ALTO HSR Fifty-Year Lifecycle CO_2 Budget

Consolidated Model Output — Phased Opening, Ridership Envelope and Dual-Boundary Comparison

Alto HSR Citizen Research Initiative — November 2026 Update — Second edition, revised. Supersedes the March 2026 edition prepared for the Alto HSR Public Consultation. — citizenresearch.ca

WHAT CHANGED IN THIS EDITION

- Every scenario table is restated. The March edition's flat 4, 8 and 12 million passenger cases are replaced throughout by the ridership envelope of Modal Shift Note 3 (May 2026), applied year by year including its ramp.
- Construction carbon is phased by route-kilometre across the three announced openings rather than incurred at a single opening.
- Average trip distance is derived at 430 km at maturity, replacing an asserted 650 km.
- Grid intensity is a declining trajectory on the IESO 2025 Annual Planning Outlook, with a slow-decarbonisation and a frozen-intensity sensitivity, replacing three static scenarios.
- The electric-vehicle fleet trajectory is revised following the repeal of the federal mandate.
- Every per-passenger comparison is reported at two boundaries. The March claim that an electric vehicle is cleaner than ALTO at any ridership level is withdrawn, and the callout box carrying it has been rewritten.
- Four internal inconsistencies corrected: the fixed operational total, the EV counterfactual box, the payback paradox box, and the fleet trajectory shared with the severance note.

EXECUTIVE SUMMARY — This note consolidates the construction, operational and road-severance inputs into a fifty-year lifecycle CO_2 budget for ALTO, rebuilt on the project as announced in December 2025: three phases, Ottawa–Montréal first. On the central ridership trajectory of Modal Shift Note 3, at the central construction estimate of 14.69 Mt CO_2e, the construction carbon debt is not repaid by 2090 at either comparison boundary. Payback falls between 2083 and 2110 on the IESO grid path, and later on slower decarbonisation. On the lower trajectory it is never repaid. Only the upper trajectory — 25.7 million annual passengers, above every independent forecast for the corridor — repays within the operating life.

1. Scope, Framework and Key Assumptions

The budget integrates three companion research notes — construction-phase carbon, operational-phase carbon, and road severance — across a fifty-year operating life from the first phase opening in 2040. Construction carbon is a one-time cost, allocated to the phase that incurs it. Operational carbon and modal-shift savings are integrated annually against the ridership trajectory rather than applied at a flat rate.

1.1 The ridership envelope

The March edition ran flat scenarios of 4, 8 and 12 million annual passengers. Modal Shift Note 3 (May 2026) supersedes them with a dated envelope built from corridor population, per-capita intercity trip

generation and modal share under three fare and subsidy regimes. That envelope is used here in full, year by year.

Table 1. Annual ridership, millions, from Modal Shift Note 3

Year	Network status	Lower	Central	Upper
2040	Phase 1 (Montréal–Ottawa) opening years	0	0.4	1.8
2045	Phase 1 maturing; Phase 2 (Ottawa–Toronto) opens	0.5	2.8	9.2
2050	Phases 1–2 maturing; Phase 3 (Montréal–Québec) opens	1.9	6.7	14.8
2055	Phases 1–2 mature; Phase 3 ramping	3.7	9.2	17.2
2060	All phases near-mature	4.8	10.2	18.7
2080	Mature plus forecast growth	6.1	12.5	25.7

ALTO's published targets of 24 million by 2055 and 43 million by 2084 are not tested as scenarios. Modal Shift Note 3 finds that 24 million by 2055 sits 40 per cent above the upper bound of its own envelope for that year and is incompatible with the announced phasing under any plausible ramp. For scale at the other end, the lower trajectory of 6.1 million is itself about three times the 2.1 million passengers carried across VIA Rail's entire Montréal–Ottawa–Toronto corridor in 2023.

1.2 Phasing

The Government of Canada confirmed Ottawa–Montréal as the first segment in December 2025. Construction carbon is allocated across the three announced phases by route-kilometre and incurred at each opening.

