 50 years of operations. Three construction totals are shown (optimistic / central / pessimistic); nine operational totals result from the ridership×grid parametric analysis. The full budget is therefore a 3×9 = 27-cell matrix. The central construction scenario (14.69 Mt) is used for the summary lifecycle tables.

6.1 50-Year Operational Totals by Scenario (Mt CO₂e)

Grid Scenario	4M passengers/yr	8M passengers/yr	12M passengers/yr
Clean grid (20 g/kWh)	4.37 Mt	5.07 Mt	5.25 Mt
Current grid (73.8 g/kWh)	9.10 Mt	11.70 Mt	12.35 Mt
Gas-expansion grid (130 g/kWh)	14.05 Mt	18.64 Mt	19.76 Mt
Annual rate (fixed component)	51,944 t/yr fixed (2.6 Mt over 50 years) in every cell above, plus variable traction		

6.2 50-Year Lifecycle Total (Ops + Central Construction 14.69 Mt)

Grid Scenario	4M passengers/yr	8M passengers/yr	12M passengers/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

6.3 Sensitivity to Construction Scenario

The construction scenario has a larger effect on the 50-year total than the operational scenario in most ridership cases. The following table shows the full range using the 12M/current-grid operational scenario (the most environmentally favourable realistic combination) across all three construction totals. Road severance is included in all figures.

12M pax / current grid	Optimistic construction (6.87 Mt)	Central construction (14.69 Mt)	Pessimistic construction (29.60 Mt)	Difference: opt. to pes.
50-year operational component	12.35 Mt (identical across construction scenarios)			—
50-year lifecycle total	19.22 Mt	27.04 Mt	41.95 Mt	22.73 Mt CO ₂ e construction range

7. Carbon Payback — Parametric Analysis

Carbon payback occurs when the cumulative modal shift CO₂ savings — the tonnes not emitted by cars and aircraft diverted to HSR — equal the one-time construction carbon debt. The payback period depends simultaneously on construction carbon, ridership volume, grid intensity, and the emission intensity of displaced modes. This section runs the calculation parametrically across all combinations. Road severance detour emissions (6,844 t/yr central, 3,934–10,851 t/yr range) are included in the operational total and therefore reduce the annual modal shift saving, extending payback.

7.1 Displaced-Mode Emission Assumptions

Trip category (assumed modal split)	g CO ₂ e/pkm	Basis and notes
Car — 50% of diverted trips (ICE fleet, 1.2 avg occupancy)	108	170 g/km per vehicle; 1.2 occupancy; current national average
Short-haul flight — 25% of diverted trips (without radiative forcing)	150	Conservative; RF correction roughly doubles this figure
VIA Rail (existing service) — 15% of diverted trips	25	No net CO ₂ saving vs. Alto; may be negative at low Alto ridership
Induced / new travel with no prior mode — 10%	0	No displacement saving; represents genuinely new demand
WEIGHTED DISPLACED MODE — Current ICE fleet	~100 g/pkm	$0.50 \times 108 + 0.25 \times 150 + 0.15 \times 25 + 0.10 \times 0 = 54 + 37.5 + 3.75 + 0 = 95.3 \approx 100$ g/pkm (rounded)
WEIGHTED DISPLACED MODE — EV-transition fleet (2045+, 50% of cars are EVs at current Ontario grid)	~73 g/pkm	Car fleet: $0.5 \times 108 + 0.5 \times 10.2 = 59.1$ g/pkm. Weighted: $0.50 \times 59.1 + 0.25 \times 150 + 0.15 \times 25 + 0.10 \times 0 = 29.6 + 37.5 + 3.75 + 0 = 70.8 \approx 73$ g/pkm

7.2 Annual Modal Shift Saving and Implied Payback — Current ICE Fleet Displaced

Payback period = Central construction carbon (14.69 Mt) ÷ Annual modal shift saving (Mt/yr). A positive annual saving requires the displaced mode to emit more per pkm than ALTO HSR. Where Alto's all-in per-pkm exceeds the displaced mode, the entry is 'Never' — the project is a net emitter relative to the counterfactual for that scenario.

Grid Scenario		4M pass/yr	8M pass/yr	12M pass/yr
Clean grid (20 g/kWh) — annual saving	kt/yr	173 kt/yr	419 kt/yr	675 kt/yr
Clean grid (20 g/kWh) — payback period	years	~85 yrs	~35 yrs	~22 yrs
Current grid (73.8 g/kWh) — annual saving	kt/yr	78 kt/yr	286 kt/yr	533 kt/yr
Current grid (73.8 g/kWh) — payback period	years	~188 yrs	~51 yrs	~28 yrs
Gas-expansion grid (130 g/kWh) — annual saving	kt/yr	Net increase	147 kt/yr	385 kt/yr
Gas-expansion grid (130 g/kWh) — payback period	years	Never	~100 yrs	~38 yrs

7.3 Annual Modal Shift Saving and Implied Payback — EV-Transition Fleet Displaced (2045+)

This is the most policy-relevant scenario: by the time ALTO opens (optimistically 2040–2045), approximately half of Canada's vehicle fleet will be electrified. The weighted displaced-mode emission falls from ~100 g/pkm to ~73 g/pkm, materially narrowing or eliminating the per-passenger saving.

