CHAPTER 5

Environmental and Community Impact

The ecological and community advantages of a brownfield-led route.

The environmental case for a railway is usually argued as a single number: the carbon it saves by moving people out of cars and planes. That number matters, and it is dealt with first. But the deeper environmental fact about a corridor is decided before a single train runs — by where the line is put. A route that follows an existing transport corridor inherits ground that has already been cleared, drained, fenced, and fragmented; a route driven through open country creates a new line of disturbance across land that had none. The same choice governs the human landscape: whether a project assembles its right-of-way from farms and communities that never expected a railway, or lays it alongside infrastructure the corridor already lives with. This chapter takes the four consequences of that single siting decision in turn — lifecycle carbon, species and ecological connectivity, construction-phase disturbance, and community friction — and in each the brownfield-led HPPR alignment and ALTO's new greenfield corridor diverge not by a margin but in kind.

Status of the figures. Figures attributed to a named external source — Alto, HS2 Ltd, Crossrail, the C.D. Howe Institute, Metrolinx, Environment and Climate Change Canada, the Treasury Board, Natural Resources Canada, UNESCO, COSEWIC, the Railway Association of Canada, or a named developer or operator — are quoted from the sources listed at the end of each section and can be checked there. Everything else in this chapter is output from the Initiative's own models and is identified as such where it appears. That includes both columns of every carbon table: the HPPR lifecycle account, the ALTO full-corridor lifecycle account, the freight displacement credit, the breakeven years, the carbon present values and their monetised equivalents, the Latent and Community Friction Indices, the corridor land-cover audit, the materials tonnage and train counts, and the delay-escalation estimate. These are estimates built on stated assumptions, not measurements; the assumptions are set out in Chapters 3, 4 and 8 so that any of them can be replaced and the arithmetic re-run. Where Alto has not published a figure, this chapter says so rather than inferring one, and makes no claim about why any figure has not been published.

5.1 CO_2 Lifecycle

On lifecycle carbon the two projects do not merely differ in degree — they differ in sign. Over a fifty-year horizon HPPR is a net *removal* of carbon; ALTO, assessed on the same lifecycle basis, is a net *emitter*. The result follows from three structural facts, each traceable to the siting decision, and it holds across every combination of ridership, grid intensity, and freight uptake the model was run against.

5.1.1 The Three Inputs

The lifecycle account combines three inputs. **Construction carbon** is the one-time embodied emission of building the line. **Operational carbon** is the recurring emission of running the passenger trains — traction plus a fixed inventory of stations, maintenance, and winter operations. **Freight displacement** is the recurring *credit* earned when long-haul trucks move off Highway 401 onto the liberated Kingston Subdivision — the carbon expression of the freight dividend developed in Chapter 3. The first two are costs; the third is the saving that carries the account, and it is the saving ALTO cannot claim.

5.1.2 Construction Carbon

HPPR is built at grade, co-constructed with the eastern 401 widening, on ground already disturbed by the highway. It requires no Shield tunnelling, no cold-climate embankment premium, and no Leda-clay treatment — the three items that inflate a 300 km/h greenfield backbone. The central construction estimate is 4.86 Mt CO_2e for the electric spine and 4.46 Mt for the diesel variant, the difference being the electrification system the diesel line omits. ALTO's central construction carbon, from the Initiative's full-corridor lifecycle account, is 14.9 Mt — roughly three times higher. The co-construction dividend with the 401 widening is the primary driver: HPPR spends its embodied carbon widening a disturbance that already exists rather than opening a new one.

5.1.3 Operations and Traction

At 200 km/h on Ontario's low-carbon grid, electric traction emits about 6 g CO_2e per passenger-kilometre; even on a pessimistic "gas-expansion" grid it stays near 11 g. The diesel variant burns fuel and is grid-independent at about 58 g/pkm — higher, but still below every mode it displaces except electric rail. Either way, passenger operations are a rounding error against the freight term: at six million passengers on the current grid the electric spine's traction is on the order of a few thousand tonnes a year, while the freight credit runs to a quarter of a million.

5.1.4 The Freight Credit

Each long-haul truck shifted from the 401 to rail saves about 0.236 t CO_2 over a representative 350 km haul. At the central uptake of 3,000 trucks per day — an undemanding eight double-stack trains a day on a dedicated corridor — the direct displacement credit is roughly 259 kt per year, or 12.93 Mt over fifty years. Adding avoided pavement wear, avoided incremental 401 widening, and reduced congestion brings the freight-attributable total to about 13.47 Mt. This credit is *identical* in the electric and diesel cases, because freight is hauled by diesel locomotives regardless of how the passenger trains are powered. It is also independent of passenger uptake, and it grows as Ontario's grid decarbonises while trucking stays diesel. It is the reason the traction choice sets the *size* of HPPR's carbon win rather than whether it wins.

> A single investment in passenger capability liberates freight capacity as a byproduct — and on the carbon account that byproduct is the term that does the heavy lifting. The “free” asset is free to the climate case because the corridor was already going to be built.

5.1.5 The Consolidated Fifty-Year Budget

Stacking the three inputs plus the passenger modal-shift saving gives the lifecycle net. The electric spine returns approximately −15.25 Mt CO_2e over fifty years; the diesel spine about −7.58 Mt — roughly half as much, but still a large net removal. ALTO’s account is assembled differently. Its emitting side is far larger — 14.9 Mt construction, 5.4 Mt of operations over fifty years, and a further 1.69 Mt of road-severance emissions from the permanently dead-ended rural roads a fully-fenced 300 km/h corridor creates — for a lifecycle carbon debt of roughly 22 Mt. Against that debt ALTO has only one credit: passenger modal shift, with no freight function to draw on. And that credit erodes: as the vehicle fleet electrifies, the carbon saved by moving a passenger out of a car falls toward zero. Crediting ALTO’s modal shift at the reference-class ridership of about ten million — and eroding it on the Initiative’s own EV-adoption trajectory — recovers only around 7 Mt over fifty years, leaving ALTO a net emitter of roughly +15 Mt. Even that is generous: it excludes about 1 Mt of unquantified wetland and peatland disturbance, and it assumes the diverted passengers come from cars and aircraft rather than from the corridor’s existing low-carbon VIA service.