Table 2. Construction carbon by phase, central estimate

Phase	Segment	Route-km	Share of route	Opening	Construction carbon
1	Montréal–Ottawa	190 km	19%	2040	2.79 Mt
2	Ottawa–Toronto	450 km	45%	2045	6.61 Mt
3	Montréal–Québec City	360 km	36%	2050	5.29 Mt
Total	Full corridor	1,000 km	100 %	—	14.69 Mt

1.3 Key modelling assumptions

Table 3. Key modelling assumptions

Parameter	This edition	March 2026 edition
Ridership	Modal Shift Note 3 envelope, annual, with ramp	Flat 4 / 8 / 12 million
Average trip distance	430 km mature; 440 km triangle; 190 km Phase 1 window	650 km throughout

Parameter	This edition	March 2026 edition
Opening	Three phases: 2040, 2045, 2050	Single opening, 2040–2045
Operating period	Fifty years from first opening, to 2090	Fifty years
Grid intensity	Declining trajectory, IESO 2025 outlook	Static 20 / 73.8 / 130 g/kWh
Fixed operational cost	51,944 t/yr at full network, scaled by route-km in service	45,100 t/yr, unscaled
Electric fleet share	15 % (2040) rising to 70 % (2080)	20 % (2040) rising to 90 % (2090)
Comparison boundary	Tailpipe and life-cycle, both reported	Tailpipe comparators only
Discounting	None. Physical tonnes throughout	None

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).

Table 4. Construction Carbon (One-Time, Independent of Ridership)

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	PREVIOUSLY UNCOSTED CATEGORIES — Not present in any	PREVIOUSLY UNCOSTED CATEGORIES — Not present in any	PREVIOUSLY UNCOSTED CATEGORIES — Not present in any	PREVIOUSLY UNCOSTED CATEGORIES — Not present in any

Category	Optimistic	Central	Pessimistic	Primary driver
	Alto public document	Alto public document	Alto public document	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 CO_2e) is now included in the construction total above. The permanent annual detour emissions from 350–700 road closures (3,934–10,851 t CO_2e/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 CO_2 Calculation (March 2026). Neither category appears in any Alto environmental document.

3. Operational Carbon

3.1 Fixed component

The fixed component is 51,944 t CO_2e a year at the full network, comprising station operations, infrastructure maintenance, rolling-stock replacement, vegetation, waste, administration, decommissioning, the cold-climate operational premium of 13,600 t and road-severance detour

emissions of 6,844 t. The March edition quoted 45,100 t in its assumptions table and 51,944 t in its working — the difference was the severance line, and 51,944 t is correct. In this edition the fixed component is scaled by the share of route in service, so it rises as each phase opens.

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 CO_2e/yr

Table 5. Fixed Operational Component — Central Estimate: 51,944 t CO_2e/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 105,243–298,157 t CO_2e
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 Traction intensity at maturity

Traction intensity falls with ridership, as higher occupancy spreads a largely fixed energy cost per train-kilometre across more passengers, and falls with grid intensity. The figures below are mature-state, in 2080.

Table 6. Mature traction and all-in intensity by trajectory and grid path, 2080

Grid path		Lower (6.1M)	Central (12.5M)	Upper (25.7M)
IESO 2025 outlook	all-in g/pkm	22.4	11.2	6.3
Slow decarbonisation	all-in g/pkm	36.3	19.8	14.9
Frozen at 2024 intensity	all-in g/pkm	60.4	34.7	29.7
Annual operational emissions, IESO path	t/yr	58,684	60,441	69,414

4. Per-Passenger Benchmarks and Modal Comparison

> WHAT A COMPARISON BOUNDARY IS — Comparing a train journey with a car journey requires deciding what counts as part of the journey. The tailpipe boundary counts only what is emitted while travelling: fuel burned, or electricity drawn. The life-cycle boundary adds the making of the vehicle, the building of the infrastructure and the supply chains behind both, spread across everything the asset carries in its lifetime. An ordinary car costs roughly 8 tonnes of CO_2 to build and an electric one nearer 12 because of the battery, which at 240,000 km and 1.2 occupants is about 42 g on every passenger-kilometre it ever travels. ALTO's construction is about 72 g on every passenger-kilometre it carries over fifty years. Neither boundary is wrong; mixing them is. This section reports both, and the payback range of §6 — 2083 to 2110 on the central trajectory — is the span between them rather than uncertainty about the project. Note that ALTO's figure in the tailpipe column is broader than a true tailpipe measure: it carries station energy, maintenance, administration, the cold-climate premium and road severance, where a car's carries fuel alone. The tailpipe column therefore remains modestly unfavourable to ALTO, and the life-cycle column is the properly symmetric one.

