High-speed rail in Australia: will it reduce greenhouse gas emissions?

Dr Paul Boulter EMM Consulting

Dr Robin Smit Transport Energy/Emission Research

Martin Chow Endgame Analytics

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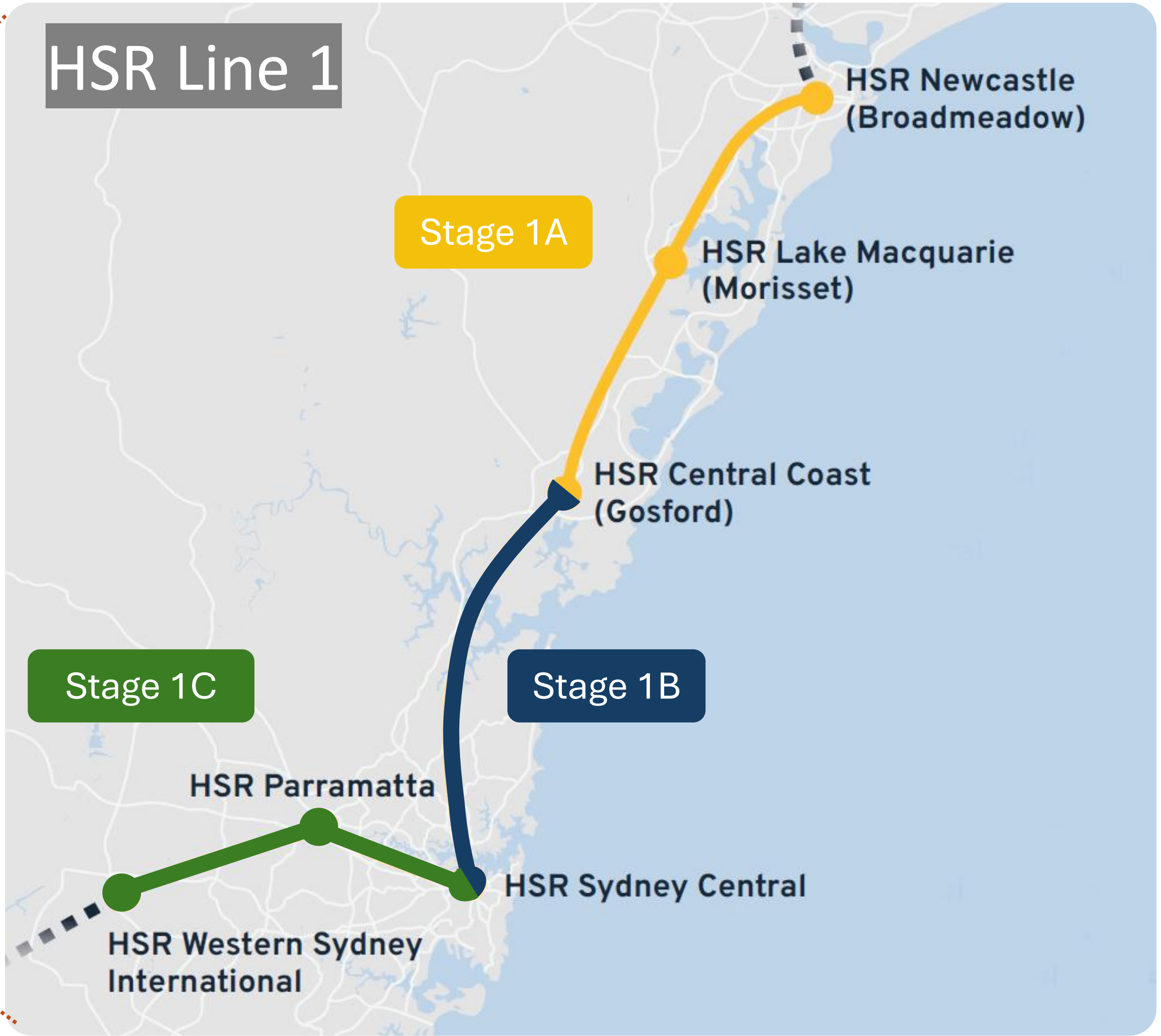
History of high-speed rail in Australia

- High-speed passenger rail in Australia has been considered by various governments since early 1980s
- The proposed route is typically between Brisbane, Sydney & Melbourne
- Some events:
    - 1984: CSIRO proposal based on French TGV technology
    - 1986: Very Fast Train Joint Venture
    - 1990: NSW Government was considering tilting train technology
    - 1993: Speedrail Consortium
    - 2000: TMG high-seed rail investigation
    - 2008-2013: Very Fast Train (High Speed Rail Study)
    - 2019: National Faster Rail Agency (to explore options)

High Speed Rail Authority



Study overview

- HSR often promoted as low-C alternative to road & air transport for passengers
- HSR = low *operational* GHG emissions intensity
- Previous studies
  - High Speed Rail study (AECOM et al. 2013); Grattan Institute (Terrill 2020)
- Gaps
  - Tend to focus on <u>operational</u> emission intensity (g/pkm) rather than life-cycle performance
  - Little research with up-to-date <u>Australian policy settings</u> (e.g. projected electricity generation & vehicle electrification)
  - Little on <u>simultaneous decarbonisation</u> of competing modes
- Our study: life-cycle assessment (LCA) for Line 1