Table 5.1 — Consolidated 50-year lifecycle CO_2 budget, central case. HPPR at 9M passengers, current grid, 3,000 trucks/day; ALTO from the Initiative’s full-corridor lifecycle account, with its passenger modal-shift credit taken at the reference-class 10M and eroded on the EV-adoption trajectory. Negative = net removal. A dash denotes a term the project structurally lacks. Scope differs — HPPR is the ~485 km triangle spine, ALTO the ~1,000 km Toronto–Québec City corridor — which is itself part of the comparison: ALTO builds a longer, heavier line. Excludes ~1 Mt of unquantified ALTO wetland/peatland disturbance.

Component	HPPR electric	HPPR diesel	ALTO
Construction (one-time)	+4.86 Mt	+4.46 Mt	+14.9 Mt
Traction (50 yr)	+0.49 Mt	+4.54 Mt	+2.75 Mt
Fixed operational (50 yr)	+0.76 Mt	+0.71 Mt	+2.68 Mt
Road severance (50 yr)	—	—	+1.69 Mt
Freight displacement (50 yr)	−13.47 Mt	−13.47 Mt	none
Passenger modal shift (50 yr)	−7.88 Mt	−3.82 Mt	≈ −7 Mt
Net 50-year balance	**−15.25 Mt**	**−7.58 Mt**	**≈ +15 Mt**

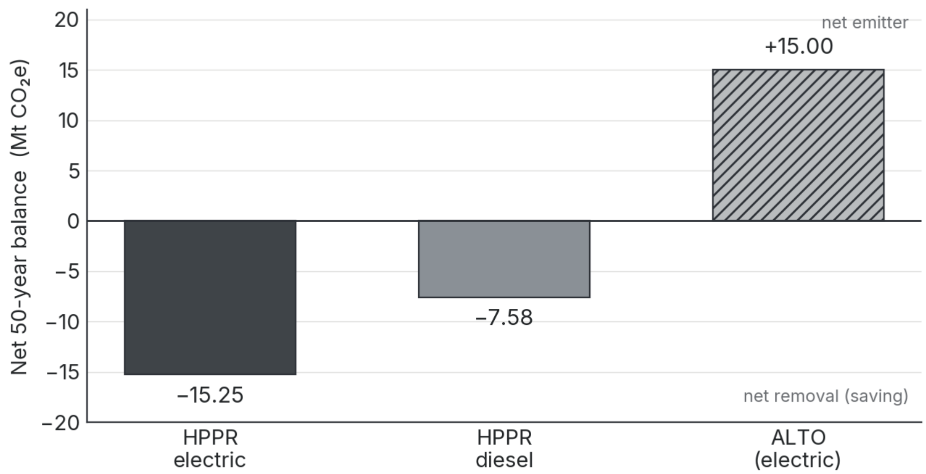

Figure 5.1 — Net fifty-year lifecycle CO_2 balance, central case. Both HPPR traction modes are net carbon removals; ALTO, even after crediting its passenger modal shift at reference-class ridership, remains a net emitter of roughly +15 Mt. The gap between the two HPPR modes is set by traction and modal-shift capture; the gap to ALTO is set by construction carbon, road severance, and the freight credit ALTO structurally lacks.

5.1.6 Carbon Breakeven

The sharper test is lifecycle breakeven — the year at which cumulative savings first cover the whole carbon debt, construction included. Here the freight credit is decisive. Because HPPR's freight saving is large, stable, and independent of passenger uptake, its breakeven arrives quickly and is essentially the same across ridership levels: on the order of 12 years for the electric spine and 18 for the diesel spine, after which the line is permanently in credit. ALTO has no such anchor. It must repay a debt three to four times larger from an eroding modal-shift credit alone: at reference-class ridership (~10M) it reaches breakeven only around 22 years in; at 6M around 39 years; and at low ridership it does not break even within the horizon at all. Worse, because the modal-shift advantage keeps shrinking as the fleet electrifies, ALTO's position can slip back toward deficit after breakeven — the credit that repaid the debt is the same credit that is disappearing.

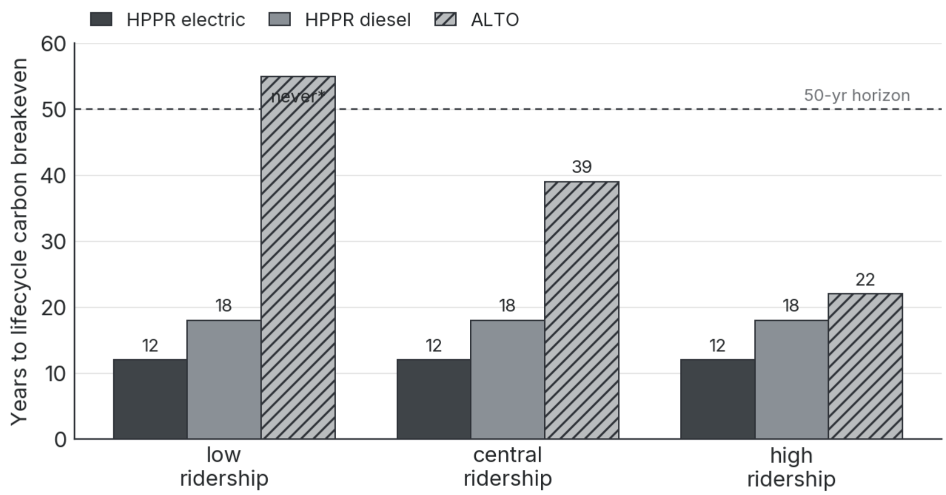

Figure 5.2 — Years to lifecycle carbon breakeven, by ridership band (HPPR 3/6/9M; ALTO 3/6/10M). HPPR breaks even in 12–18 years and stays in credit, its timing near-flat because the freight saving carries it regardless of passengers. ALTO's breakeven is entirely ridership-dependent — 22 years at reference-class ridership, 39 at central, never (*within the 50-year horizon) at low — because it depends wholly on a modal-shift credit that erodes as the vehicle fleet electrifies.

> ALTO's carbon case rides on modal shift from cars, a benefit that erodes as the vehicle fleet electrifies. HPPR's case is anchored by freight displacement — a structural saving that persists whatever passengers do, and grows as the grid decarbonises while the trucks stay diesel.