A per-passenger-kilometre comparison is only meaningful if every mode is measured to the same boundary. The March edition set ALTO's fully allocated emissions against operational-only figures for cars and aircraft, and against an electric vehicle figure excluding battery manufacture. That comparison was asymmetric and favoured the conclusion reached. This edition reports both boundaries, applying the life-cycle multipliers of Chester and Horvath (1.63 for road, 1.31 for air) and a vehicle-cycle term of approximately 42 g/pkm for electric cars, from a 12-tonne manufacturing footprint over 240,000 km at 1.2 occupants.

Table 7. Emission intensity by mode and comparison boundary, 2050–2080

g CO_2e per passenger-km	Boundary	2050	2065	2080
ALTO rail, central trajectory	operational only	20.5	13.0	11.2
ALTO rail, central trajectory	including amortised construction	92.4	85.0	83.2
Car, fleet average	tailpipe	77.1	55.0	32.9
Car, fleet average	life-cycle	137.6	110.0	82.4

g CO_2e per passenger-km	Boundary	2050	2065	2080
Car, electric only	operational (grid) only	0.6	0.6	0.6
Car, electric only	life-cycle, incl. battery	42.3	42.3	42.3
Short-haul air	operational only	140	140	140
Short-haul air	life-cycle	183	183	183
Memo: Ontario grid, g/kWh	—	5	5	5
Memo: electric share of light fleet	—	29%	49%	70%

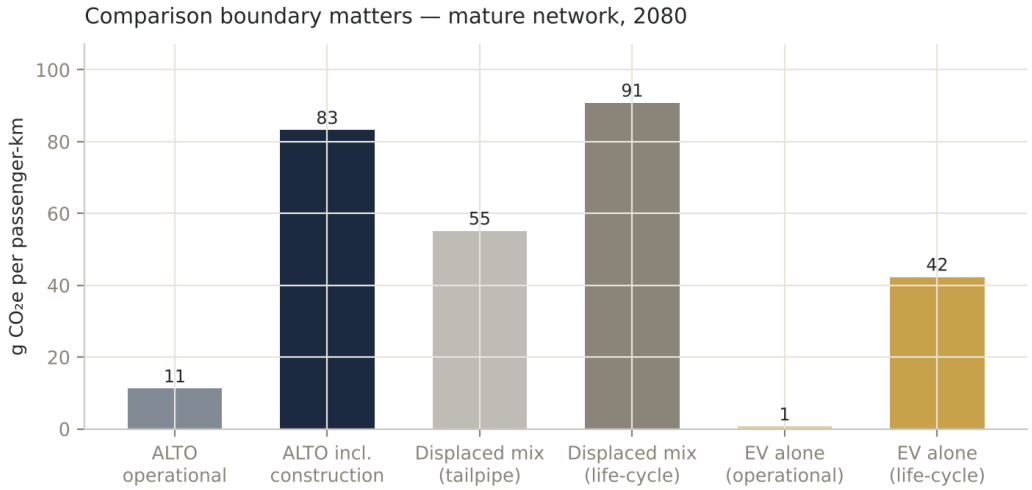


Figure 1. Comparison boundary at the mature network, 2080. ALTO's operational figure excludes construction; the second bar amortises the central 14.69 Mt estimate over the 2040–2090 operating period at the central trajectory.

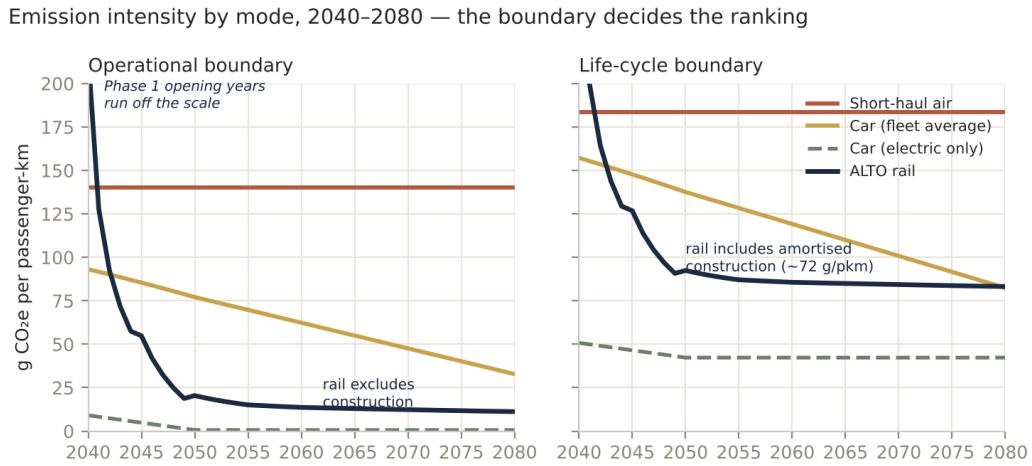


Figure 2. Emission intensity by mode, 2040–2080. On the operational boundary ALTO is the cleanest mode other than an electric car. Once its construction carbon is amortised on the same basis as an electric car's battery, the ranking changes and the margins narrow sharply. Air is held constant, which is generous to ALTO.

