

Incorporating climate scenario analysis into public transport emissions modelling

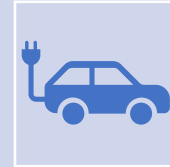
Transportation Conference 2026 | Auckland
Authors: Shahaanan Arulgnanapragasam (WSP NZ)
Dr. Manoj Pokhrel (Auckland Transport)
Cal Roughan (WSP NZ)



Why this matters



Public transport (PT) is AT's second-largest emissions source (37%)*



Operational PT emissions are ~94 ktCO₂e per year – mostly diesel



Funding uncertainty risks locking in high emissions fleet



We need to test if our pathways hold under different climate futures



Research objective



Integrate climate scenarios into AT's PT emissions model



Compare current vs accelerated decarbonisation to 2050



Provide insights across Orderly, Disorderly, Hot House World futures

Scope and boundary



Covers operational PT emissions plus selected life-cycle impacts



Includes: energy use; upstream energy, embodied manufacturing, maintenance and end-of-life.



Excludes: commercial operator energy, network infrastructure, corporate emissions.



Modelling calibrated with FY2021-25 data and starts FY2025/26



Climate scenarios used



Orderly (OT): Early, coordinated action; fast tech uptake; aligned with ambitious $\sim 1.5^{\circ}\text{C}$ pathways



Disorderly (DT): Delayed action \rightarrow abrupt transition; achieves $< 2^{\circ}\text{C}$



Hot House World (HHT): weak policy; high physical climate impacts; $> 3^{\circ}\text{C}$

Modelling approach (conceptual)



Fleet stock model for bus, ferry, train.



For each vehicle type & fuel: vehicles procured and disposed; vehicles in operation; annual km travelled; fuel efficiency.



Emissions = operational fuel/electricity use × scenario-specific emission factors + embodied manufacturing + maintenance + end-of-life.



Scenario parameters affect procurement trajectories and emissions factors (e.g., grid decarbonisation).



Grid emissions factors aligned to MBIE Electricity Demand and Generation Scenarios (EDGS)

Orderly ↔ Environmental scenario (near-zero grid emissions by mid-century).

Disorderly ↔ Combination of Reference and Innovation (moderate decarbonisation).

Hot House World ↔ Reference scenario (slower decarbonisation; higher residual EF).

Key inputs - buses

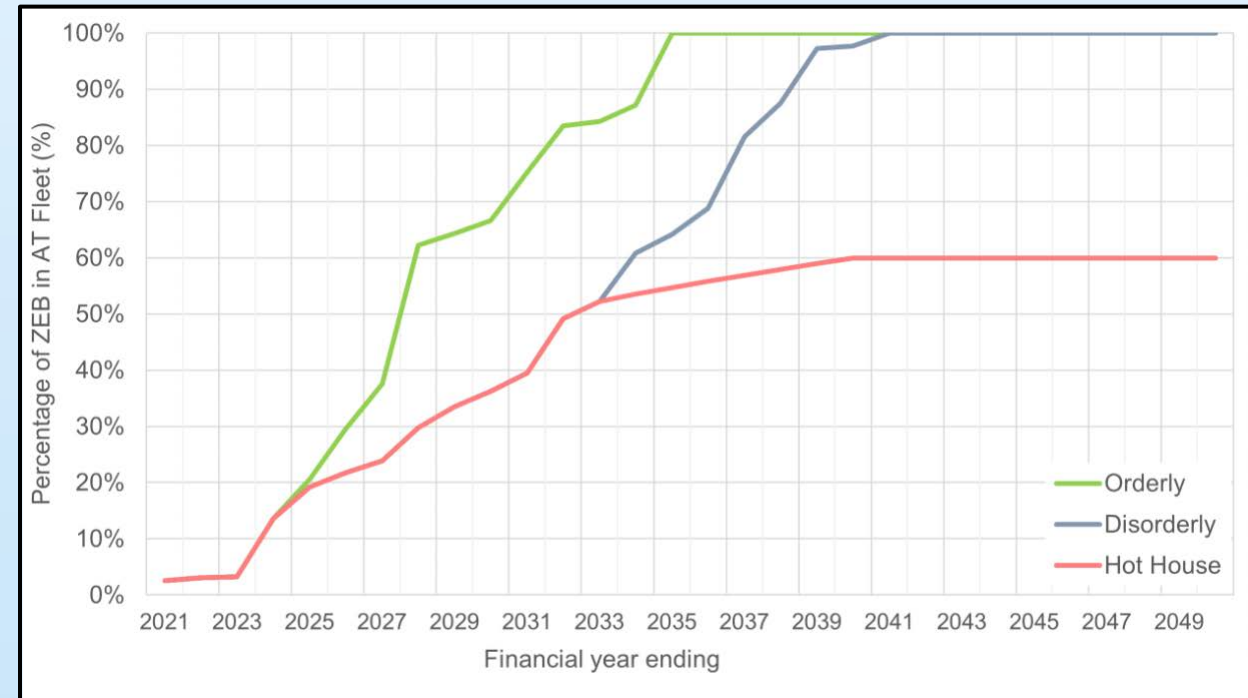
Based on AT Low-Emission Bus Roadmap:

- **Orderly:** Fastest ZEB uptake - Option G.
- **Disorderly:** Option E.
- **Hot House World:** modified Option E (ZEB ~60% by 2050).

Assumes transition of ~1,350 existing buses + ~603 new vehicles.

Embodied emissions broken into chassis/batteries/fuel cells/ICE; manufacturing efficiency improves by 2050 (20/45/75% across scenarios).

Financials extrapolated to 2050 from roadmap.



Results - buses

Orderly delivers early and steep emission decline.

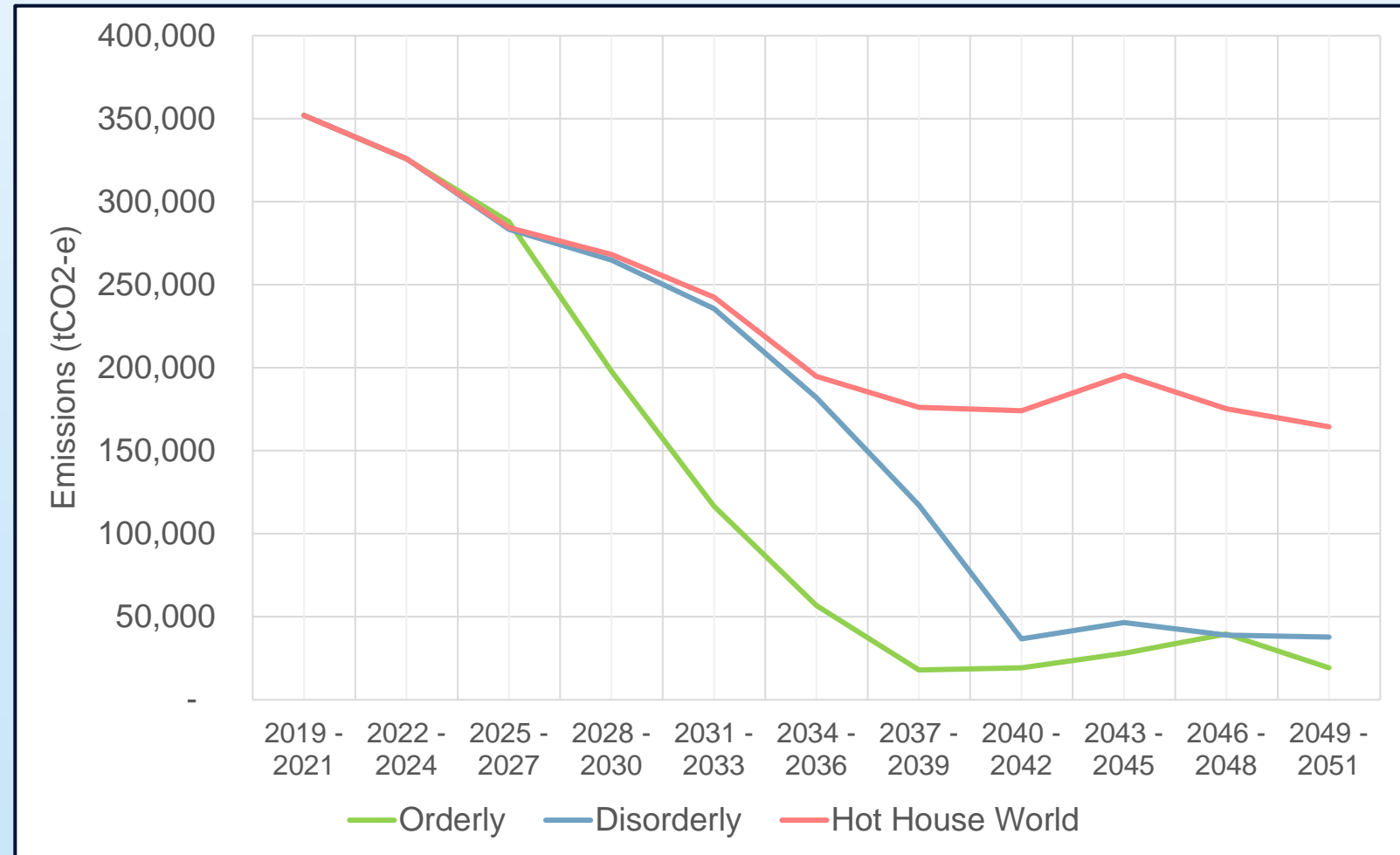
Operational carbon savings > embodied manufacturing emissions.