5.1.7 Electric or Diesel

Between the two HPPR traction modes, electric is the clearly superior long-run carbon choice on Ontario's clean grid: its traction is nearly free, it captures roughly twice the passenger modal-shift credit, and it is far more robust to fleet electrification. Diesel is the deliverable, lower-capital, grid-independent alternative that remains carbon-negative on the strength of freight and can transition to electric traction later without ever stranding the freight credit. Both decisively outperform ALTO. The physical sign is the decisive result. Its monetised value is treated in Chapter 8, where the front-loaded construction emission and the back-loaded freight and modal savings are discounted — and there the choice of rate is not a technical preliminary but the result itself.

HPPR's carbon present value changes sign at a discount rate of about 5.9%. At the 8% rate of the Treasury Board's regulatory guidance it is marginally positive — a small net emission in present-value terms. At the 3.5% rate Metrolinx prescribes, and which the C.D. Howe Institute applied to this same corridor in 2025, it is a removal of about 2.6 Mt; at the 2% rate Environment and Climate Change Canada uses for the social cost of greenhouse gases, 6.0 Mt. Valued at that department's carbon price rather than discounted as raw tonnes — the method its own guidance prescribes, since the price of a tonne rises in real terms through 2080 — HPPR is worth roughly $2.0 billion at 3.5% and $4.0 billion at 2%.

What does not move is the comparison. ALTO is a carbon disbenefit at every rate between zero and eight per cent, because a construction debt of 14.9 Mt is never repaid by an operating phase that is close to carbon-neutral once road severance is counted against its modal-shift credit. This chapter therefore takes 3.5% as its base case, on the precedent of the only published benefit analysis of this corridor, and reports 8% as a stress test rather than a standard. On a full-lifecycle basis, at any discount rate between zero and eight per cent, ALTO is the net emitter of the two. That is worth stating plainly, because carbon reduction is among the grounds on which the project has been publicly supported.

Table 5.2 — Fifty-year carbon present value by discount rate, Mt CO_2e; negative is a net removal. Computed on the streams of Table 5.1, with construction spread over a ten-year build and operating flows over the following fifty years. HPPR’s present value changes sign at approximately 5.9%; ALTO is a disbenefit at every rate shown.

Discount rate	Source of the rate	HPPR carbon PV	ALTO carbon PV
0% (undiscounted)	—	−15.24 Mt	+15.02 Mt
2%	ECCC, social cost of greenhouse gases	−6.00 Mt	+13.45 Mt
3.5%	Metrolinx business case guidance; C.D. Howe (2025)	−2.64 Mt	+12.43 Mt
7%	US OMB Circular A-4 (retired 2023)	+0.59 Mt	+10.48 Mt
8%	Treasury Board, regulatory cost-benefit guide	+0.98 Mt	+10.01 Mt

SOURCES FOR §5.1.7

• Alto, Canada’s Moment: The Economic Opportunity of High-Speed Rail, 20 August 2026 — altotrain.ca. Benefits of ~$49.5 billion are reported over a 60-year operating period; no discount rate is published.
• C.D. Howe Institute, All Aboard: The Benefits of Faster, More Frequent Passenger Trains between Ontario and Québec (D. Jones and T. Fariha), February 2025 — 3.5% social discount rate, 60-year appraisal, 2039–2098 — cdhowe.org
• Metrolinx, Business Case Manual Volume 2: Guidance — metrolinx.com
• Environment and Climate Change Canada, Social cost of greenhouse gas emissions — 2% near-term Ramsey rate, replacing a constant 3%; SC-CO_2 $261/t for 2023 emissions in 2021 dollars — canada.ca
• Treasury Board of Canada Secretariat, Canadian Cost-Benefit Analysis Guide: Regulatory Proposals — canada.ca
• US Office of Management and Budget, Circular A-4 (revised November 2023) — the 7% capital rate was withdrawn in this revision.

5.1.8 Bi-Mode Trainsets

§5.1.7 poses traction as a binary; the rolling-stock market answers it a third way. A bi-mode trainset carries a pantograph and onboard engines and changes between them in service, so the decision need not be taken uniformly across a network — which matters when the geography is one long new-build spine with unwired legs hanging off it. Wiring a new railway ahead of traffic is the cheapest catenary available; the costly kilometres are those over an operating railway, where clearance work, immunisation and possessions dominate. Bi-mode would let HPPR wire the 479 km spine and defer the Ottawa legs, the Peterborough service and the terminal approaches. ALTO does not escape the problem either: its corridor is described as mainly electrified, not wholly.

Britain ran the experiment at scale. The Intercity Express fleet was ordered as two variants of one platform — the Class 800 bi-mode and the Class 801 electric — both certified for 200 km/h, the bi-mode's penalty being mass: 243 tonnes against 233 for a five-car set, some 4% carried as dead weight under the wires. What it bought was decoupling, the train order no longer depending on the wiring programme finishing on time; the Railway Industry Association's Electrification Cost Challenge 2.0 of 2026 endorses the approach as policy. Blending the intensities of §5.1.3, a bi-mode running 70–90% of its passenger-kilometres under wire lands at 11–22 g/pkm and a fifty-year net of −12.9 to −14.6 Mt, against −15.25 Mt fully electric and −7.58 Mt diesel. The range is narrow because the −13.47 Mt freight credit is untouched by traction: it comes from trucks leaving the 401, not from anything inside the train. No traction choice available to HPPR changes the sign of the balance — only the margin.

The engines also buy something the carbon account does not capture. In a freezing-rain corridor a bi-mode can drop its pantograph and keep running when ice breaks current collection or the supply fails — Ottawa's Confederation Line lost its contact wire to concentrated arcing under ice in January 2023 and closed for six days — though the fallback covers loss of power, not a wire on the ground. Against that, the premium is paid twice, in engines carried under the wires and in two maintenance regimes, and the deeper risk is programmatic. Britain's bi-mode orders accompanied electrification schemes later curtailed, leaving trains built for a wired railway working on diesel. Canada's case is sharper: exo's twenty ALP-45DP dual-mode locomotives were bought for a Montréal network whose electrified section closed permanently in January 2020, and now work as expensive diesels.

Bi-mode is therefore a staging instrument rather than a third traction philosophy, and it earns its premium on one condition — that the spine is energised from opening and the unwired remainder is a costed, dated part of the programme rather than an open-ended deferral. Without that, it is the diesel case carrying extra mass and a larger capital bill.