THE ELECTRIC VEHICLE COMPARISON, RESTATED — The March edition stated that an electric vehicle carrying 1.2 passengers is cleaner than ALTO at every ridership level. That claim is withdrawn. It compared ALTO's fully allocated emissions against an electric vehicle's grid consumption alone, excluding the battery and vehicle manufacture that dominate an electric car's life-cycle footprint. Measured consistently, at maturity in 2080 ALTO's operational intensity is approximately 11.2 g/pkm against an electric vehicle life-cycle figure near 42.3 g/pkm. Including ALTO's amortised construction carbon of approximately 72.0 g/pkm the comparison narrows sharply but does not reverse. The substantive point survives in weaker form: as the fleet electrifies, the saving available from moving a passenger out of a car narrows, and with it the case for the railway.

VIA RAIL DISPLACEMENT — VIA Rail, diesel, emits approximately 25 g CO_2e/pkm on the corridor today. Passengers diverted from VIA to ALTO produce no net carbon saving and, during the Phase 1 window when ALTO's all-in intensity is at its highest, produce a net increase. A Beijing–Shanghai ex-post study found that high-speed rail initially raised net emissions because it diverted passengers primarily from existing rail rather than from cars and aircraft. The Toronto–Ottawa–Montréal corridor already has VIA service; the same displacement risk applies. The displaced-mode weighting in §6 assigns 15 per cent of diverted trips to VIA on that basis.

5. Consolidated Fifty-Year Lifecycle Budget

Operational emissions are integrated annually from the first phase opening in 2040 to 2090, against the ridership trajectory and the grid path. They are therefore lower than a flat-rate calculation would give, because the network is partial and lightly used for its first decade.

Table 8. Fifty-year operational emissions, 2040–2090 (Mt CO_2e)

Grid path	Lower	Central	Upper
IESO 2025 outlook	2.65	2.88	3.29
Slow decarbonisation	4.39	5.33	7.59
Frozen at 2024 intensity	6.53	8.17	12.77

Table 9. Fifty-year lifecycle total, operations plus central construction of 14.69 Mt (Mt CO_2e)

Grid path	Lower	Central	Upper
IESO 2025 outlook	17.34	17.57	17.98
Slow decarbonisation	19.08	20.02	22.28
Frozen at 2024 intensity	21.22	22.86	27.46

Table 10. Sensitivity to the construction scenario, central trajectory on the IESO grid path (Mt CO_2e)

Component	Optimistic	Central	Pessimistic
Construction, one-time	6.87	14.69	29.60
Operations, 2040–2090	2.88	2.88	2.88
Lifecycle total	9.75	17.57	32.48
Modal-shift saving, 2040–2090	−10.07	−10.07	−10.07

6. Carbon Payback

Carbon payback occurs when cumulative modal-shift savings cover the construction debt incurred to date. The displaced-mode counterfactual weights 50 per cent of diverted trips to cars, 25 per cent to short-haul air, 15 per cent to VIA Rail and 10 per cent to induced travel with no prior mode. The car term tracks the fleet electrification trajectory; short-haul air is held at 140 g/pkm, reconciling the 130 and 150 g/pkm figures used in different tables of the March edition.