Grid decarbonisation strengthens reductions through late 2030's.

Emissions rise in the 2040s as fleets are replaced, but ongoing grid improvements offset this spike.

Extra funding (+150%) achieves ~72% more reduction.

High social cost savings.



Key inputs - ferries

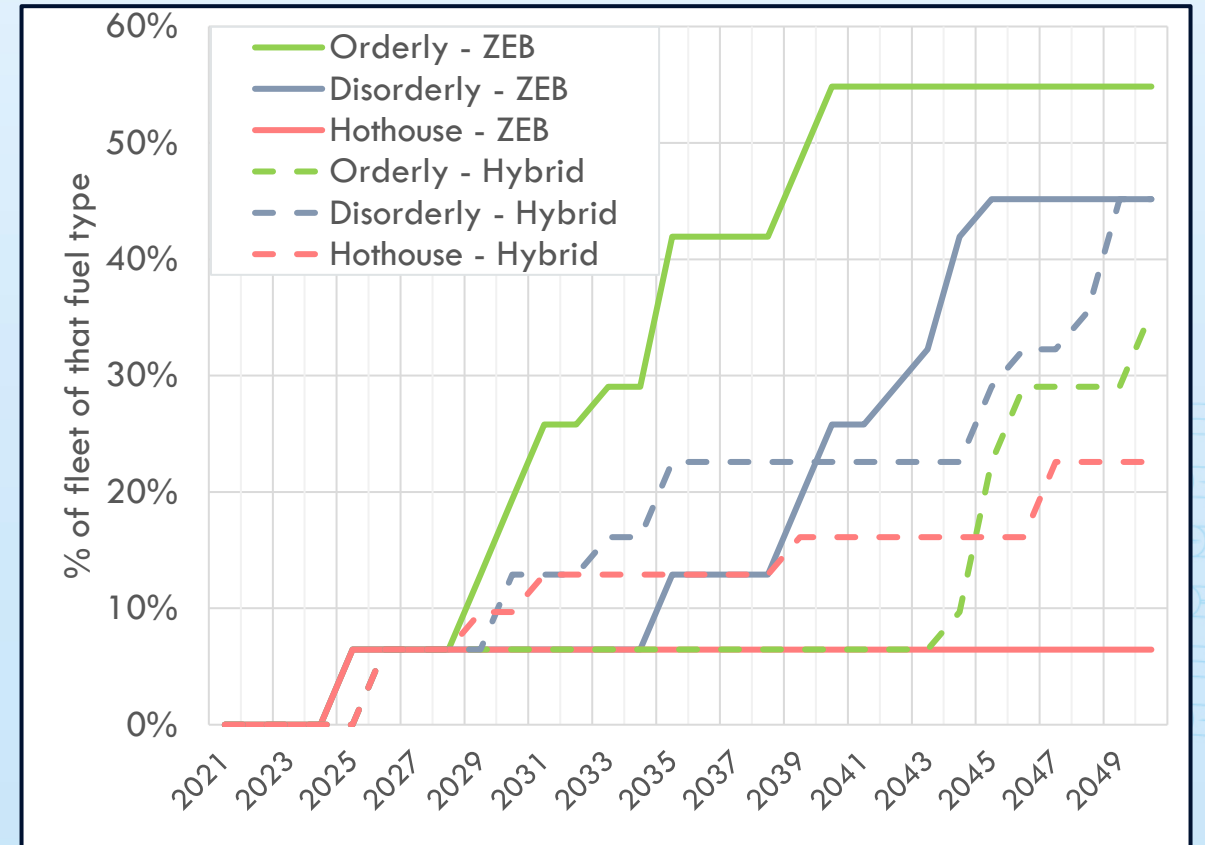
Limited long-term data → workshop-derived lifecycle assumptions.