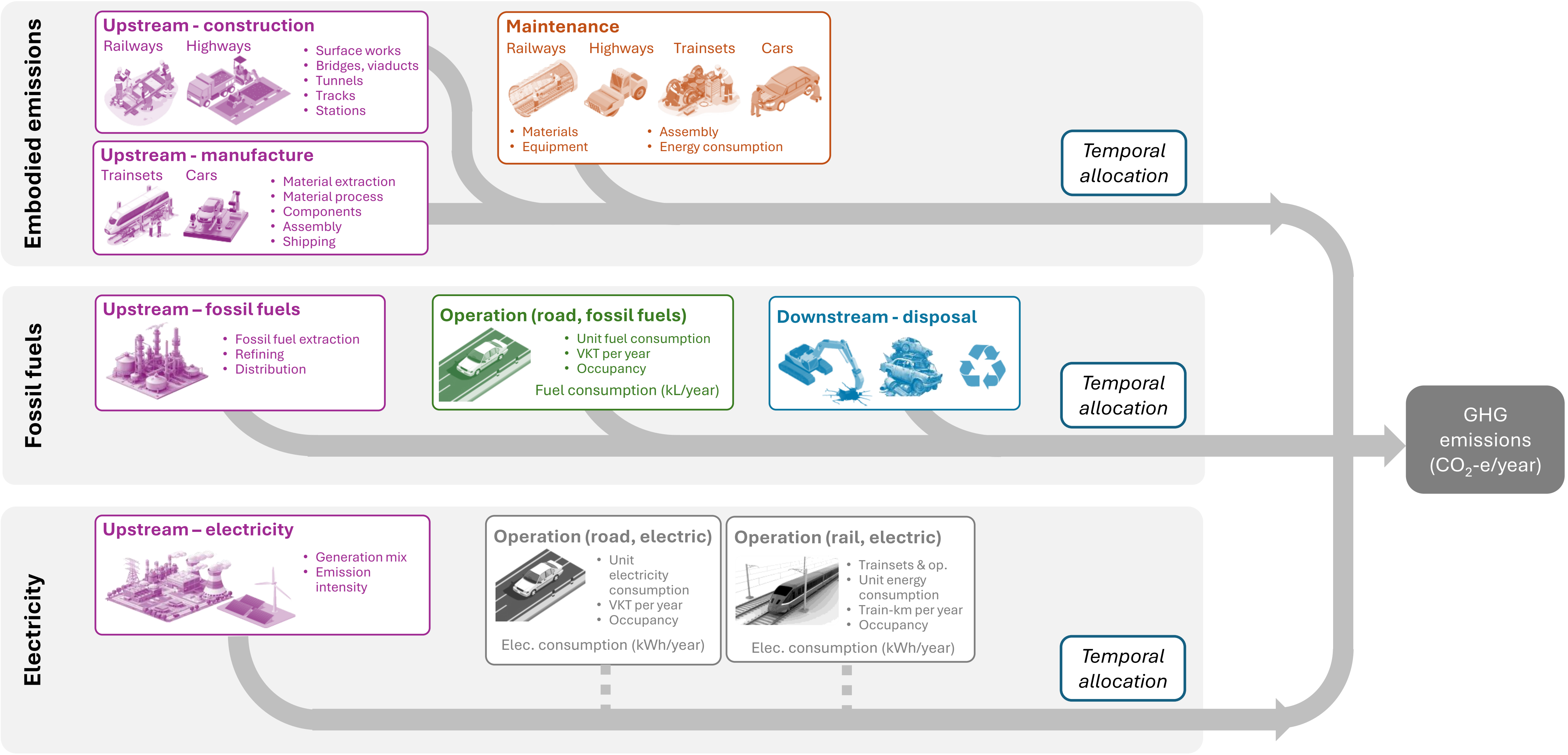
Study objectives

- Compare HSR Line 1 with an equivalent road corridor using a dynamic LCA approach
- On the basis that HSR would shift passenger-km (pkm) from road to rail, determine when it would start to reduce emissions
- Identify principal drivers of emission outcomes
- Inform infrastructure planning & transport decarbonisation policy
- Study not an argument for or against HSR

Timeframe, functional units & scenarios

- Timeframe: 2027 to 2080
- Functional units for outputs
  - Cumulative GHG emissions (Mt CO_2-e) for passenger transport between Sydney and Newcastle over the study timeframe (E_{rail} and E_{road})
  - Difference between E_{rail} and E_{road} (ΔE) ➡ 'break-even' year ('carbon payback')
- Scenarios
  - 'New rail - new road' (NR-NR)
    - Both HSR Line 1 and an equivalent road transport route would be built
    - Level playing field, but not realistic (roads already exist)
  - 'New rail – existing road' (NR-ER)
    - Emissions for road construction & maintenance = zero
    - More realistic representation of HSR Line 1 relative to road transport