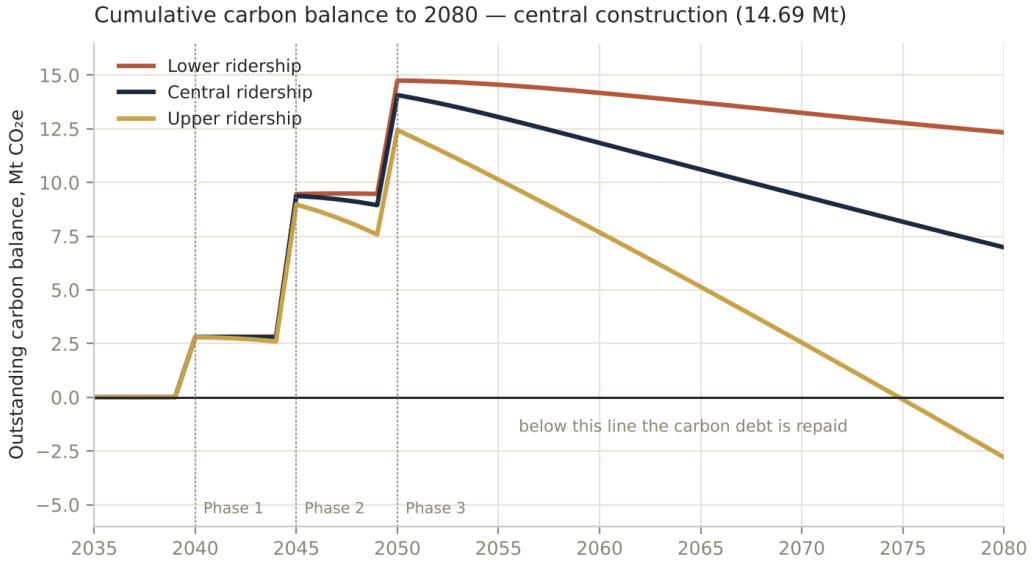


Figure 3. Cumulative carbon balance to 2080 at the central construction estimate, across the three ridership trajectories. Each step marks a phase opening and the construction carbon it incurs. Tailpipe comparison boundary, IESO grid path.

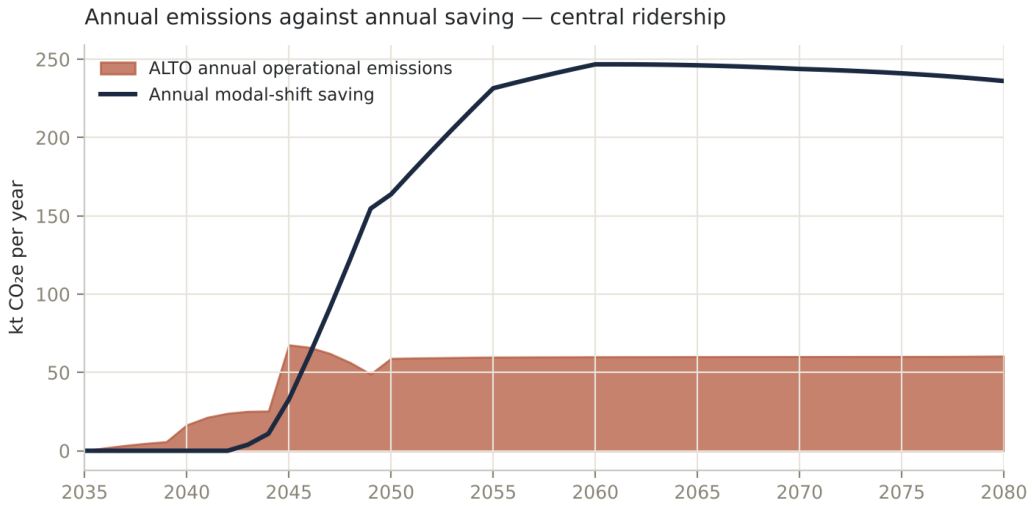


Figure 4. Annual operational emissions against the annual modal-shift saving, central trajectory. The saving does not exceed annual emissions until the middle 2040s, and the step at 2050 is the Phase 3 opening adding fixed operational cost ahead of the demand that services it.

Table 11. Carbon payback year by trajectory, grid path and comparison boundary

Grid path	Boundary	Lower	Central	Upper
IESO 2025 outlook	tailpipe	never	2110	2075
IESO 2025 outlook	life-cycle	never	2083	2064
Slow decarbonisation	tailpipe	never	2125	2081
Frozen at 2024 intensity	tailpipe	never	never	2091

CENTRAL FINDING — On the central ridership trajectory at the central construction estimate, ALTO does not repay its construction carbon by 2090 at either comparison boundary. Payback falls between 2083 and 2110 on the IESO grid path and later on slower decarbonisation. Both lie beyond the 2084 horizon ALTO uses for its own ridership claims and beyond the sixty-year appraisal period applied by the C.D. Howe Institute and by ALTO's own economic analysis. On the lower trajectory the debt is never repaid; on a grid frozen at today's intensity the lower trajectory is a net emitter outright.