Fleet grows modestly, VKT held constant.

Fleet mix varies: Orderly mostly electric; Disorderly balanced; HH mostly diesel.

CAPEX only (2021 costs): diesel \$14m; 2nd-hand diesel \$3.75m; hybrid \$20m; electric \$25m.

PV additional CAPEX: Orderly \$346m; Disorderly \$298m; HH \$202m.



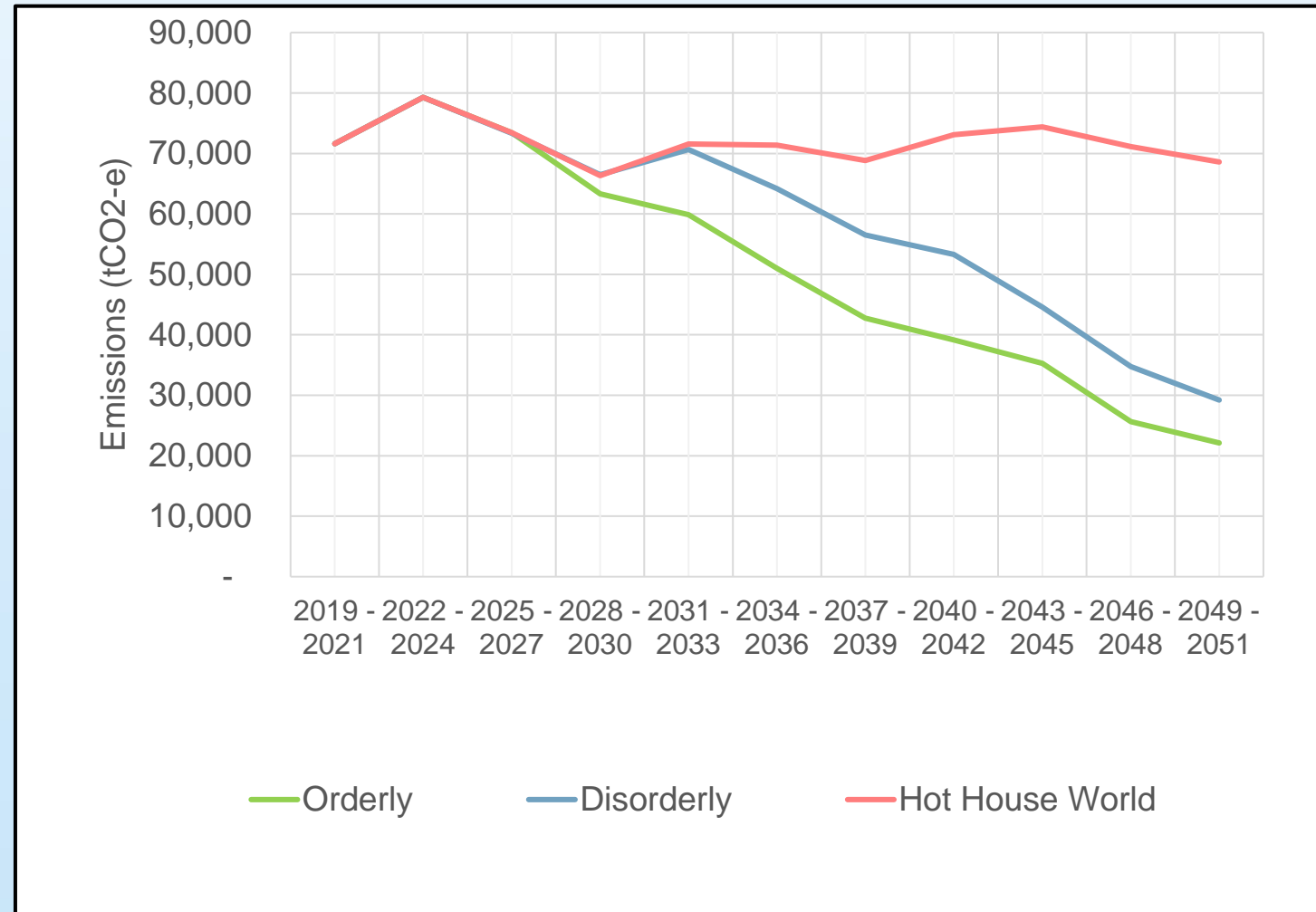
Results - ferries

HHT shows minimal reductions until ~2040 → creates lock-in risk.