LCA methodology



System characteristics: Infrastructure

Rail infrastructure

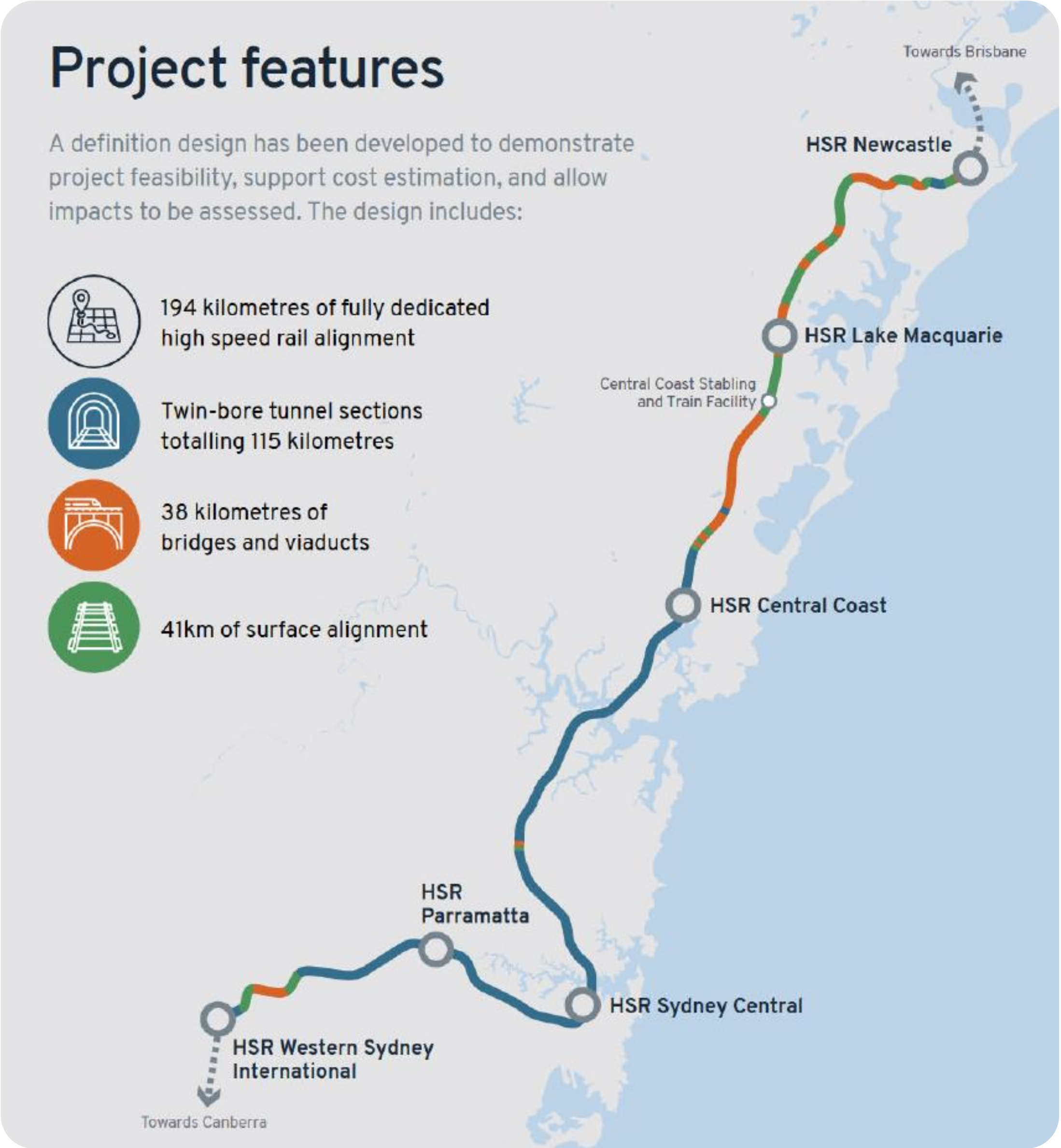
Parameter	Stage 1A	Stage 1B	Stage 1C	Total
Construction years	2027-36	2027-38	2034-42	-
Operation start year	2037*	2039*	2043*	-
Line length (km)	85	75	34	194
Tunnels (km)	13*	73*	29*	115
Bridges/viaducts (km)	35*	1*	2*	38
Surface (km)	37*	1*	3*	41
Number of stations	3	1	2	6

Sources: High Speed Rail Authority (2025); *estimate of the authors

Road infrastructure

Parameter	Value
Construction years	2027-36
Operation start year	2037
Road length (km)	227
Lanes	6 (2 x 2 plus hard shoulders)
Lane width (m)	3.5

Sources: Estimates of the authors



System characteristics: Transport units (vehicles)

Rail – trainset

Transport unit	
CRH2 trainset (x6)	
Parameter	**Value**
Cars	8
Seats	520
Empty mass (tonnes)	470
Average occupancy (%)	60
Average train lifetime (years)	30

Sources: High Speed Rail Authority (2025); Zhang et al. (2022); AECOM et al. (2013)

Road - car

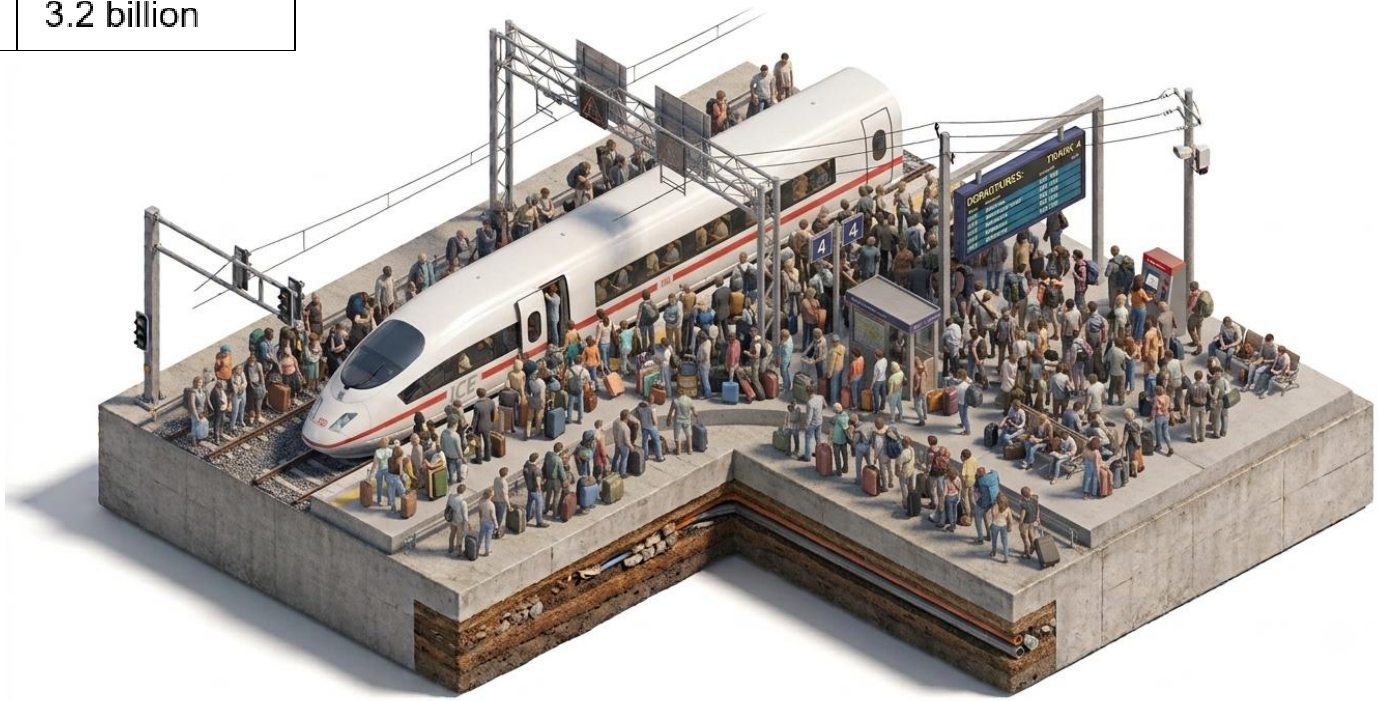
Transport unit	
Average Australian passenger vehicle, based on a VKT-weighted mix (by year) of small/medium/large cars and compact/large SUVs, with a mix of powertrains: ICEV (petrol, diesel, LPG), HEV, PHEV, BEV, and FCEV.	
Parameter	**Value**
Average car occupancy (people)	1.6
Average car lifetime (years)	15*