Table 5.3 — Traction options for the HPPR spine. The electric and diesel columns are the modelled cases of Table 5.1; the bi-mode column is a first-order estimate on the same assumptions, with catenary on the spine only and 70–90% of passenger-kilometres run under wire. The freight credit is invariant to the traction choice because it arises from road-to-rail transfer rather than from train operation.

Measure	Electric	Diesel	Bi-mode (estimate)
Traction intensity	6 g/pkm	58 g/pkm	11–22 g/pkm
Traction, 50 yr	+0.49 Mt	+4.54 Mt	+0.9 to +1.7 Mt
Construction	+4.86 Mt	+4.46 Mt	≈ +4.75 Mt
Passenger modal	−7.88 Mt	−3.82 Mt	−6.7 to −7.5 Mt

Measure	Electric	Diesel	Bi-mode (estimate)
shift, 50 yr			
Freight credit, 50 yr	−13.47 Mt	−13.47 Mt	−13.47 Mt
Net 50-year balance	−15.25 Mt	−7.58 Mt	−12.9 to −14.6 Mt
Catenary scope	whole network	none	spine only
Winter resilience	none if OLE iced or supply lost	grid-independent	engine fallback if OLE iced or supply fails
Chief risk	capital; grid connection timing	fuel price; weaker modal capture	deferred wiring becomes permanent

SOURCES FOR §5.1.8

- Hitachi Rail, "Class 800 Series (800–810)" product data — hitachirail.com
- British Rail Class 800 and Class 801 fleet data (formation weights, engine fit, certified speeds) — en.wikipedia.org
- Railway Industry Association, Electrification Cost Challenge 2.0, June 2026 — riagb.org.uk
- Rail Engineer, "Next steps for discontinuous electrification" — railengineer.co.uk
- Rail UK, "Bi-mode trains: unlocking opportunity?" — railuk.com
- RSSB, "Mitigating the issues caused by ice on overhead line equipment" — rssb.co.uk
- CBC News, "LRT wires 'melted' during January ice storm, transit commission hears", 2023 — cbc.ca
- Railway Gazette International, "Decarbonisation: the true cost of replacing the diesel railcar", 29 August 2026
- Bombardier ALP-45DP dual-mode locomotive data and exo (Montréal) fleet history — en.wikipedia.org
- Alto, project description and corridor characteristics ("mainly electrified") — altotrain.ca; Major Projects Office, canada.ca

5.2 Species at Risk and Ecological Corridors

A railway is a linear barrier. Where that barrier is laid decides whether it severs habitat that is intact and connected, or adds a strand to a corridor already fragmented. ALTO's greenfield alignment and the ministerial variant now under study both run through, or immediately adjacent to, three of eastern Ontario's most sensitive landscapes: the Frontenac Arch, the Napanee Limestone Plain, and the Leda-clay wetlands south of Ottawa. HPPR follows the Highway 401 and CN Kingston Subdivision envelope — a strip already crossed by a four-hundred-series highway and a Class I freight main.

5.2.1 The Frontenac Arch: A Continental Pinch-Point

The Frontenac Arch is an ancient granite ridge, over a billion years old, that bridges the Canadian Shield to the Adirondacks across the St. Lawrence. Recognised as a UNESCO World Biosphere Reserve in 2002 and spanning roughly 2,700 km², it is where five forest regions converge and is among the most biodiverse landscapes in Canada. It is also the narrowest pinch-point of the Algonquin-to-Adirondacks corridor — the continental linkage along which wildlife move between the boreal Shield and the Appalachians. The Arch supports a long list of species at risk, including Blanding's turtle, the grey ratsnake, the eastern whip-poor-will, and a cerulean warbler population that represents roughly half of the Canadian total, alongside wide-ranging mammals such as fisher, black bear, moose, and eastern wolf.

Because the Arch is already the tightest point in a continental corridor, a *new* barrier laid across it does disproportionate harm: it does not merely disturb habitat, it narrows the last pinch-point through which a continent's wildlife still move. Highway 401 is already a documented resistance surface here, with a published record of wildlife road-mortality and studies of the highway's barrier effect on movement. That is precisely the argument for the disturbed-corridor alignment: HPPR concentrates its barrier where a barrier already exists, rather than opening a second line of severance through the same pinch-point.

5.2.2 The Napanee Limestone Plain: A Globally Imperilled Habitat

The Napanee Limestone Plain is one of Ontario's principal alvar landscapes — flat, sparsely-vegetated limestone pavement with thin or absent soils, subject to seasonal flooding and summer drought. Alvar is globally rare: it occurs in only two regions on Earth, the Great Lakes basin and the Baltic, and roughly 85 % of North America's alvar lies in Ontario, yet collectively it covers a fraction of a percent of the landscape. It is an irreplaceable repository of rare and disjunct species — grassland birds, regionally rare snakes, and specialised plants — and it supports part of Ontario's tiny remaining eastern loggerhead shrike population, a species reduced to a handful of nesting pairs province-wide. The plain's karst hydrology, in which water moves through dissolved limestone underground, makes it both ecologically distinctive and geotechnically awkward to build across.

THE ECOLOGICAL LEDGER

A greenfield alignment through the Arch and the Napanee Plain imposes fragmentation, edge effect, and barrier cost on intact, connected, globally-rare habitat. A disturbed-corridor alignment along the 401/CN envelope adds a strand to a landscape that is already fragmented — the same length of rail, a fraction of the ecological consequence.

None of this is a claim that HPPR is ecologically free. Its 50 m right-of-way still crosses natural land — the corridor land-cover audit in Chapter 4 finds about 41 % natural cover (forest, wetland, and shrub), 29 % agricultural, and 29 % already built. The point is comparative and structural: HPPR's natural crossings sit against an existing highway-and-rail disturbance envelope, where edge effects and a barrier are already present, whereas ALTO's crossings open fresh severance through the very corridors that the biosphere designation and the alvar's global rarity exist to protect.

