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Decarbonising heavy road freight transport in Queensland | Zero-emission construction sites

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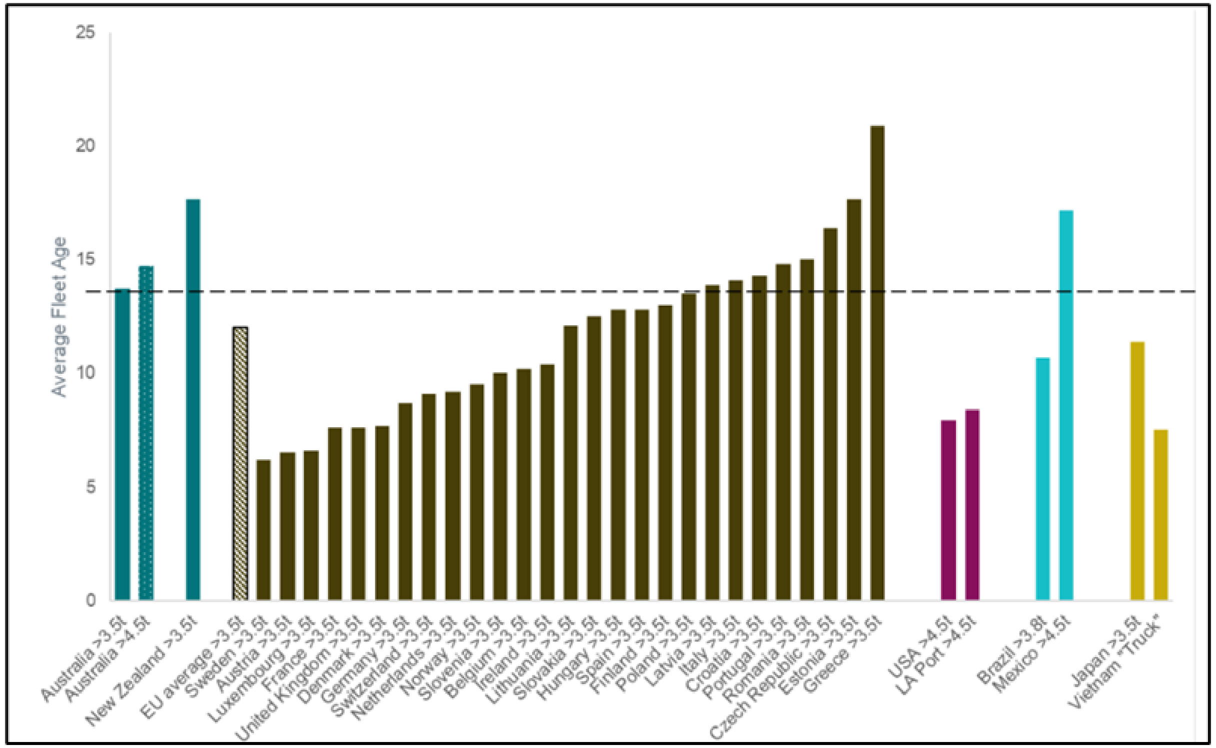
Road freight transport GHG emissions in Queensland

Rigid and Articulated trucks (> 4.5 tons) are less than 10% of the total vehicles in Queensland; however, together with buses, these vehicles contribute approximately **25%** of the total **GHG emissions** from the transport sector, in addition leading to **high air pollution** in urban areas.



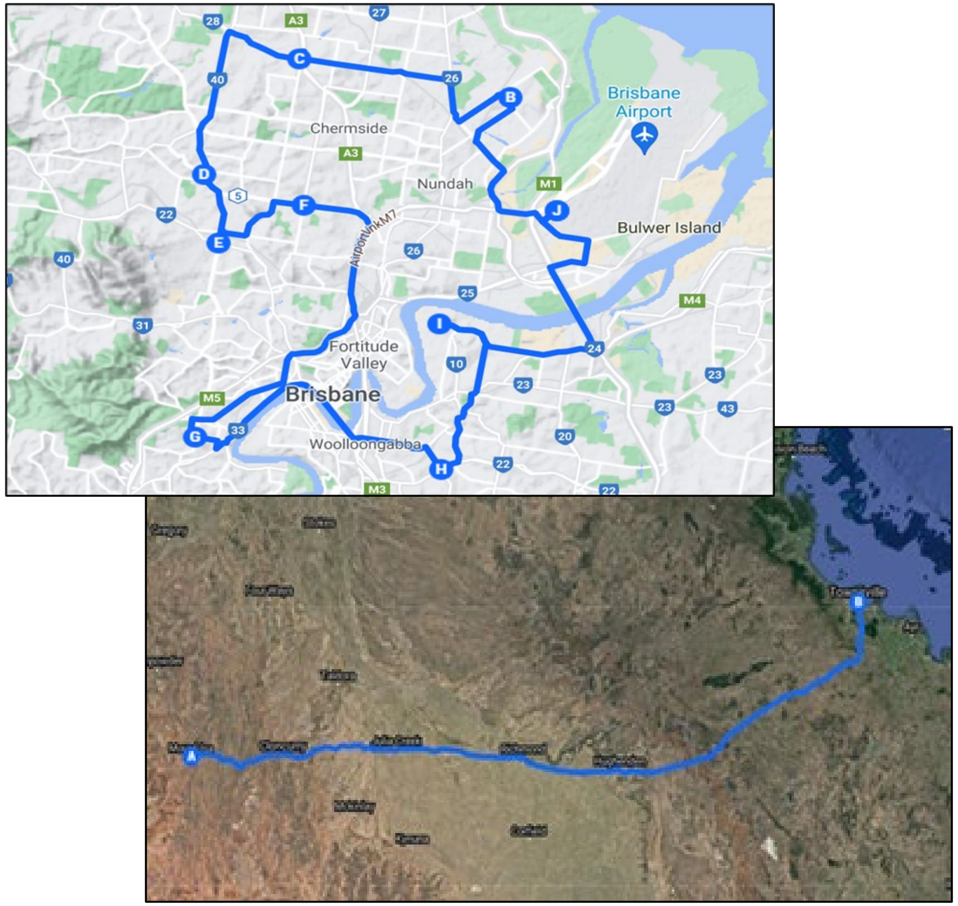
International comparison of average age of trucks [Austroads 2021]