Sources: Smit & Boulter (2024); *estimate of the authors

System characteristics: Travel demand

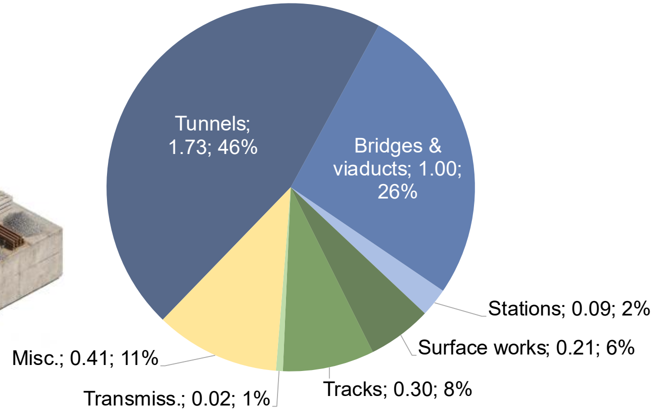
Parameter	Value	
	2030	2050
Two-way train journeys per day	72	144
Journey time (hours)	~1	~1
Train activity (train-km/year)	5.1 million	10.2 million
Passenger activity (passengers/year)	4.1 million	8.2 million
Passenger activity (passenger-km/year)	1.6 billion	3.2 billion

Sources: High Speed Rail Authority (2025) and estimates of the authors



Upstream emissions: key assumptions

- **Railway construction:** no detailed public data; estimated from Osong–Gwangju line, South Korea (Lee et al. 2020): 3.8 Mt CO_2-e (cf. Infrastructure Australia 2025: 3.7 Mt CO_2-e)
- **Road construction** (NR-NR only): ~1 t CO_2-e/m^2 (Yao et al. 2024; NSW RMS 2019); 10-year build period
- **Trainset manufacture:** 7.7 kt CO_2-e/trainset (Cai et al. 2025); 6 trainsets, 30-year life
- **Car manufacture:** EFs from Bieker (2021): ICEV 7.5 / EV 13 t CO_2-e; adjusted for AU fleet & EV share (CSIRO)
- **Electricity & fuels:** NSW grid 0.08 t CO_2-e/MWh from 2036 (DCCEEW 2025)*; fleet-weighted WTT intensity for road (Smit & Boulter 2024)