SOURCES FOR §5.2

CITIZEN RESEARCH INITIATIVE

- Alto HSR Citizen Research Initiative, Environmental Impact Assessment: Impacts on the Frontenac Arch Biosphere Reserve (A. Hyett; reviewed by R. Upitis), March 2026 — citizenresearch.ca
- Alto HSR Citizen Research Initiative, Environmental Policy Assessment: The Napanee Limestone Plain — Implications for High-Speed Rail Route Choice (S. Moore and K. Hennige), March 2026 — citizenresearch.ca

• Alto HSR Citizen Research Initiative, The Southern Corridor: SARA and UNESCO Risks, May 2026 — citizenresearch.ca
• Alto HSR Citizen Research Initiative, species briefs: Eastern Loggerhead Shrike; Grey Ratsnake; Plant Species at Risk, 2026 — citizenresearch.ca
• Corridor land-cover audit at a 50 m right-of-way: Chapter 4, §4.2.2.

EXTERNAL

• UNESCO Man and the Biosphere Programme, Frontenac Arch Biosphere Reserve — designated 2002, reserve area 220,973 ha, five converging forest regions — unesco.org
• Frontenac Arch Biosphere — frontenacarchbiosphere.ca; Algonquin to Adirondacks Collaborative — a2acollaborative.org
• Nature Conservancy of Canada, Frontenac Arch Natural Area — natureconservancy.ca
• Birds Canada, Cerulean Warbler species-at-risk profile — the Frontenac Arch is predicted to hold 55–65% of the Canadian breeding population — birdscanada.org
• COSEWIC, Assessment and Status Report on the Cerulean Warbler; Environment and Climate Change Canada, Cerulean Warbler Recovery Strategy (2020) — canada.ca
• Wildlife Preservation Canada, Eastern Loggerhead Shrike — wildlifepreservation.ca
• Important Bird and Biodiversity Areas Canada, Napanee Limestone Plain (ON152) — ibacanada.org
• D. Baxter-Gilbert et al., “An adaptive design to reduce animal road mortality: a fence-culvert ecopassage on Highway 401, Ontario”, Queen's University — queensu.scholaris.ca
• “Patterns and drivers of amphibian and reptile road mortality vary among species and across scales: evidence from eastern Ontario, Canada”, Global Ecology and Conservation, 2024 — sciencedirect.com
• Ontario Nature, “Reconnecting the Frontenac Arch: how wildlife crossings can heal a fragmented landscape” — ontarionature.org

5.3 Disturbed-Corridor Siting and Construction-Phase Impact

The siting principle that governs the operating footprint governs construction as well. Linear infrastructure placed inside an existing transport corridor adds its dust, sediment, noise, and clearing to a strip that already carries those pressures; a greenfield line imposes them on quiet ground. HPPR’s spine follows a single rule — grade-separated, 200 km/h, no tunnels and limited viaducts, adjacent to whichever of Highway 401 or the CN Kingston Subdivision offers the straighter path — which keeps its construction disturbance immediately alongside an envelope that is already disturbed.

5.3.1 A Smaller, Shallower Construction Footprint

Building at grade alongside the 401 avoids the heavy-civil works that dominate a 300 km/h greenfield backbone. There is no Shield tunnelling, no deep cut through the Arch, and no Leda-clay stabilisation — the sensitive marine clay south of Ottawa that turns embankment into a major geotechnical undertaking. The structures programme is real but bounded: on the order of 220 road grade-separations and 32 named watercourse crossings along the spine, sited where the highway and rail corridor already cross those roads and streams. Frost heave, at 200 km/h, is a maintenance item rather than a speed-restriction event, so the alignment does not need the over-built, carbon-heavy foundations a high-speed line requires to hold tight geometry through the freeze–thaw cycle. The construction-carbon result in §5.1 — roughly a third of ALTO’s embodied emission — is the quantified expression of this shallower footprint.

Table 5.4 — HPPR spine corridor land-cover at a 50 m right-of-way, from the Chapter 4 corridor audit. The alignment runs the length of the already-disturbed 401 / CN Kingston Subdivision envelope; agricultural and built land together account for well over half the crossing.

Corridor land-cover (50 m ROW)	Share	Note
Natural — forest, wetland, shrub	41 %	crossed alongside existing disturbance
Agricultural	29 %	only ~19 % actively cropped
Built	29 %	highway, rail, settlement edge

Construction impact is also a matter of duration and reversibility. Co-construction with a highway widening that is already programmed means much of HPPR's disturbance is marginal — additional to works that were going to happen anyway — rather than a wholly new disturbance event. ALTO's greenfield backbone, by contrast, is a first and permanent disturbance across land with no prior transport corridor: every tunnel portal, viaduct pier, and embankment through the Arch and the Napanee karst is a new footprint on ground that had none.

5.3.2 Materials by Rail and the 401

A 479 km construction site has to be fed. The spine needs on the order of 9.8 Mt of imported fill, ballast, track components and structural concrete — roughly 20,400 tonnes for every kilometre built — and how that tonnage reaches the works is a community question before it is a carbon one. Delivered entirely by road it is about 390,000 loaded truck trips, and the road they would run on is the same Highway 401 the railway is being built beside, during the decade in which that highway is itself being widened.

HS2 is the reference case, and the reason it turned to rail is the instructive part. Its Materials by Rail programme was not conceived as a carbon measure. In the central section it was adopted after local authorities refused the lorry routes the project had planned under Schedule 17 of the HS2 Act: rail was how the works stayed consented. The programme has since moved more than 10 Mt of material, with about 20 Mt projected across Phase One, on 15,000 freight trains rising to a projected 30,000, and is expected to take 3 million lorry journeys off British roads. In Buckinghamshire alone the Quainton and Calvert railheads removed some 300,000 lorry movements. At Willesden, more than 2,500 spoil trains carried 3.6 Mt of excavated material out of London, with a conveyor bridging the last leg from Old Oak where no siding existed. Crossrail had established the method before it, moving 80% of its excavated material by tonne-kilometre on rail and water.

Applied to the HPPR spine the arithmetic is favourable, but modest in carbon terms, and it is worth being exact about that. At the 1,650-tonne train HS2 found to be the economic minimum, 9.8 Mt is about 5,900 trains, each displacing roughly 66 trucks. At Canadian freight-rail efficiency — a locomotive moves a tonne some 220 km on a litre of fuel, three to four times the efficiency of a truck — shifting 60–80% of the tonnage to rail avoids in the region of 0.05–0.08 Mt CO_2. That is between 1 and 2% of the spine's 4.86 Mt construction debt in §5.1. It is a real saving and it is a second-order one; the lifecycle case in this chapter does not rest on it and should not be argued as though it does.