Proportion of road freight kilometres by area of operation and truck type [QTLC 2022]

Feasibility Assessment Study

Transport Academic Partnership (**TAP**) project commissioned by the **Queensland TMR Freight team** – Feasibility Assessment of Transitioning to **Low or Zero Emission Truck** (LZET) Technologies in Queensland

1. Selection of a sample of 33 different key **road freight routes** across **Queensland** (Queensland Freight Model - QFM)
2. Development of candidate ('typical') **Battery Electric Trucks (BET)** and **Hydrogen Fuel Cell Trucks (HFCT)** for simulation
3. Estimation of the impact of **road gradient** and **climatic conditions** on energy consumption (based on trial data) – **trip simulation**
4. **Driving range / charging requirement** based on route conditions – **Operational feasibility assessment**
5. Estimation of **total cost of ownership (TCO)** scenarios for BETs, HFCTs, and Renewable Diesel – **Economic feasibility assessment**
6. **Feasibility decision tree** to support the initial assessment of LZET suitability for different road freight routes

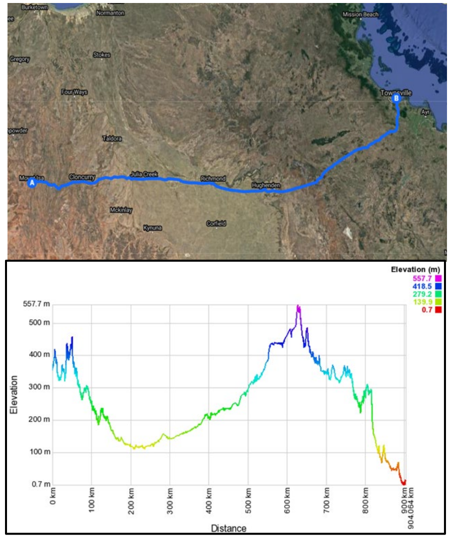


Selected candidate LZETs for simulation

- Few different candidate BETs and candidate HFCTs were selected to calculate projected driving range under different conditions, and in turn inform the feasibility assessment
- Again, however, the **average consumption** figures used in this study should be reviewed in the future when local deployment data becomes available

Modelled LZETs	**Candidate BETs**				**Candidate HFCTs**		
Vehicle Type	**HDT**	**HDT**	**MDT**	**Light-Rigid**	**HDT**	**HDT**	**Light-Rigid**
Weight Class	27,000 kg	36,000 kg	16,500 kg	7,500 kg	19,000 / 36,000 kg	36,000 kg	7,500 kg
Battery Capacity	400 kWh	600 kWh	138 kWh	83 kWh	Not considered	Not considered	Not considered
Hydrogen Storage	N/A	N/A	N/A	N/A	32 kg	60 kg	10 kg
Average Consumption	1.0 kWh/km	1.24 kWh/km	0.69 kWh/km	0.83 kWh/km	0.09 kg/km	0.09 kg/km	0.03 kg/km

Impact of road gradient and climatic conditions



Elevation data for a sample Route

- Changes in road gradient has an impact on the **energy consumption** of LZETs
- When travelling up a steeper terrain, energy consumption increases, while the opposite is true when travelling downhill – **regenerative braking** capabilities of LZETs
- There is limited availability of local data, and therefore this report relies on **international trial data** to approximate the relationship between **consumption** and **road gradient**
- The assessment of road terrain for each of the sample routes in this analysis was based on elevation data sourced from **Google Earth Pro**, and a **GPS Visualizer**

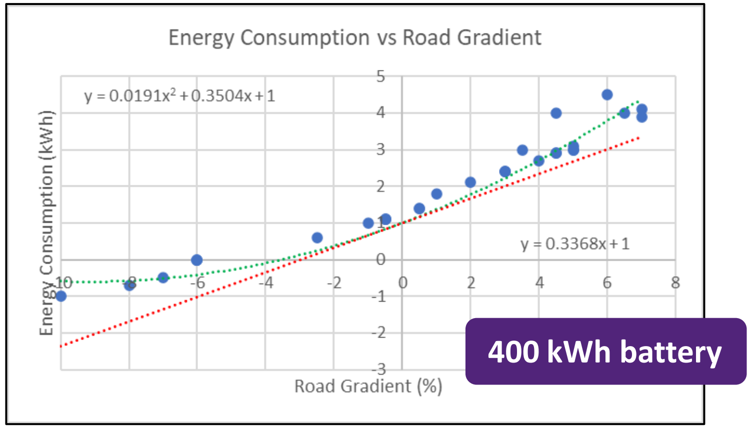
Energy consumption relative to Road Gradient for BET with **400 kWh battery**:

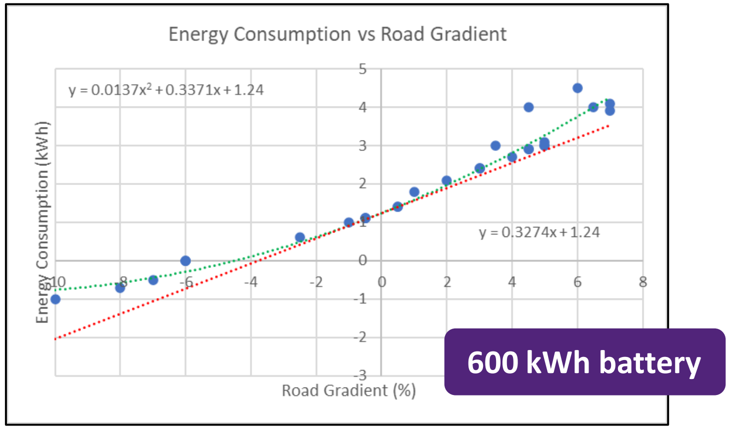
$$E_c = 0.0191 \times G^2 + 0.3504 \times G + 1.0$$

where:

$$E_c = Approximated\ BET\ Energy\ Consumption\ (kWh/km)$$

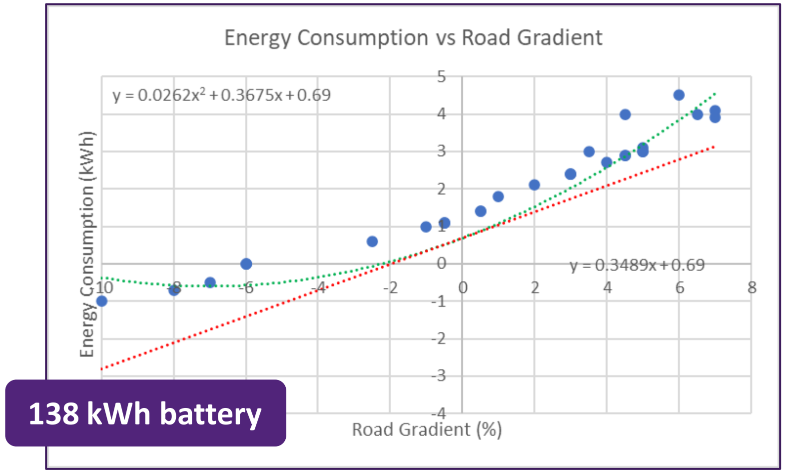
$$G = Road\ Gradient\ (\%)$$





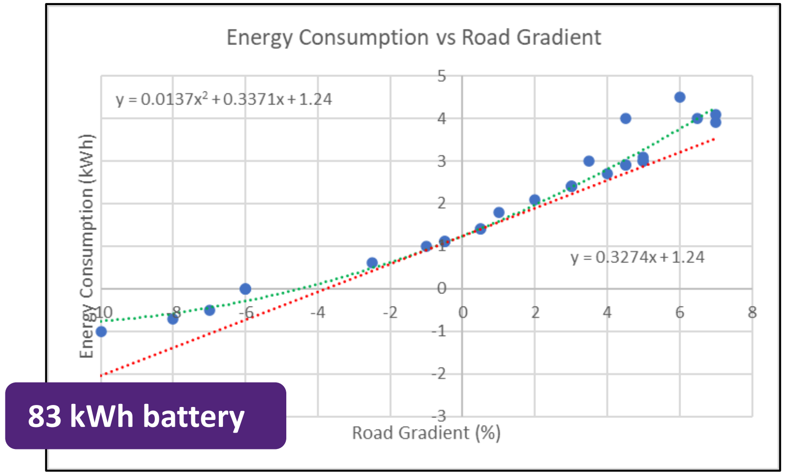
$$E_c = 0.0137 \times G^2 + 0.3371 \times G + 1.24$$

Trip simulation



138 kWh battery

$$E_c = 0.026 \times G^2 + 0.3675 \times G + 0.69$$



83 kWh battery

$$E_c = 0.023 \times G^2 + 0.3598 \times G + 0.83$$

- For **HFCT energy consumption** relative to road gradient, it is assumed that the relationship is similar to that approximated for BETs
- Bringing together the GPS visualizer and the road gradient data, and LZET consumption functions, the **trips were simulated**. Calculations were based on the assumption that the trucks start out with a full load

$$D_{BET.projected} = \frac{B_{capacity}}{(\sum_{i=0}^{n} E_c \times L_s)/L_{total}}$$

where:

$D_{BET.projected} = projected\ BET\ driving\ range\ (km)$

$B_{capacity} = BET\ usable\ battery\ capacity\ (kWh)$

$n = Total\ number\ of\ route\ points$

$E_c = Approximated\ BET\ energy\ consumption\ for\ specific\ route\ segment,\ accounting\ for\ road\ gradient\ and\ climate\ (kWh/km)$

$L_s = Length\ of\ route\ segment\ for\ each\ gradient\ point\ when\ calculating\ E_c\ (km)$

$L_{total} = Total\ length\ of\ truck\ route\ (km)$

The data files have over **5000 route points** for gradient and consequent energy consumption calculations resulting in **higher accuracy**

Assessing operational feasibility

- To assess the feasibility of deploying LZETs on different routes, a number of criteria need to be applied. In this report, the following questions were asked for each technology, on all 33 routes:

  1. Is the **projected LZET driving range** greater than the route trip distance?
  2. Requirement for on-route **opportunity charging/refuelling**?
  3. Is the **National Heavy Vehicle Regulator (NHVR) mandated breaks** for each route enough for on-route charging/refuelling?
  4. Is there a significant **scheduled layover** of several hours during the trip?