THE PAYBACK PARADOX, RESTATED — Fleet electrification cuts both ways. It cleans the grid that powers the trains, and it cleans the cars they displace. Which effect dominates decides the payback. The March edition judged that electrification would outrun grid decarbonisation and quoted a payback near 980 years at 4 million passengers; that figure rested on a fixed operational total since corrected and on a ridership case below the mature lower bound of Modal Shift Note 3, and it is withdrawn. On the trajectories and policy settings of this edition the paradox is milder but real: between 2050 and 2080 the saving from moving a passenger out of a car narrows from about 57 to about 22 g per passenger-kilometre on the operational boundary, which is why payback arrives late even on the central case.

7. Assumption Trajectories

Two inputs govern the result above all others: how fast Ontario's grid decarbonises, and how fast the light-vehicle fleet electrifies. The first sets ALTO's traction emissions, the second the emissions of the cars it displaces.

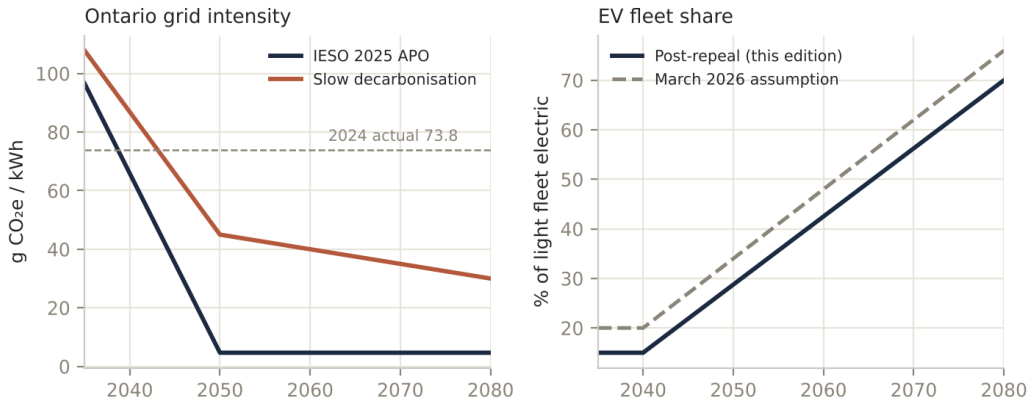


Figure 5. Left: Ontario grid carbon intensity. The IESO path follows the 2025 Annual Planning Outlook, peaking near 133 g/kWh in 2029 and falling to single digits by 2050; the slow-decarbonisation variant is retained as a sensitivity. Right: light-vehicle fleet electrification, against the March 2026 assumption that preceded the repeal of the federal mandate.

The fleet trajectory no longer rests on policy. The federal Electric Vehicle Availability Standard, which required all new light-vehicle sales to be zero-emission by 2035, was paused in September 2025 and its repeal posted in the Canada Gazette in August 2026 with no replacement in force. Quebec reduced its 2035 target to 80 per cent and British Columbia to 75 per cent. The proposed federal greenhouse gas standard, at 75 per cent by 2035, is not law.