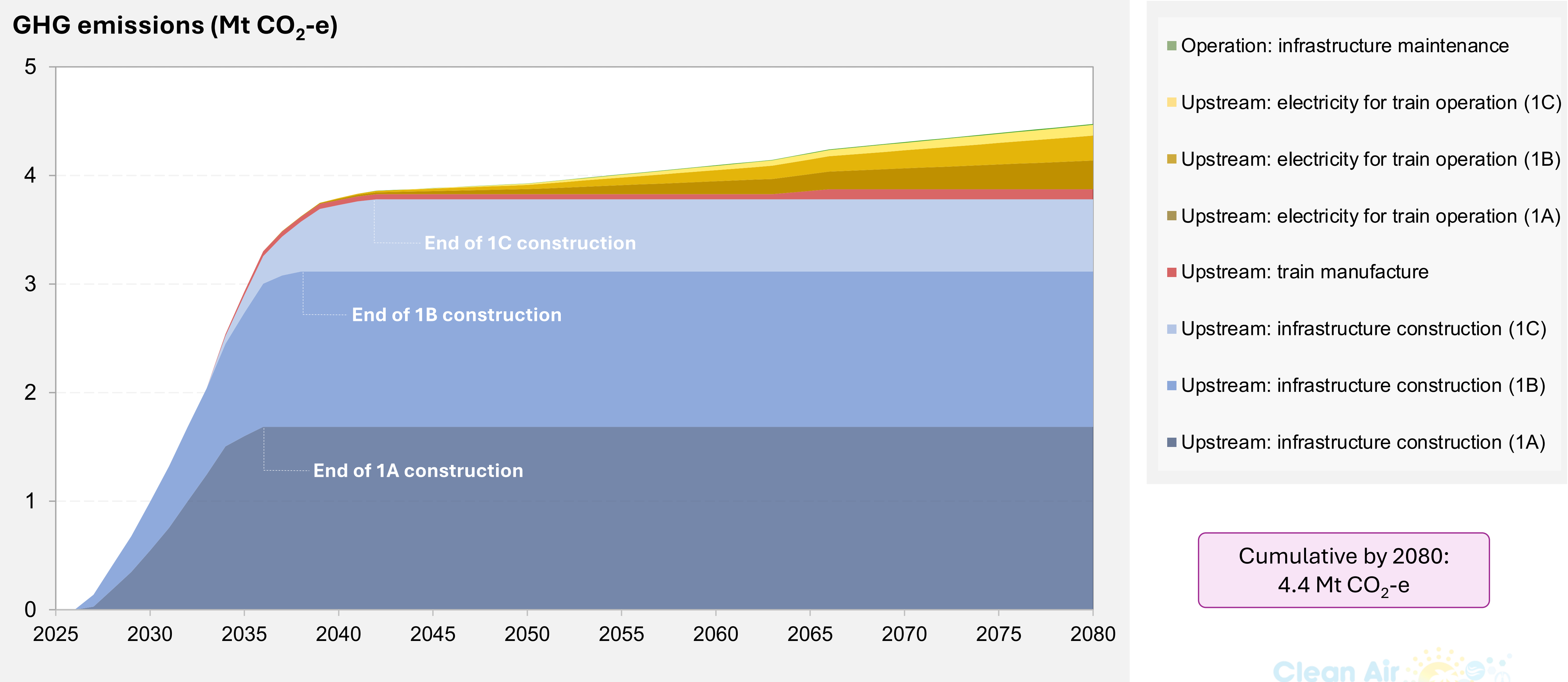


*HSRA claims HSR will be net-zero in operation, using 100% renewable energy.

Operational & downstream emissions: key assumptions

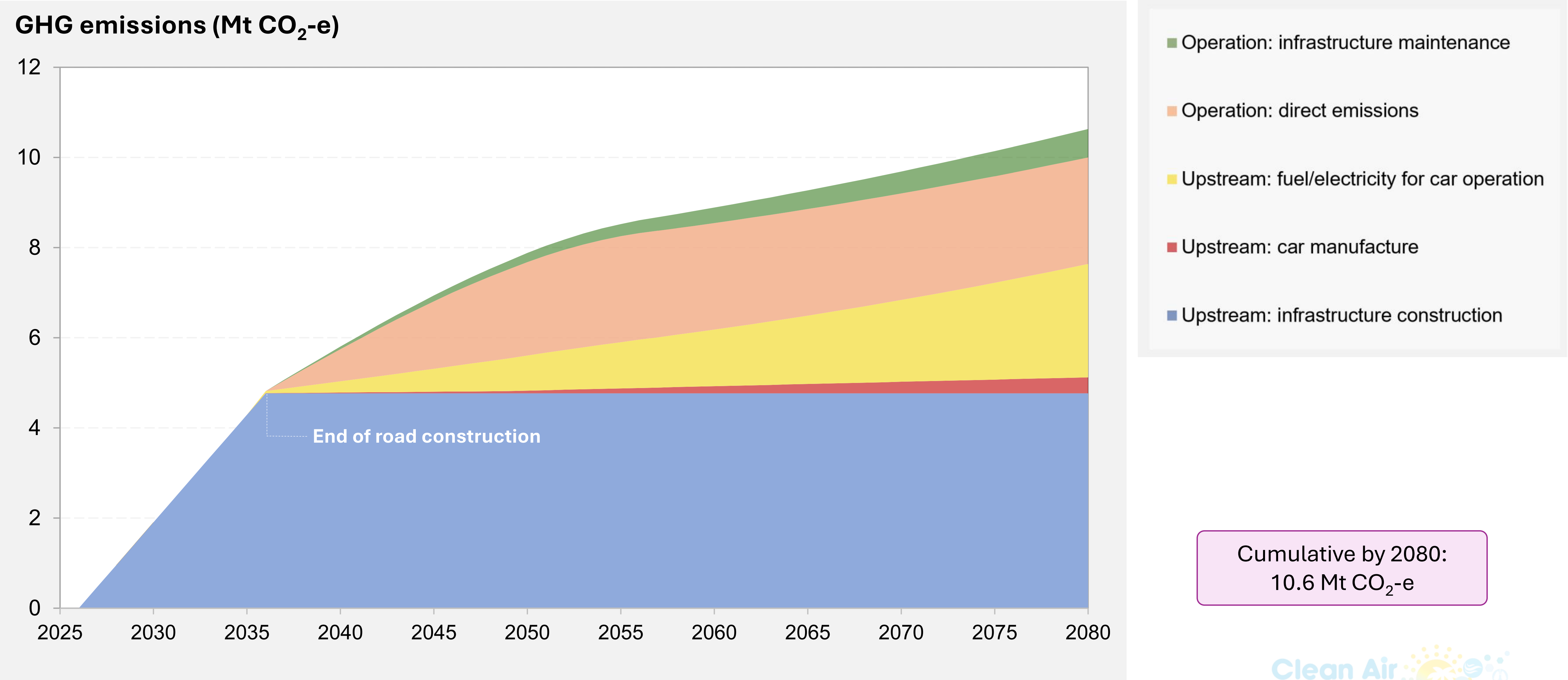
- **Rail operation**: electrified; zero direct emissions; 20.3 kWh per gross train-km (Zhang et al. 2022)
- **Road operation**: fleet-weighted tank-to-wheel emission intensity by vehicle type (Smit & Boulter 2024)
- **Rail maintenance**: ~102 t CO_2-e/100 km per year, based on large HSR networks (Damián & Zamorano 2025)
- **Road maintenance** (NR-NR only): ~30 kg CO_2-e/m^2 per 10-year cycle → ~14.3 kt CO_2-e/year (WA) (Jiang et al. 2020)
- **Train/car maintenance**: negligible
- **Disposal**: infrastructure demolition far in future (excluded); trainsets/cars mostly recycled — negligible contribution (Cai et al. 2025)