- It should be noted that the currently available LZET vehicle models may not match the efficiencies of large long-range diesel HDT for a **particular freight task** at hand
- There is a need for **LZET trials** in Queensland to collect **real-world data** to understand and analyse the impact of freight capacities on operational feasibility of different LZETs

Assessing operational feasibility

In answering these questions, the overall feasibility of each technology was subjectively determined, and categorised according to the following schema:

(1) Very feasible i.e., lowest hanging fruit	No further measures are required, and these options should be considered to be **feasible** (excluding assessment of costs)
(2) Feasible with minor planning of infrastructure	Some **minor measures** are required, such as HFCTs possibly needing refuelling infrastructure on route for hydrogen top-up during operations, or for charging infrastructure to be installed on route for a BET to receive a minor top-up **(<60 minutes @ 350 kW)** during operations
(3) Feasible with major planning of infrastructure	More **major measures** are required, such as HFCTs needing multiple hydrogen refills during operations, or for higher power charging infrastructure to be installed on route for a BET to receive **several top-ups** during operations and these charging layovers are considerably **longer than the NHVR mandated breaks** for those trips. The addition of **battery swapping technology** (particularly BETs) may also need to be considered to reduce longer charging layovers.
(4) Possible but difficult	While it may be possible to deploy LZETs, there are **major challenges**, and these are generally not the types of routes where the technology should be deployed, at least initially. Operators and planners should actively monitor technology developments to be aware of when LZETs may become available that are capable of being deployed on these routes. Alternatively, network planning may be required to enable a transition to LZETs.

Operational feasibility results: HDT

Heavy-duty BETs with 400 kWh battery	Heavy-duty BETs with 600 kWh battery
9 operationally feasible	10 operationally feasible
7 feasible with minor on-route infrastructure additions	13 feasible with minor on-route infrastructure additions
8 feasible with major on-route infrastructure additions	6 feasible with major on-route infrastructure additions
6 are challenging	1 is challenging

Heavy-duty HFCTs with 32 kg hydrogen	Heavy-duty HFCTs with 60 kg hydrogen
8 operationally feasible	18 operationally feasible
10 feasible with minor on-route infrastructure additions	12 feasible with minor on-route infrastructure additions
12 feasible with major on-route infrastructure additions	-

The Charging Interface Initiative (CharIN) are currently working to develop even higher power Megacharger for electric trucks and buses with a charging capacity in the **500 kW** to **3 MW range**. These Megachargers, once rolled out, would significantly reduce on-route charging time, and most of the yellow and orange routes would become operationally feasible.

For both BETs and HFCTs, route terrain was found to have an impact on energy consumption, which in turn affected projected driving range. The overall impact was not as significant as one might expect –due to LZET regenerative braking providing the ability to gain energy during downhill route segments

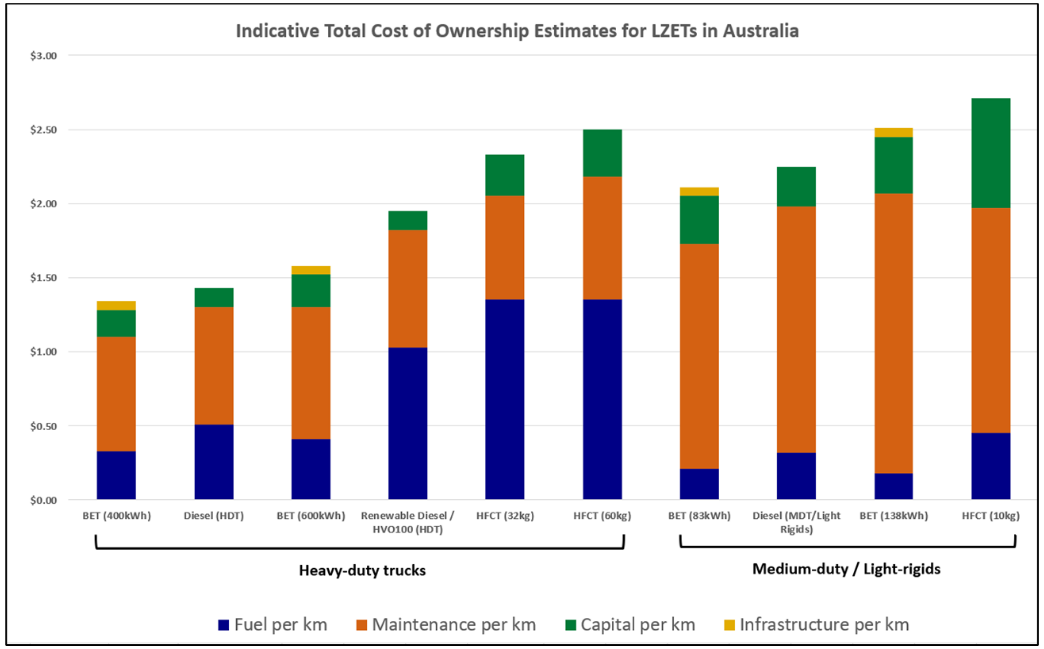
Operational feasibility results : Medium-duty & Light-rigids

Route	Types of Routes	Climate	Terrain	Total Route Distance (km)	Battery Electric Trucks (BET)						Hydrogen Fuel Cell Trucks (HFCT)			Total No. of Stops b/n Origin-Destination
					83 kWh battery capacity (0.83 kWh/km)			138 kWh battery capacity (0.69 kWh/km)			10 kg hydrogen capacity (0.03 kg/km)			
					Driving Range (km)	Recharging	Feasibility	Driving Range (km)	Recharging	Feasibility	Driving Range (km)	Refuelling	Feasibility	
LR-1	Delivery Services Carrier	Sub-Tropical	Flat	73.62	99.99	No	Yes	199.99	No	Yes	333.32	No	Yes	8
LR-2	Goods Carrier from Port	Sub-Tropical	Flat	177.08	99.99	15min x 350kW	Yes, Minor	199.98	No	Yes	333.32	No	Yes	5
LR-3	Supermarket Chain Food Distribution	Sub-Tropical	Flat	189.97	99.99	18min x 350kW	Yes, Minor	199.98	5min x 350kW*	Yes	333.31	No	Yes	5