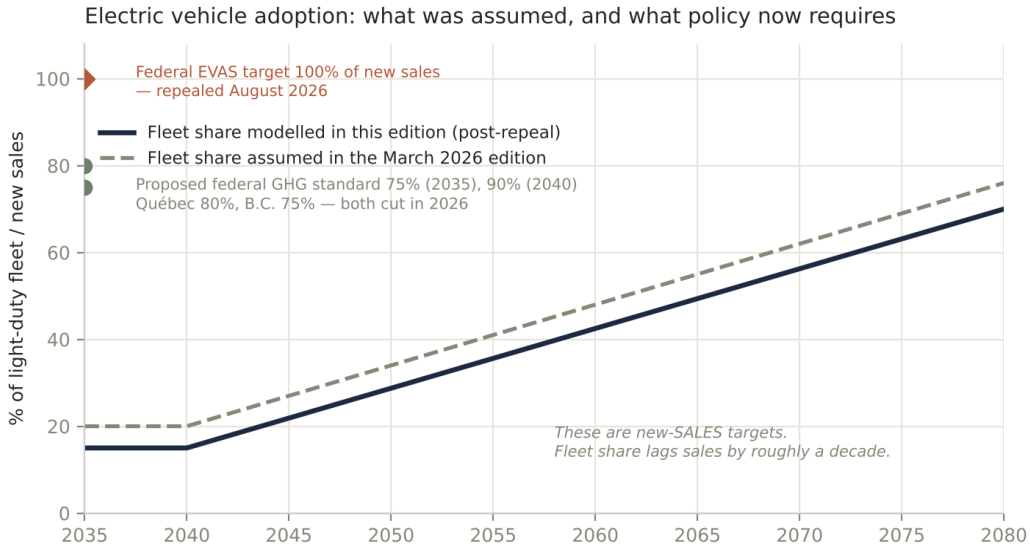


Figure 6. Electric vehicle adoption: the fleet trajectory modelled here against the policy targets that have been withdrawn or reduced. Markers are new-sales targets; lines are fleet share, which lags sales by roughly a decade. The modelled path sits below every target shown, which makes the displaced car fleet dirtier and shortens ALTO's payback — a change that works against this analysis's own conclusion.

The grid path deserves the same caution in the other direction. The IESO's own outlook takes Ontario close to a zero-carbon grid by 2050, which is generous to ALTO and is not treated here as certain. The

frozen-intensity column in §6 shows what a stalled transition would mean: on the lower trajectory ALTO becomes a net emitter, and on the central trajectory the debt is never repaid.

8. ALTO’s Own Emissions Claim

Canada’s Moment, published by ALTO on 20 August 2026, states that the network will remove “about 100,000 cars from the road annually” and that the trains will be “100% electric.” At a conventional 4 to 5 tonnes of CO_2e per car-year the first claim implies an annual saving of roughly 400 to 500 kt.

This analysis puts the mature annual saving on the central trajectory at approximately 236 kt, and below 250 kt in every year of the modelled period. The published claim is therefore roughly twice the figure this analysis supports at the ridership the Initiative considers central, and it is unaccompanied by a lifecycle assessment, a construction carbon estimate or a stated counterfactual. The second claim is true and incomplete: electric traction on a clean grid is close to carbon-free, and it is the building of the railway that carries the carbon cost.

9. 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:

Table 12. Critical Gaps in ALTO's Environmental Disclosure

•	**Annual ridership projections for the first 10, 20, and 30 years of operation, subject to independent scrutiny — the Modal Shift Note 3 envelope used here spans the credible range, but ALTO has not published even a base ridership projection against which it could be tested**
•	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

•	**Annual ridership projections for the first 10, 20, and 30 years of operation, subject to independent scrutiny — the Modal Shift Note 3 envelope used here spans the credible range, but ALTO has not published even a base ridership projection against which it could be tested**
•	Comparison of full lifecycle carbon between the northern and southern route options, using consistent methodology, and between the three announced phases

10. Status of the March 2026 Findings

Table 13. Status of the March 2026 findings

March 2026 finding	Status in this edition
Construction carbon of 6.87 / 14.69 / 29.60 Mt	Unchanged. Better supported at the upper end by the PBO cost review of 1 October 2026.
Cold-climate construction and operational premiums	Unchanged.
Leda clay ground treatment penalty	Unchanged.
Road severance as a permanent, non-abatable category	Unchanged. Detour emissions revised upward after the EV mandate repeal.
Fixed operational total of 45,100 t/yr	Corrected to 51,944 t/yr. The difference was the road-severance line.
No carbon payback at 4 million passengers	Withdrawn as a headline. 4 million lies below the mature lower bound of Modal Shift Note 3. Replaced by the central-case result in §6, which is stronger.
An electric car is already cleaner than ALTO at any ridership level	Withdrawn. The comparison was drawn at asymmetric boundaries.
Payback near 980 years at 4 million passengers	Withdrawn. Rested on the uncorrected fixed total and on a ridership case below the envelope.
Ontario's grid is getting dirtier over the relevant timeframe	Withdrawn for the operating period. Retained for the Phase 1 window.
ALTO has disclosed no lifecycle carbon assessment	Unchanged. Still outstanding as at November 2026.

11. 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% (CN¥95B vs CN¥76B 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 CO_2e/kWh); IESO Annual Planning Outlook (forecast 10.9–12.2 Mt system emissions by 2030)

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); A5 diesel equipment surcharge +15% on material carbon total (HS2 data)

Diesel CO_2 factor: 2.68 kg CO_2/litre (Natural Resources Canada). EV efficiency: 6 km/kWh (NRCan average). Ontario grid: 73.8 g CO_2e/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