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

PAYBACK PARADOX

The EV transition simultaneously helps ALTO (by cleaning the grid, lowering per-pkm traction emissions) and hurts ALTO's payback case (by reducing the emission intensity of the cars it displaces). The net effect depends on the relative speed of grid decarbonisation versus fleet electrification. In most scenarios, fleet electrification happens faster than grid decarbonisation, widening the paradox: ALTO improves modestly in absolute emissions while its displacement benefit narrows faster. At 4M passengers on the current grid with an EV-transition fleet, ALTO's all-in per-pkm (67.3 g) exceeds the weighted displaced-mode emission (73 g) by only 5.7 g/pkm, and the annual saving falls to just 15,000 tonnes/yr — producing an implied payback of approximately 980 years.

7.4 Impact of Previously Uncosted Categories on Payback

The cold-climate construction premium (2.30 Mt central) and the Leda clay ground treatment penalty (0.80 Mt central) together add 3.10 Mt CO₂e to the construction debt. Road severance detour emissions (6,844 t/yr central) reduce annual modal shift savings, further extending payback. The table below isolates the payback impact of all previously uncosted categories, relative to the base construction estimate of 11.59 Mt.

Scenario (EV-transition fleet, current grid)	4M pax/yr	8M pax/yr	12M pax/yr
Annual saving (Mt/yr)	8 kt/yr	146 kt/yr	322 kt/yr
Payback WITHOUT cold-climate + Leda clay penalty (base construction 11.59 Mt)	~1486 yrs	~80 yrs	~36 yrs
Payback WITH cold-climate + Leda clay (central: 14.69 Mt)	>500 yrs	~101 yrs	~46 yrs
Additional payback years from uncosted categories (3.10 Mt + detour ops)	+397 additional years	+21 additional years	+10 additional years

8. Critical Gaps in ALTO's Environmental Disclosure

The parametric analysis in this document is constructed entirely from international data, engineering first principles, and published research because ALTO has not released the information required for evidence-based environmental assessment. The following disclosures are required to validate or refute the budget ranges presented here:

- Annual ridership projections for the first 10, 20, and 30 years of operation, subject to independent scrutiny — the 4M, 8M, and 12M scenarios in this analysis span the credible range but Alto has not published even a base ridership projection
- 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
- Embodied carbon estimates for all major materials categories
- ANY acknowledgement that cold-climate subgrade design requirements apply to the corridor (3.1 m enhanced subgrade, XPS insulation, cement-stabilised surface layers, enhanced drainage — all mandatory 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 — specifically: 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
- Comparison of full lifecycle carbon between the northern and southern route options, using consistent methodology

9. Methodology and Sources

This lifecycle budget is derived from two companion research notes, which in turn draw on the following primary sources:

- HS2 Environmental Statement (2013); HS2 BBV Carbon Reduction Report (2024); HS2 Net Zero Carbon Plan; HS2 Parliamentary written evidence
- Chester & Horvath, UC Berkeley (2010); Chang & Kendall (2011, ScienceDirect) — California HSR lifecycle studies
- Chang et al. (2019) — Beijing–Shijiazhuang lifecycle; Beijing–Tianjin multi-footprint study; CRH380BL 20-year lifecycle (ScienceDirect 2025)
- Harbin–Dalian HSR: Liu et al. (2016) Cold Regions Science and Technology; Niu et al. (2017) frost heave monitoring; Miao & Niu (2020, ScienceDirect); XPS insulation engineering test (ResearchGate 2016); Canadian Geotechnical Journal (2015); HDPDL CRH380BG trainset modifications; HDPDL operational cost overrun 25% (CNY95B vs CNY76B planned)
- UIC Carbon Footprint of High Speed Rail (2011); Carbon Footprint of Railway Infrastructure (2016) — including per-metre viaduct material data
- NRC Surficial Geology and Sensitive Marine Clay database; Dawson (1883) Champlain Sea whale bone finds; NRC Quick Clay research programme
- Ontario grid: CER Provincial Energy Profiles (2022); GTHA Carbon Emissions Inventory (2024, 73.8 g CO₂e/kWh); IESO Annual Planning Outlook (forecast 10.9–12.2 Mt system emissions by 2030)
- Construction carbon factors: C40 concrete 371 kg CO₂/m³ (PMC/NCBI Railway Construction Carbon Database); structural steel 1,900 kg CO₂/t (World Steel Association); A5 diesel equipment surcharge +15% on material carbon total (HS2 data)
- Diesel CO₂ factor: 2.68 kg CO₂/litre (Natural Resources Canada). EV efficiency: 6 km/kWh (NRCan average). Ontario grid: 73.8 g CO₂e/kWh (2024 IESO actual)
- Spanish Basque Y project; Madrid–Toledo LCA (ScienceDirect 2023); California HSR Chester & Horvath (2010) 71-year payback estimate
- IPCC 2014 Wetland Supplement (2023 updated emission factors); Ontario Nature carbon storage research; IUCN peatlands brief

Alto HSR Citizen Research Initiative

altohsrcitizenresearch.ca

Submission to the Alto HSR Public Consultation — Deadline: April 24, 2026