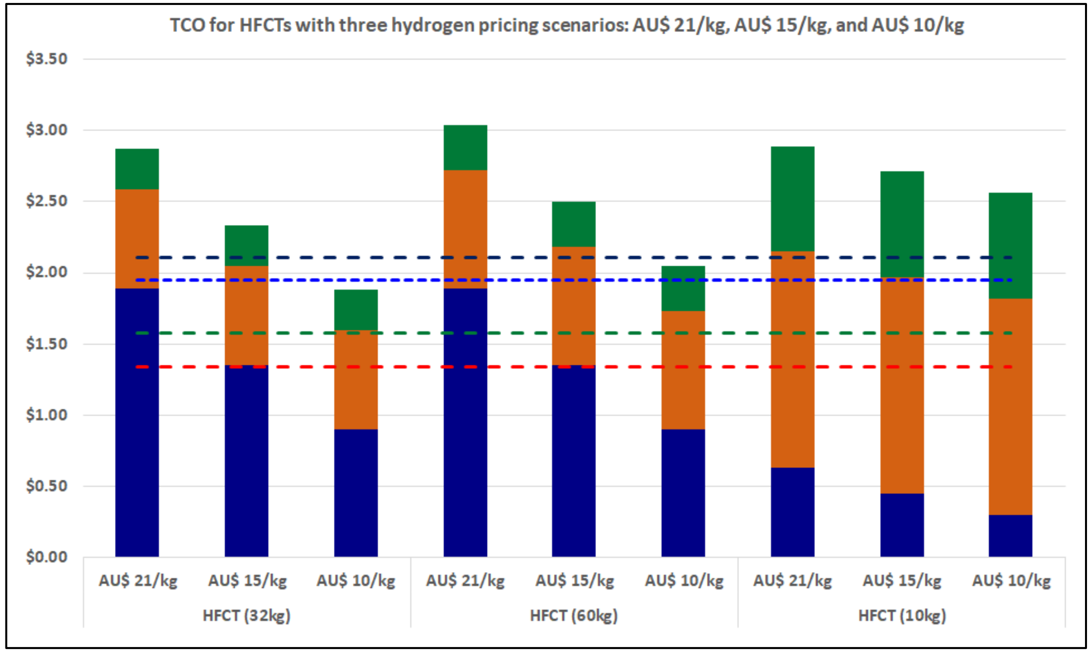
**The charging infrastructure specified is likely not required but suggested for additional redundancy.*

- All 3 routes were **operationally feasible** (dark green) for HFCTs (10 kg hydrogen capacity) and BETs with 138 kWh battery capacity
- For BETs with 83 kWh battery capacity, 1 of the 3 routes was operationally feasible (dark green), and the other 2 were feasible with minor on-route infrastructure additions (light green)

Total Cost of Ownership (TCO) / km



**this figure uses the hydrogen pricing scenario of AU$ 15/kg*



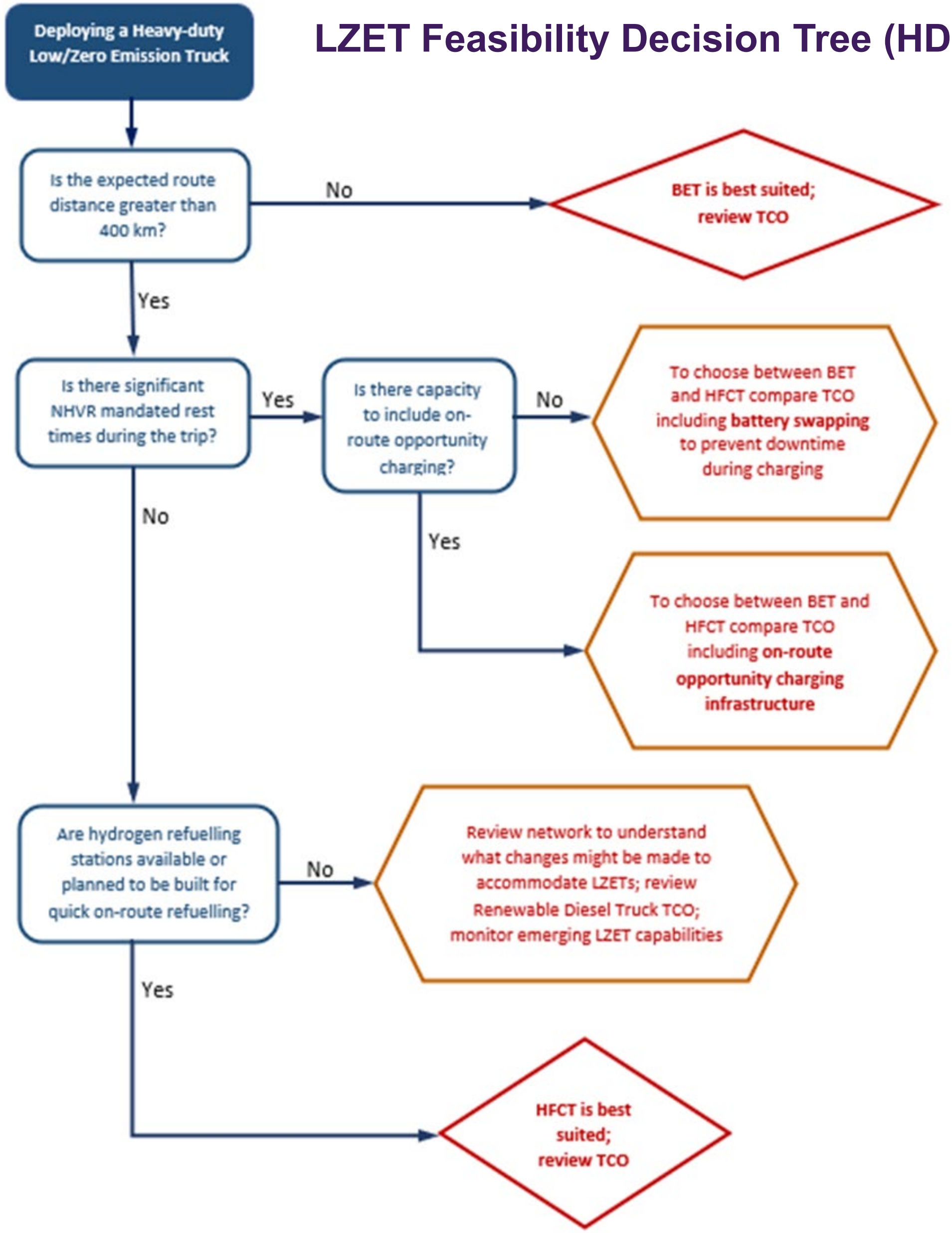
*Published real-world prices for **hydrogen refuelling** in Australia is currently not available; 3 scenarios: *California (**AU$ 21/kg**), China & Europe (**AU$ 15/kg**), and assumed **AU$ 10/kg***