What the strategy changes is community friction — the resistance a project accumulates among the people who live along its route, which §5.4 scores formally as the Latent and Community Friction Indices — and community friction is the variable that decides whether a corridor is deliverable at all. Consent is lost during construction rather than during operation — not at the finished railway, but across the years of truck movements through places that never agreed to them. HS2 is the evidence for this and not merely an illustration of it: the councils refused the lorry routes, and the project had to find another way to move its material or stop. Keeping some 390,000 loaded truck trips off the 401 and off the county roads between Pickering and Dorval removes the most visible daily imposition a linear project makes on the communities it passes, at precisely the point in the programme when opposition is cheapest to acquire and hardest to reverse.

That option is not a strategy either project can simply elect to adopt. It is a property of where the line is put. HPPR's alignment rule — adjacent to whichever of Highway 401 or the CN Kingston Subdivision offers the straighter path — places an operating railway beside the works along effectively the whole spine, with existing yards at Belleville, Kingston, Brockville, Cornwall and Coteau available as railheads and, on the Ottawa legs, VIA-owned Crown track that requires no host negotiation at all. ALTO's greenfield corridor has no such adjacency. Through the Frontenac Arch and across the Shield there is no railway to deliver to, so materials arrive by road over haul roads built for the purpose, and excavated rock leaves the same way, on rural routes through exactly the communities whose forward community friction §5.4 scores at 65 on the Latent Friction Index. The siting decision that determines the operating footprint determines the construction logistics as well.

The counterpart question is why CN would sell the paths, and the answer is that CN is a beneficiary twice over. During construction it is paid to haul: 5,900 trains over a decade is freight business rather than a favour, which gives the arrangement a commercial basis instead of depending on goodwill. After construction it inherits infrastructure it did not fund — grade separations at road crossings the two corridors share, renewed drainage and crossing works along its own right-of-way — and, more valuably, a parallel passenger-capable spine that would lift intercity passenger trains off the Kingston Subdivision and release capacity on the busiest freight corridor in eastern Canada. The freight credit that carries the lifecycle result in §5.1 — 13.47 Mt over fifty years, from long-haul trucks moving off the 401 — is that same proposition seen from the other side of the table. Those tonnes are carloads, and they are CN's.

Two cautions belong with this. There is no Canadian precedent at this scale, and no equivalent of Network Rail's published path-allocation cycle obliging a Class 1 railway to sell construction paths; the arrangement would have to be negotiated commercially, and early. HS2's own lesson was that bringing rail logistics expertise in late cost it options — the strategy was retro-fitted to a road plan that had already failed, and railheads, sidings and stockpile grounds are far cheaper to plan for than to insert. For HPPR the corollary is that materials by rail is a corridor-stage design decision, not a construction-stage procurement decision.

Table 5.5 — Materials by rail: HS2 Phase One outturn against a first-order estimate for the HPPR spine. HPPR tonnage is inbound bulk only — imported fill at 60% of an 8 m × 1.5 m formation, ballast, track components and structural concrete for the grade-separation programme — and excludes excavated material moved out. Train count at the 1,650 t load HS2 found to be the economic minimum; carbon range at 60–80% rail share over a representative 100 km road haul.

Measure	HS2 Phase One	HPPR spine (first-order estimate)
Route length	~225 km	479 km
Material moved by rail	10 Mt to 2023; ~20 Mt projected	~9.8 Mt inbound
Material per route-km	~89,000 t/km	~20,400 t/km
Freight trains	15,000 → ~30,000 projected	~5,900 at 1,650 t
Lorry / truck journeys avoided	~3 million projected	~390,000 loaded trips
Construction CO_2 avoided	~19,000 t on 1.8 Mt (central section)	~0.05–0.08 Mt (1–2% of 4.86 Mt)
Reason adopted	lorry routes refused under Schedule 17	corridor adjacency; 401 widening concurrent

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5.4 Community Friction and Expropriation

The human corridor obeys the same logic as the ecological one. A route laid beside an existing highway and rail line passes ground that communities already live alongside; a route driven through open country assembles its right-of-way from farms, homes, and communities that never expected a railway. The Initiative measures this two ways. The **Latent Friction Index** (LFI) scores a route’s forward, structural friction across five dimensions on a 20–100 scale before any opposition materialises; the **Community Friction Index** (CFI) measures the realised opposition a project has actually generated.

On the forward measure the HPPR spine scores about 29; ALTO scores about 65. On the realised measure ALTO has already reached 54, and rising.

Friction is not merely a political inconvenience — in the Initiative's reference-class cost model it is a statistically significant predictor of cost escalation, and the community-friction term carries most of the explanatory power in per-kilometre outturn across the international sample. The regression, its sample and its diagnostics are set out in Chapter 4; the statement here summarises that work rather than adding a finding. The friction that a new corridor generates is, quite literally, priced into what it costs to build. A low-friction alignment is therefore not only quieter socially; it is cheaper, and the two facts are the same fact seen from two sides.

5.4.1 Expropriation: Where the Right-of-Way Sits

The friction gap is driven above all by land tenure — and the distinction is where the new right-of-way sits, not whether one is needed. ALTO's greenfield line must assemble a continuous new corridor through open country, expropriating farmland and severing properties along its length, through communities with no prior relationship to the project. The Initiative's cost model applies a 1.4× premium over market value to compulsory acquisition, on the basis set out in Chapter 4. HPPR's spine also requires a new right-of-way; a railway cannot be laid inside a live highway or freight-rail corridor. But it acquires that strip *proximal to* the existing 401 and CN Kingston Subdivision rather than across untouched land. The land taken already borders major infrastructure — it is fragmented, its properties are already severed by the highway and the rail line, and the acquisition widens an existing disturbance corridor rather than opening a new one. The severance, the friction, and the surprise are all lower for being additive to a corridor that already exists. The Ottawa legs are different again: they run entirely on the VIA-owned Smiths Falls and Alexandria Subdivisions — federal Crown track the public already owns, needing no new expropriation and no host-railway negotiation at all.

Table 5.6 — Community and land-tenure profile: brownfield-led HPPR spine versus ALTO's new greenfield corridor. Friction indices scored 20–100; in the cost-model equations the friction variable is written CFI.