Results: HSR Line 1



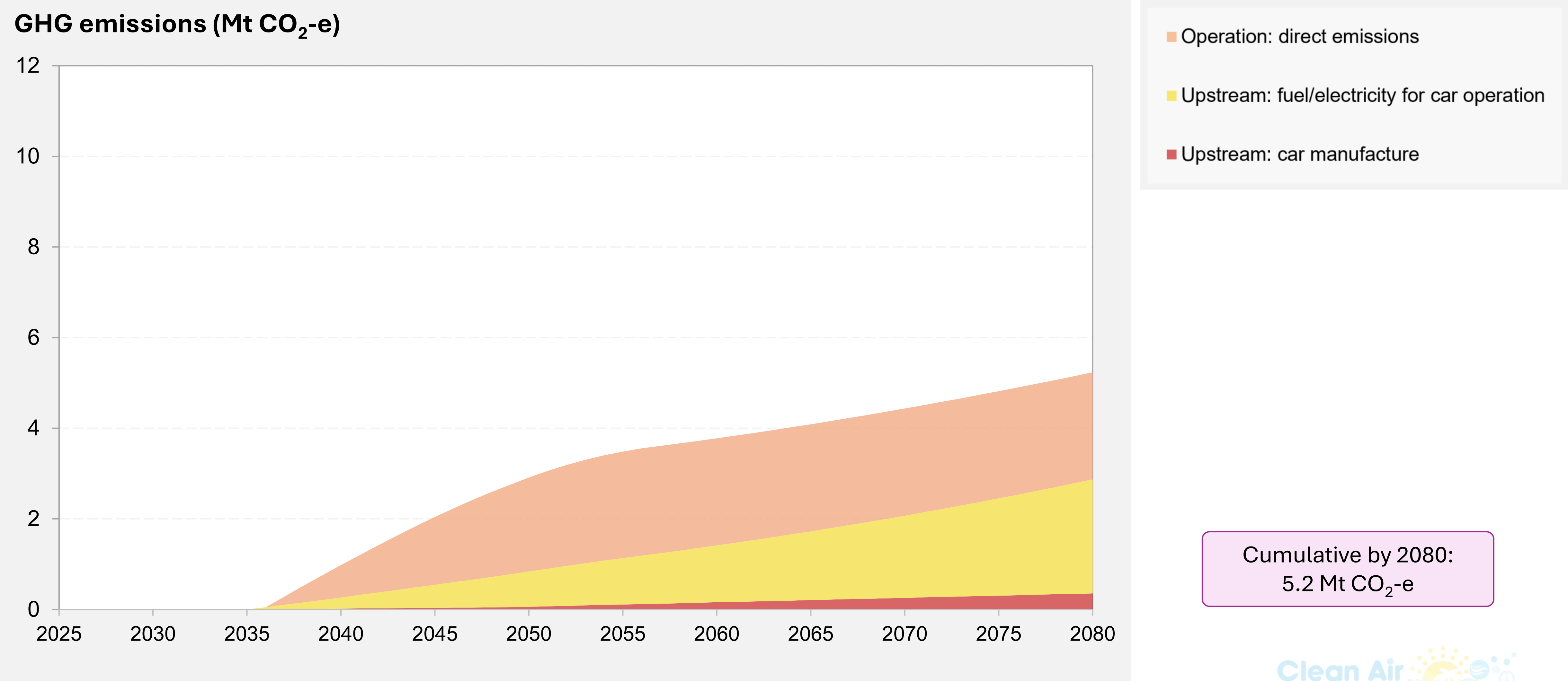
Cumulative by 2080:
4.4 Mt CO_2-e

Results: road corridor (NR-NR scenario)