- Based on **current cost** and **technology**, TCO per trip for **BETs is lower**; future developments may affect these figures, given improvements are projected for both BETs and HFCTs
- Most widely published hydrogen refuelling pricing (including infrastructure) **~AU$ 15/kg**, results in relatively **higher TCO** figures; when the pricing is reduced to **AU$ 10/kg**, the TCO estimates for HFCTs are found to be **more competitive**

Conclusion

- **BETs** would likely be a **suitable** and **cheapest** (based on TCO) LZET technology for deployment today
- Where **HFCTs** may be a better LZET option, is for those **demanding longer routes** – where BETs would require significantly longer charging times or multiple battery swaps
- **Renewable diesel** has the potential to play an important but limited role during the transition phase as a drop-in fuel in **remote areas**
- As real-world data become available from **trials of LZETs**, additional research will be required for larger, **fleet-wide deployments**
- Given the relatively long lifetimes of trucks i.e., 12-16 years, the **transition to LZETs** must **begin immediately** to meet the target of net zero economy by 2050.

LZET Feasibility Decision Tree (HDT)



Deploying a Heavy-duty Low/Zero Emission Truck

Is the expected route distance greater than 400 km?

No → **BET is best suited; review TCO**

Yes → Is there significant NHVR mandated rest times during the trip?

Yes → Is there capacity to include on-route opportunity charging?

No → To choose between BET and HFCT compare TCO including **battery swapping** to prevent downtime during charging

Yes → To choose between BET and HFCT compare TCO including **on-route opportunity charging infrastructure**

No → Are hydrogen refuelling stations available or planned to be built for quick on-route refuelling?

No → Review network to understand what changes might be made to accommodate LZETs; review Renewable Diesel Truck TCO; monitor emerging LZET capabilities

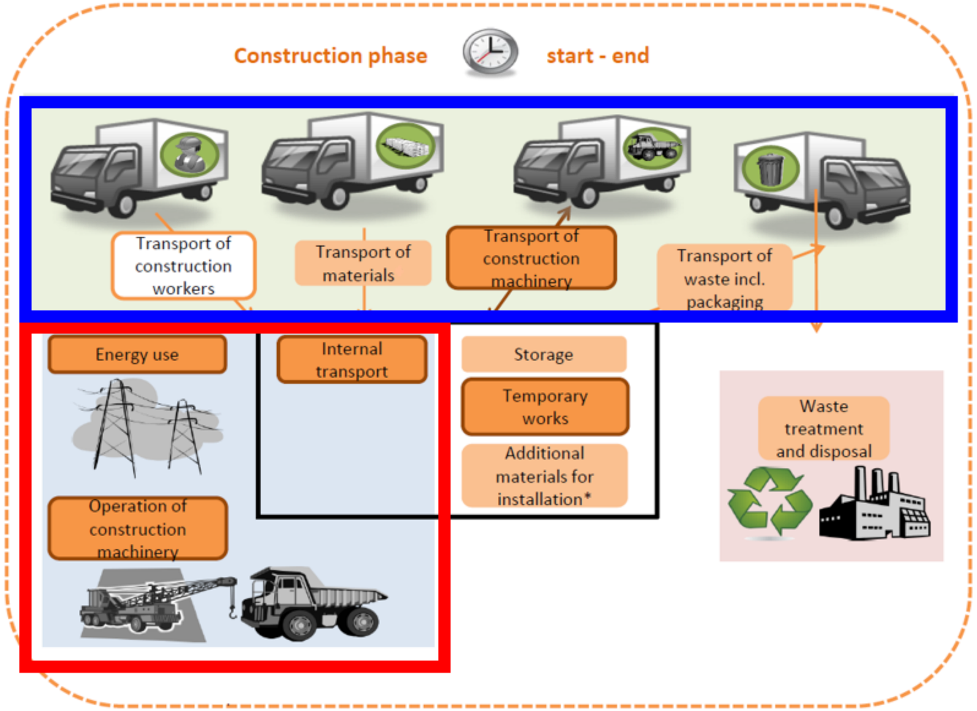
Yes → **HFCT is best suited; review TCO**