Dimension	HPPR spine	ALTO corridor
Forward friction (LFI, 20–100)	≈ 29	≈ 65
Realised friction (CFI)	low	54, rising
Spine right-of-way	new strip, proximal to 401 / CN	new corridor, open country
Ottawa legs	VIA-owned Crown track (no take)	new-build
Land expropriated	beside existing infrastructure	farmland & communities
Host-railway negotiation	none on Ottawa legs	n/a — greenfield

5.4.2 The Friction Advantage Is on a Clock

The one asymmetry that cuts against HPPR is time. The 401 margin that gives HPPR its low-friction, low-cost alignment is being consumed — by interchange commercial activation, logistics parks migrating east, residential subdivision at growth centres, and utility lock-in. As Chapter 4 sets out, the escalation in HPPR's own capital cost if the build is delayed until the corridor infills — land-value escalation plus the premium of building elevated through a developed strip rather than at grade on open land — is on the order of $20 billion, enough to roughly halve HPPR's benefit–cost ratio and erase the cost advantage that is the entire reason to prefer it. Community friction is lowest today and rises with every year of delay, because a corridor left open is progressively occupied. The brownfield-led route is the low-friction option — but only while the window is open.

5.5 Solar Potential and Corridor Stakeholders

This chapter has so far treated the corridor as something done to the land it crosses — habitat severed, parcels taken, trucks routed past homes that did not ask for them. There is a reciprocal question. An electrified railway is a large, steady, predictable industrial load laid across a region that holds the best solar resource in southern Ontario and is already building generation and storage at scale. What the corridor takes in land it can partly return in revenue — and the people it takes the land from are the people best placed to receive it.

5.5.1 The Resource: Eastern Ontario's Solar Advantage

Against the intuition that Ontario's sun improves as one travels south and west, the province's strongest photovoltaic yields are in the east. On Natural Resources Canada's photovoltaic potential data, Kingston records roughly 1,194 kWh per installed kilowatt per year and Ottawa about 1,140, against approximately 1,096 for Toronto and 1,084 for London. The difference is a matter of cloud climatology rather than latitude, and it runs the length of the spine: the counties between Kingston and the Québec border sit at the top of the provincial range, not the bottom. The railway is proposed through the sunniest ground in southern Ontario.

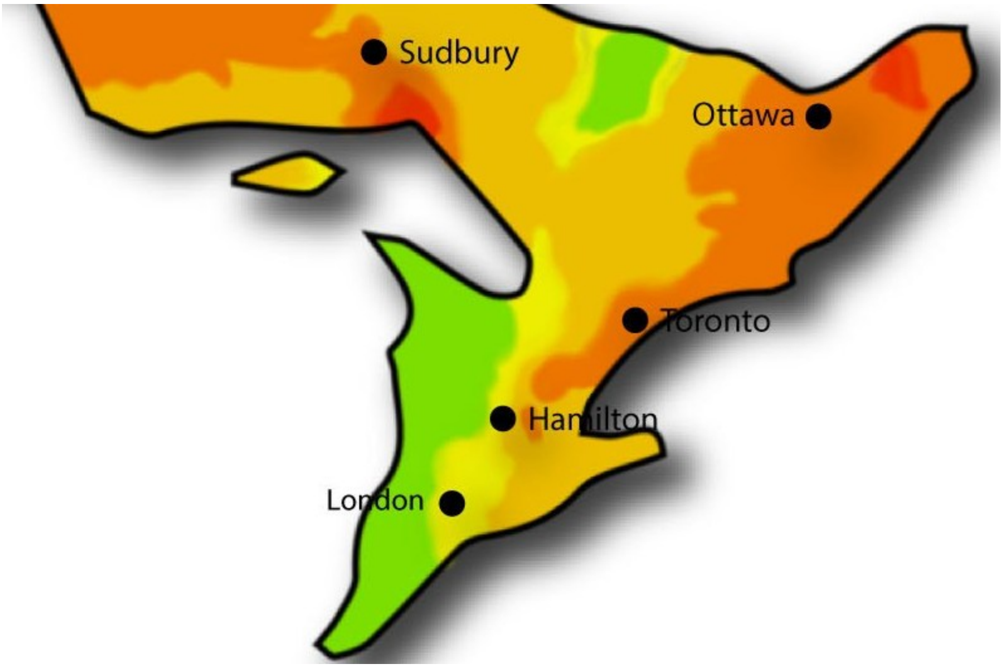

Figure 5.3 — Photovoltaic potential across southern Ontario; warmer tones denote higher annual yield per installed kilowatt. The eastern counties along the Kingston–Ottawa–Cornwall axis, through which the HPPR spine and its Ottawa legs run, carry the province's strongest solar resource; the southwest, around London, the weakest.

5.5.2 A Corridor That Is Already Building

Solar generation has proliferated beside Highway 401 east of Brockville, and the cluster is denser than a casual look suggests. Within a few kilometres of the highway around Ingleside stand four utility-scale ground-mount facilities of 10 MW each. Rutley came online in spring 2012, the earliest of them. The Cornwall Solar Project, at 18337 County Road 19 in South Glengarry, has been in commercial operation since 2013 and produces about 14,000 MWh a year from some 40,000 panels. Saturn Power's David Brown Solar Park reached commercial operation in March 2015, generates roughly 16.8 GWh a year — enough for about 1,800 households — and employed 112 local workers to build. The South Stormont project followed in early 2015. Forty megawatts, all of it inside the envelope the spine would follow.

Nor is the cluster peculiar to Ingleside. Firelight's eastern Ontario portfolio alone strings 10 MW ground-mount facilities along almost the whole of the proposed alignment — Sandhurst at Greater Napanee, Hwy 2 and Odessa at Kingston, Ray at Newboro, Alfred and Unity at Ottawa — each on or within a short distance of the spine or its Ottawa legs. The corridor that offers HPPR its cheapest kilometres has already been identified, by developers with capital at risk, as some of the province's best ground for generation.

The scale has since changed. At Edwardsburgh Cardinal, north-east of Spencerville, Potentia Renewables, the Algonquins of Pikwàkanagàn First Nation and Power Sustainable are building Skyview 2 — at 411 MW and 1,560 MWh the largest battery energy storage system in Canada, due to operate in 2027, committing roughly $1 million a year in municipal tax revenue for thirty years and some 300 construction jobs.

The corridor the railway wants is already an energy corridor, and it is being developed by the municipalities and communities the railway would have to negotiate with.