Embodied Emissions are high for vessel replacements.

Additional funding for ferries not offset by social GHG cost savings.

Orderly vs Disorderly: 51% more funding yields 50% more emissions reduction.



Key inputs and results - trains

EMUs fully electrified; fleet size & VKT +grid EF drive emissions.

Diesel phased out by 2023.

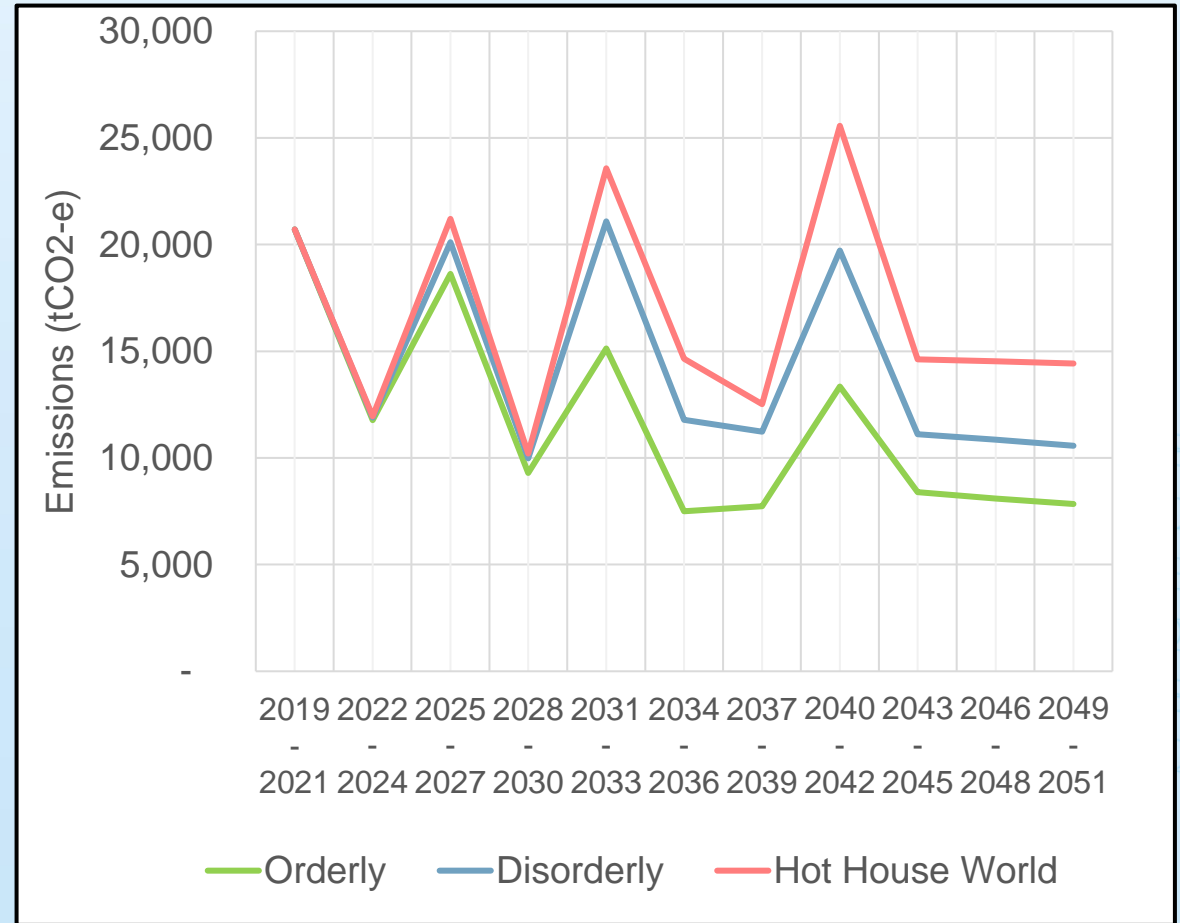
Fleet numbers stable (AT/KiwiRail plan).

VKT grows from 45,000 km to 75,000 km by 2034.

Embodied emissions: EPD Alstom (2022), manufacturing improvements (up to 65% by 2050).

Trains: embodied emissions significant (~520 tCO₂e per 3-car EMU).