Decarbonising construction sites: Stepwise approach

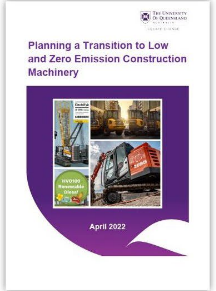
The Construction industry accounts for around 23% of worldwide carbon emissions; around **5.5%** are directly connected to construction activities, mostly through the burning of fossil fuels to power **machinery and equipment**

Emission Sources	Activity	Low-emission Class		Zero-emission Class	
		C1: Fossil-free	**C2: Low-emission**	**C3: Near Zero-emission**	**C4: Zero-emission**
Transportation	Material delivery	Fossil fuel	Fossil fuel	Fossil-free (Biofuel HVO100)	Electric
	Waste transport	Fossil fuel	Fossil fuel	Fossil-free (Biofuel HVO100)	Electric
	Employee travel	Fossil fuel	Electric	Electric	Electric
Operations and Construction Methods	Operations and methods	Fossil-free (Biofuel HVO100)	• Fossil-free (Biofuel HVO100) • Some operations use electricity • Use alternative building methods	• Site operations use electricity • Use alternative building methods	• Site operations use electricity • Use alternative building methods
Equipment Use	**Construction machinery & Internal transport**	Fossil-free (Biofuel HVO100)	• Fossil-free (Biofuel HVO100) • Some electric machinery	All machinery and equipment use electric or hydrogen	All machinery and equipment use electric or hydrogen

The three major emission sources at a construction site are **construction machinery, transport to and from the construction site**, and **on-site energy use**.

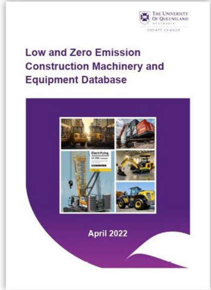


UQ – Lendlease collaborative research



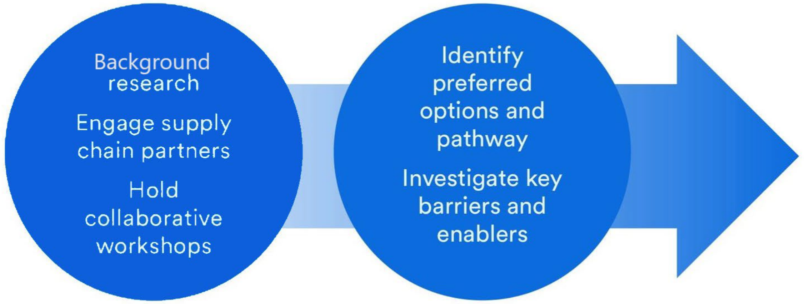
Planning a Transition to Low and Zero Emission Construction Machinery