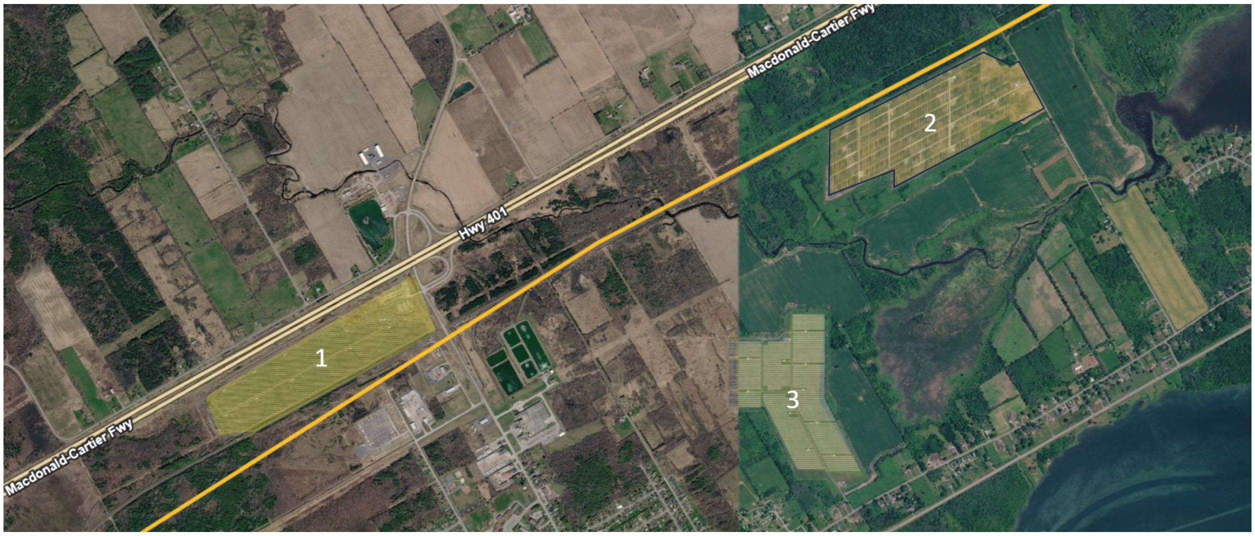

Figure 5.4 — Three of the ground-mount solar complexes beside the Macdonald-Cartier Freeway (Highway 401) near Ingleside, inside the envelope the HPPR spine would follow. Array 1 lies immediately against the highway right-of-way; arrays 2 and 3 occupy farmland set back on either side. The Ingleside cluster comprises four 10 MW facilities — Rutley (2012), Cornwall (2013), David Brown (2015) and South Stormont (2015); the numbering here is positional and does not assign a name to each array.

5.5.3 From Affected Landowner to Stakeholder

§5.4 scores the spine's forward friction low against ALTO's, but not at zero: a 50 m right-of-way beside the 401 still takes land from people who receive nothing directly in return. That is the structure of the transaction, and it is what generates opposition — the benefit is national and diffuse, the cost local and specific. Corridor solar changes the structure. A right-of-way takes a strip; a generation lease pays on the remainder, annually, for decades. The severed and awkward residual parcels that §5.4 identifies as a friction driver are poor ground for cropping and entirely adequate ground for photovoltaics.

Three classes of stakeholder are already visible in eastern Ontario's own projects. Landowners take lease income on land that continues to exist and can be returned to agriculture at end of life. Municipalities take a tax base — Skyview 2's million a year for thirty years is the local benchmark for what a single facility contributes to a rural township's budget. First Nations take equity, which in Ontario is now the ordinary structure rather than the exceptional one: the Algonquins of Pikwàkanagàn are a partner in Skyview 2, not a consultee to it.

The value at stake is worth putting in numbers, and so is the fact that it has fallen by roughly a factor of six. A 10 MW ground-mount facility in eastern Ontario generates 14.4 to 16.8 GWh a year. Under the Feed-in Tariff contracts that built the Ingleside cluster — a ground-mount rate of up to 44.3 cents a kilowatt-hour, guaranteed for twenty years — that was five to seven million dollars a year. Those contracts are closed, and utility-scale solar is now far cheaper to build; a facility contracted today at market rates of $50 to $80 per megawatt-hour earns closer to a million. The corridor's existing arrays are therefore a poor guide to what a new one is worth. But a million a year, arriving through a lease and a tax roll for thirty years rather than a single expropriation cheque, is still the difference between a landowner who is compensated once and a landowner who is paid throughout.

Table 5.7 — Revenue profile of a 10 MW ground-mount solar facility in eastern Ontario, at FIT-era and current contract prices. Generation range from the operating facilities near Ingleside. The Feed-in Tariff row is shown to explain what built the existing cluster, not as an available option.

Basis	Price	Annual revenue
Annual generation, 10 MW ground-mount, eastern Ontario	—	14.4–16.8 GWh
Feed-in Tariff contract, 20-year term (closed to new entrants)	up to 44.3 ¢/kWh	≈ $5.8–7.4 million
Contract at current market rates	$50–80/MWh	≈ $0.85–1.2 million

The railway is the fourth. An electrified 200 km/h spine is a predictable industrial load distributed along a line, which is the profile a corporate power purchase agreement exists to serve; Deutsche Bahn and Indian Railways both contract renewable generation for traction on that basis. The direct-connection version has been demonstrated but not matured — in August 2019 at Aldershot, Riding Sunbeams and Network Rail wired a 30 kWp array of about a hundred panels straight into a traction transformer, the first time solar had fed a railway's traction supply anywhere in the world, and it powered signalling and lights rather than trains.

The limits deserve stating as plainly as the opportunity. Solar output is summer-peaked and diurnal while traction load is flat and year-round, so corridor generation is a commercial and community proposition rather than a traction-supply solution: the railway will draw from the grid, and the traction figures in §5.1 already assume it does. Provincial policy constrains ground-mount development on prime agricultural land. Connection capacity and procurement timing govern what can actually be built, and when. None of that is a reason to leave the opportunity unexamined. It is a reason to examine it at corridor stage, alongside the alignment, rather than after the right-of-way has been assembled and the relationships have set.

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> The ecological advantage and the community advantage are one advantage. A route that adds a strand to an already-disturbed corridor severs less habitat and displaces fewer people than a route driven through open country — and it costs less precisely because it does. The greener option and the quieter option and the cheaper option are the same option.