Financial impact not assessed (minimal fleet changes).



Results – funding vs outcomes

Total emissions reduction by 2050 per \$1m invested:

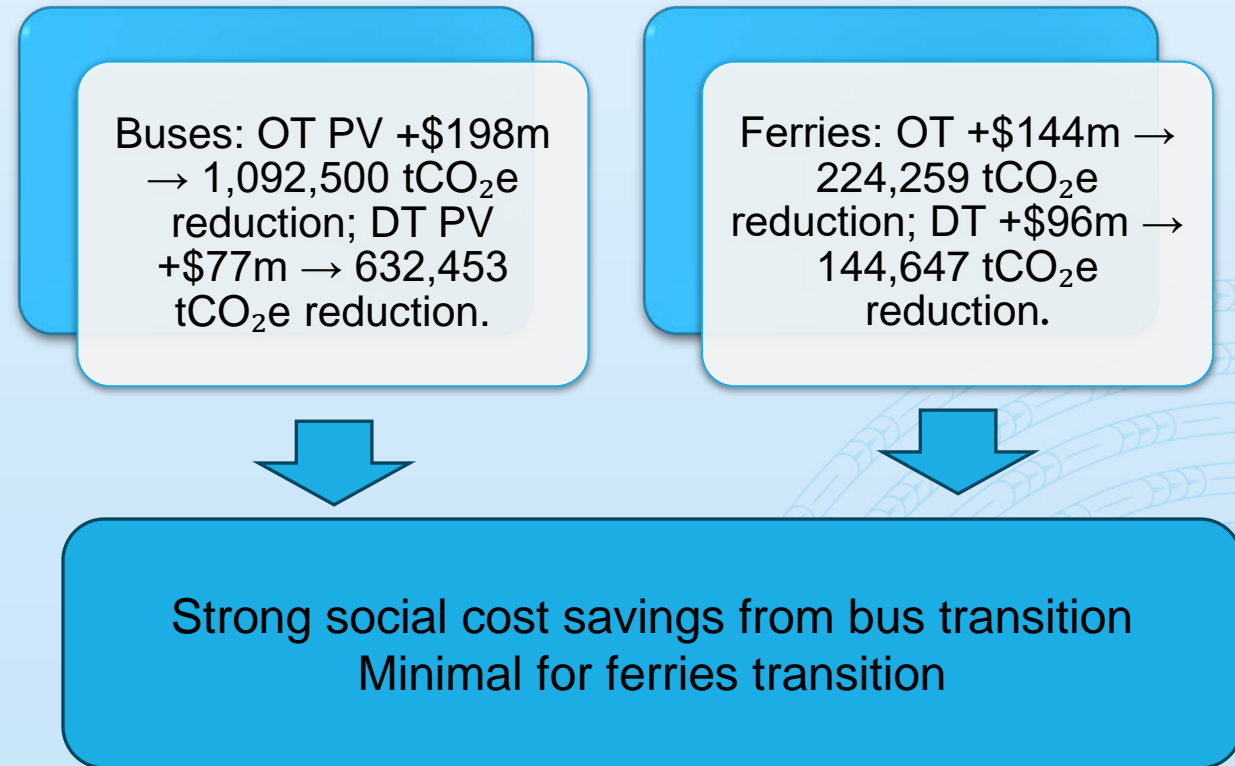
Buses:

- Orderly: 5,528 tCO₂e,
- Disorderly: 8,193 tCO₂e

Ferries:

- Orderly: 1,555 tCO₂e
- Disorderly : 1,511 tCO₂e

Buses deliver the highest emissions reduction per dollar.