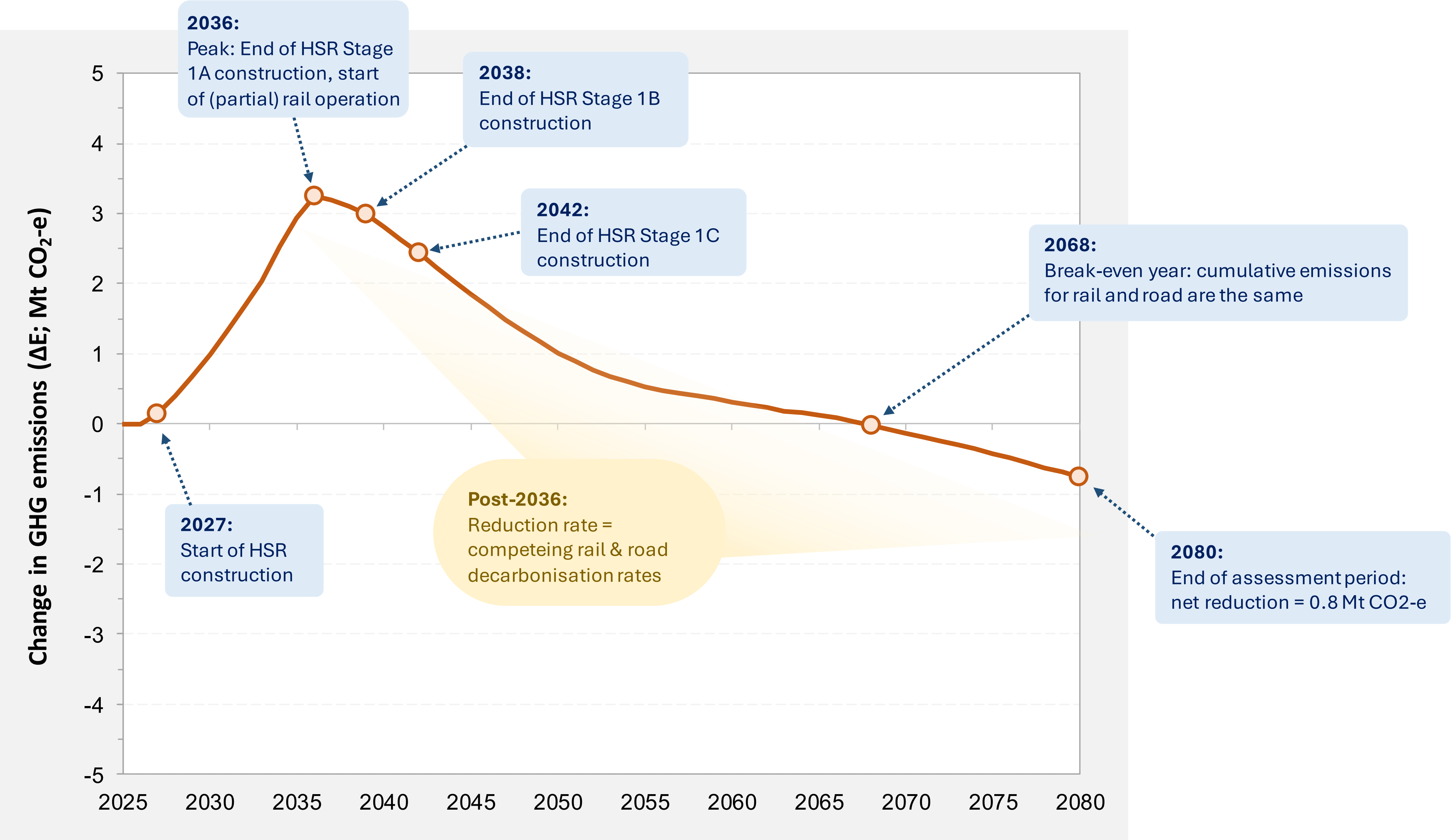
Cumulative by 2080:
10.6 Mt CO_2-e

Results: road corridor (NR-ER scenario)