April 2022



Low and Zero Emission Construction Machinery and Equipment Database

April 2022



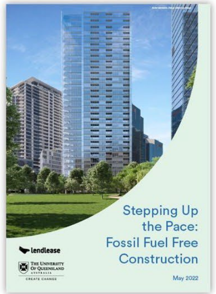
Background research

Engage supply chain partners

Hold collaborative workshops

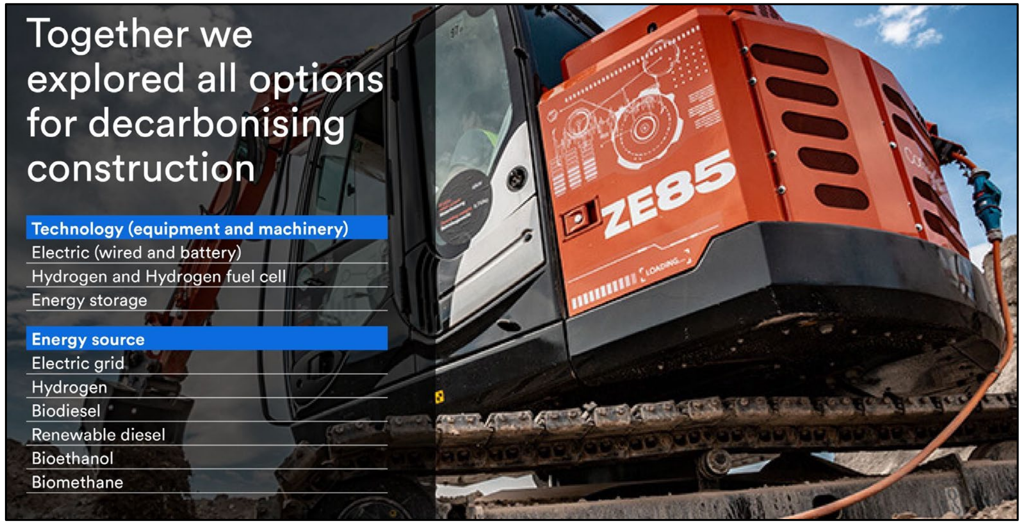
Identify preferred options and pathway

Investigate key barriers and enablers



Stepping Up the Pace: Fossil Fuel Free Construction

May 2022

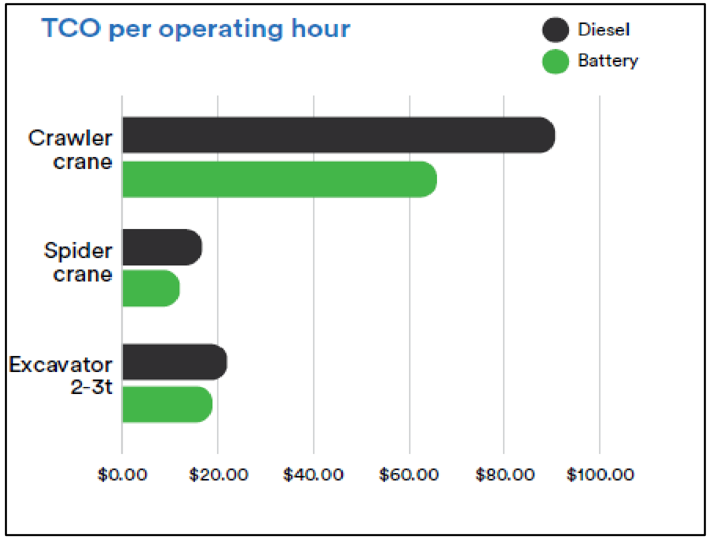


Together we explored all options for decarbonising construction

Technology (equipment and machinery)
Electric (wired and battery)
Hydrogen and Hydrogen fuel cell
Energy storage

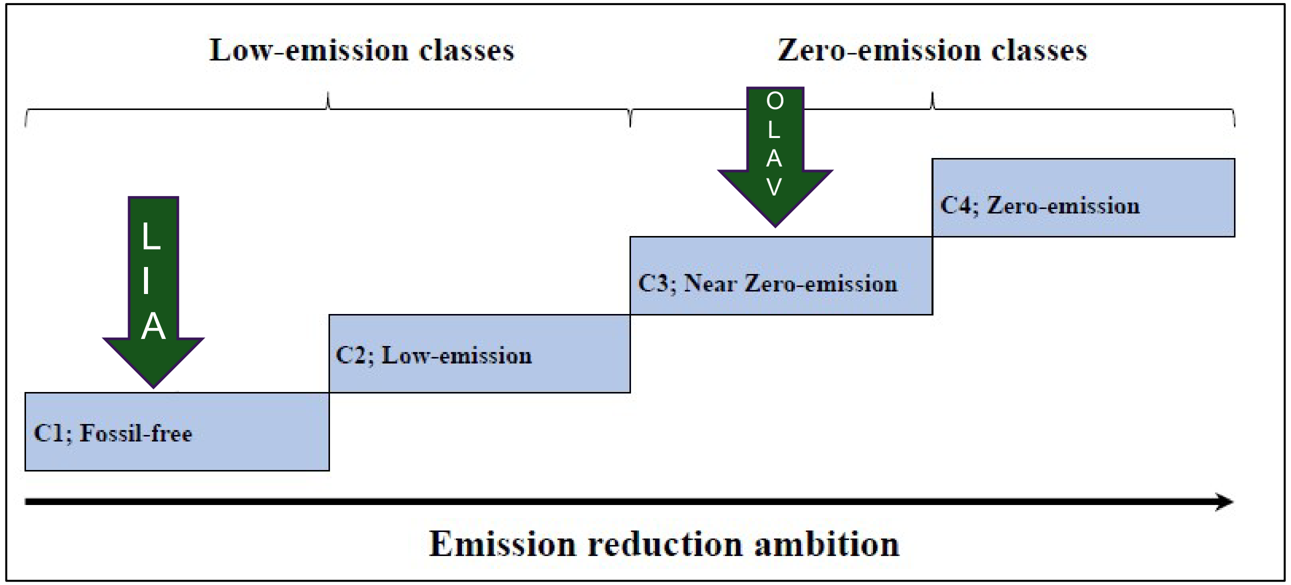
Energy source
Electric grid
Hydrogen
Biodiesel
Renewable diesel
Bioethanol
Biomethane

- In Europe, several cities have mandated a minimum requirement for **fossil fuel-free construction sites**
- Oslo is leading: By 2025 all public construction sites will operate **zero emission machinery** and **zero emission transport** to the site
- **C40 cities**: Cities around the world have created a coalition moving towards construction site decarbonisation



Fossil-fuel free and on-site emission-free construction sites:

- Lia nursery school is described as the first **fossil-fuel free construction site** (C1): **electric machineries** such as small electric excavators and wheel loaders were used; renewable diesel (**HVO100**) was used for all other construction equipment and internal transport.
- Olav Gate, world's first 100% **on-site emission-free** construction site (C3): fully adopted **zero-emission machinery** and **internal transport**. Vehicles used for external transport to and from construction sites were either **battery-electric** or running on **HVO100**.



Low-emission classes

Zero-emission classes

OLAV

LIA

C1; Fossil-free

C2; Low-emission

C3; Near Zero-emission

C4; Zero-emission

Emission reduction ambition

Key Findings:

- We need to accelerate **electrification** of construction machinery; a big percentage of construction machinery and equipment (by energy use) can be replaced by **electric by 2030**
- There are no battery-electric models currently available for a significant number of construction equipment types – this makes construction a '**hard to abate**' sector – **Government policies** and **financing** options will be required to support the industry's transition
- As the shift to electrification gathers pace, **renewable diesel (HVO)** is a critical **transition fuel to lower emissions** – can be used as a 100% 'drop-in' fuel without machinery needing any modification.

- UQ Research Report
  https://doi.org/10.14264/93110de
- UQ – Lendlease Industry Report
  https://espace.library.uq.edu.au/view/UQ:7040b76
- Zero emission construction machinery database
  https://doi.org/10.48610/6973e0a

Thank You!

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