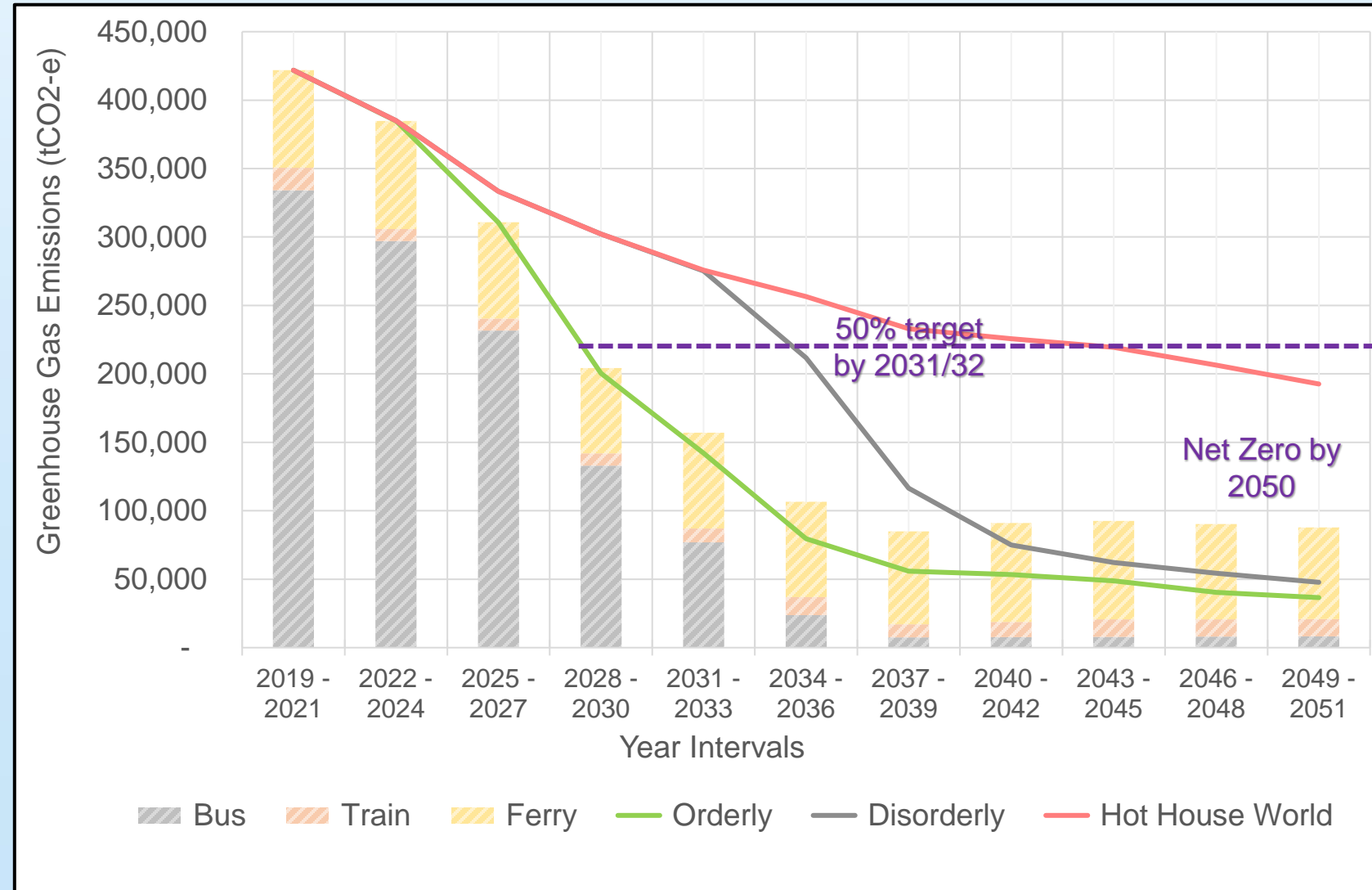
Network targets resilience (operational only)

Targets: 50% operational emissions cut by FY2031/32; 90% by FY2049/50

Operational decarbonisation achieved (Total):

- **Orderly:** Meets both
- **Disorderly:** Misses 2031/32; near-miss 2050 long-term).
- **Hot House World:** Misses both

Implications: small bus funding cuts jeopardies interim target; ferries become critical for long-term.



Implications and recommendations

Short-term: bus electrification funding is critical to meet FY2031/32 target.

Long-term: ferry decarbonisation is the key gap to reach ~90% by FY2049/50; avoid diesel lock-in.

Improve planning with adaptive pathways, regular updates to tech costs and grid EFs (MBIE EDGS).

Close data gaps: commission EPDs for local vessel types; extend embodied accounting to infrastructure and depot upgrades.

Explore financing models (e.g. grants, green bonds, PPPs; leasing/charging-as-a-service) to reduce upfront barriers.



Take-home messages

Scenario analysis helps test resilience of decarbonisation pathways under uncertainty.

Orderly pathway meets both interim and long-term operational targets; Disorderly and Hot House expose vulnerabilities.

Buses drive near-term reductions; ferries dominate remaining emissions after ~2040 if not decarbonised.

Funding timing matters: long-lived assets make delays costly.