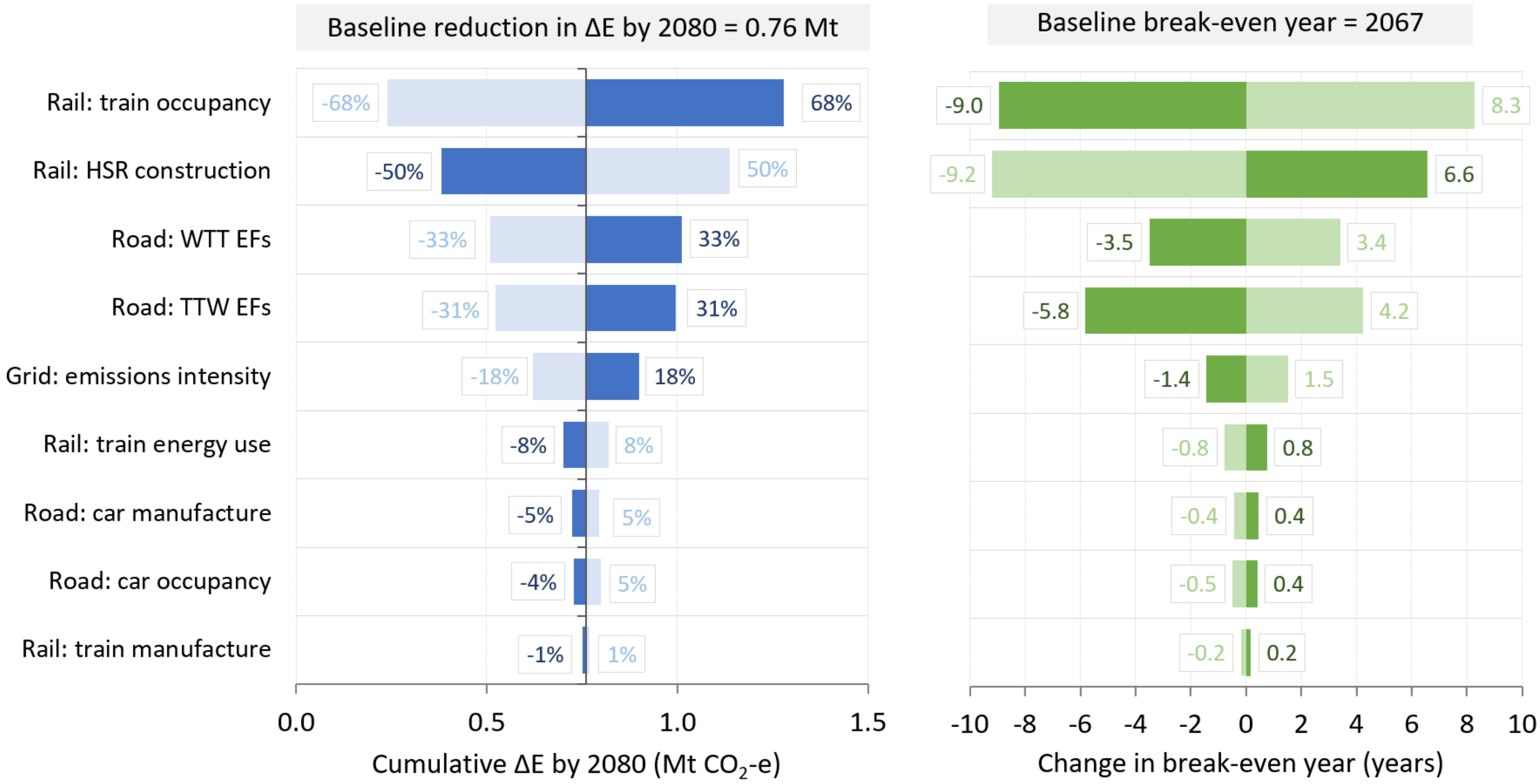


Cumulative by 2080:
5.2 Mt CO_2-e

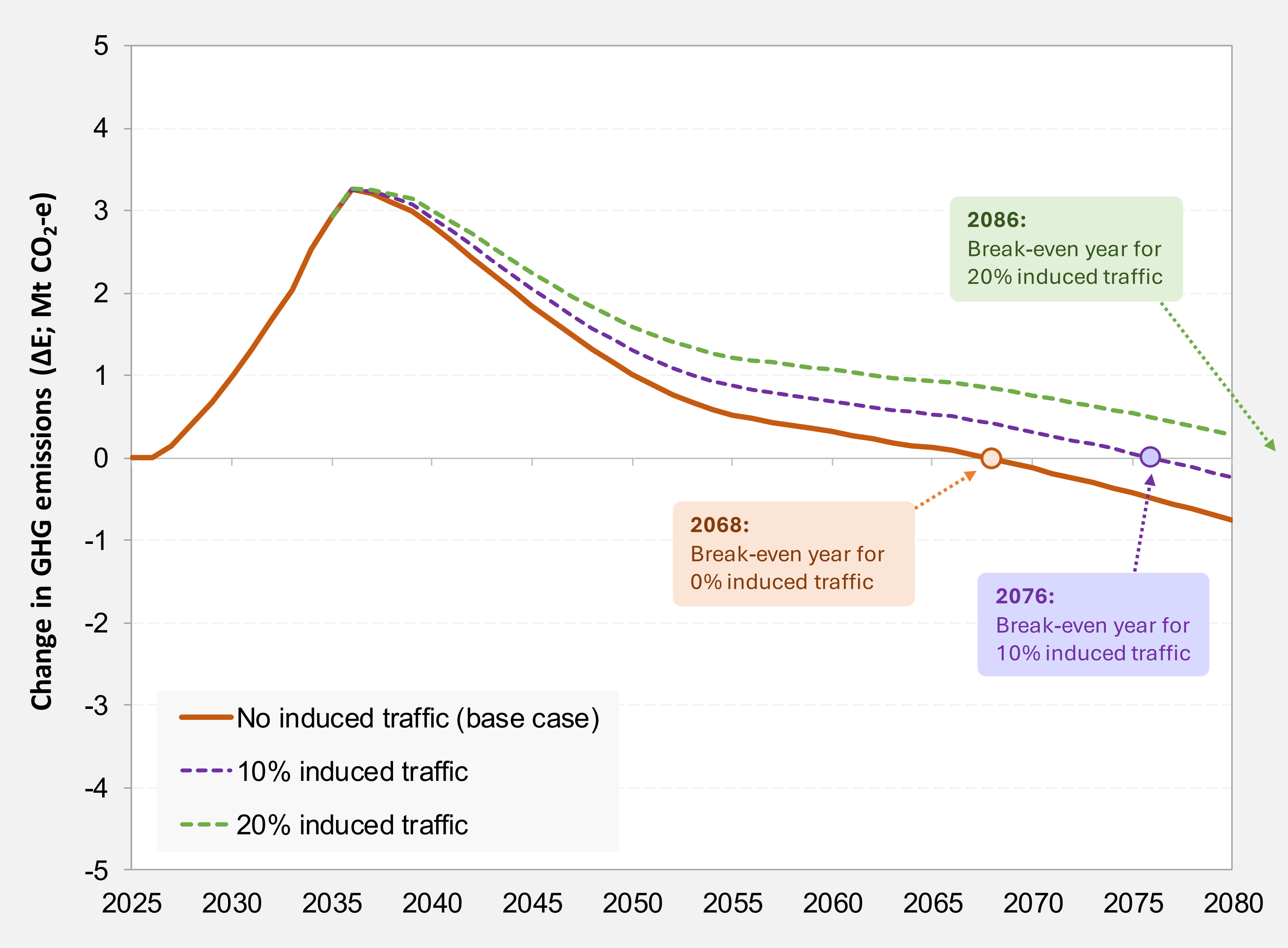
Results: NR-ER scenario (ΔE)



Sensitivity analysis: effect of 10% change (dark bars = increase)



Results: NR-ER scenario (ΔE) with <u>induced traffic</u>



- HSR could generate travel demand, whereby people make trips they would not otherwise take
- Assumed that a % of pkm would be <u>additional</u> road traffic (no chage in rail pkm)
- 10% induced traffic extends break-even year to 2076
- 20% induced traffic extends year to 2086
- Very uncertain

Mitigation of construction emissions

- No specific mitigation of GHG emissions assumed for either rail or road
- Awareness of need to reduce emissions during construction of HSR Line 1
- Infrastructure Australia (2025):
    - "HSRA will seek to achieve net-zero emissions in construction by 2035 through initiatives ... including adopting reduced emissions steel, concrete and generating renewable energy."
    - "Proposal acknowledges there is uncertainty regarding the costs and suitability of materials to reduce emissions."
    - " ... offers a major opportunity to catalyse a new wave of low carbon construction ... greatly reducing the carbon impact of both future stages of the [rail] network and wider industries in Australia."

Conclusions and policy implications

- Understanding net-zero impacts of major transport infrastructure:
  - Evaluation over decades, from an early stage of planning
  - Comparative & dynamic LCA, given changes in energy, technology and behaviour
- Break-even point for HSR Line 1 is ~2068 (C-payback period of ~40 years)
- Most important factors:
  - Infrastructure construction
    - Opportunity for reducing life-cycle emissions of Line 1 could stimulate wider production of low-C materials
  - Rail occupancy
    - Maximising HSR patronage through policy & planning actions: integration with local public transport, station accessibility, service frequency, travel time competitiveness, pricing and policies influencing private vehicle use
- Road transport decarbonisation and induced traffic are 'problems' for HSR

Limitations and future refinement

- Incorporation of more HSR-specific data
- Improved calculation for rail network construction (more detailed material flows)
- More detailed demand forecasts:
    - More nuanced trip distributions (not just end-to-end)
    - Consideration of a shift from the existing rail network to HSR
    - Effects of Western Sydney Airport
- Incorporation of other HSR stages; air transport the main alternative (quicker C-payback - decarbonisation much harder than for road vehicles)
- Application of the probabilistic approach to better understand risk and uncertainty (Smit & Boulter 2024)
- Consideration of mitigation options and effects
- Assumptions change with time, and need to be revisited