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Electric-drive Log Trucks for the Forest Industry – A Review of the Literature

Summary

This initial literature review discusses the feasibility of using electric-drive heavy-duty trucks (HDTs) for log transport in New Zealand. It has addressed the reasons why a transition to electric or alternative fuelled trucks is important, other benefits of electric HDTs, existing applications, the potential for regenerative braking in forest applications, and the barriers to viability.

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Introduction

Electric vehicles (EVs) are becoming more and more prevalent on today's roads with factors such as rising fuel costs, greater environmental concerns, and government incentives towards decarbonisation driving this change. The transportation sector is one of the largest contributors to greenhouse gas emissions, contributing 23% of global emissions in 2017, nearly 75% of which originates from road transport (International Energy Agency, 2017).

Within the Swedish forestry industry, Berg and Lindholm (2005) showed that road transport of logs (secondary haulage) accounts for the majority of total energy requirement for all processes from planting to delivery of logs. Of the total energy requirement for creating and harvesting a production forest, 56% was used for secondary haulage in the Northern Swedish regions, and 53% in the Central and Southern Swedish regions, as shown in Figure 1.

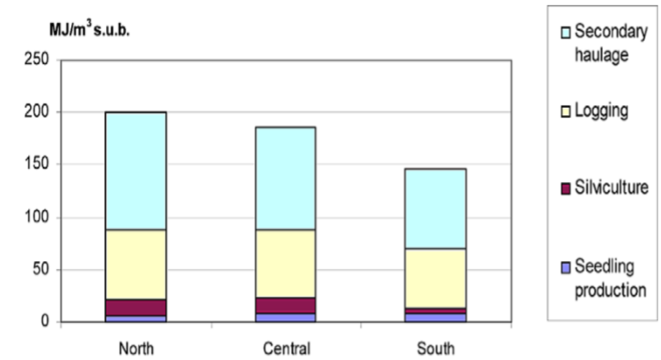

Figure 1 – Energy Requirements by forest process in Sweden (Berg & Lindholm, 2005).

Thus, to reduce environmental harm and meet decarbonisation goals, the use of electric trucking in log transport represents an important opportunity for the forest industry.

Existing Heavy-Duty EV Truck Applications

With electric vehicles seeing greater utilisation and sales in the consumer, passenger, and light-duty trucking sectors, the evolution of these vehicles into the medium- and heavy-duty trucking (HDT) sectors is increasingly likely. This is mainly due to advancements in lithium-ion battery technology making large payload haulage technically feasible and potentially viable economically viable when compared with alternative and diesel-fuelled trucks (Al-Hanahi *et al.*, 2021). These authors noted further that the uptake of electric trucks on the fleet-level scale has already been observed, with Walmart ordering 45 Tesla Semi heavy-duty trucks in 2017-2018 and Anheuser-Busch ordering 21 in 2019. Amazon also made a significant step in the decarbonisation of its fleet, ordering 100,000 light-duty electric delivery vans from start-up company Rivian Automotive in 2019, with the delivery of vans starting in 2023.

Within New Zealand, current applications of electric trucking include a water truck (45t GVM) (Eastland Port, 2021), an E700 6x4 tractor run by Mainfreight from Auckland to Hamilton at 50t GVM with swappable battery (Mainfreight, 2022), and a variety of smaller fully electric or hydrogen-electric trucks used for delivery services, refuse, and work platforms. However, the most

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promising application of electric trucking has been in mine or quarry sites, where a laden downhill trip generates energy through regenerative braking which is subsequently used in the unladen uphill trip.

Perhaps the most successful integration of this technology is the 'eDumper' with a GVM of 123t and tare of 60t. On a typical day it completes 20 trips which results in an energy surplus of 200kWh, requiring the truck to be discharged each night. The same concept has been applied by Blackhead Quarries in New Zealand utilising a TFT125 from XCMG with a GVM of 49t and tare of 19t. An unladen uphill run uses approximately 5% of the battery charge, and a laden downhill run generating approximately 6% of the battery charge. Thus, the truck may be used indefinitely without charging (Blackhead Quarries, 2022).

Regenerative Braking – The case for forestry

Deceleration, or braking, is all vehicles' most important safety feature. Regenerative braking acts on the principle that when an electric motor is driven contrary to the drive direction, it acts as a generator. Thus, some of the gravitational potential or momentum of the vehicle may be captured and stored in the vehicle batteries. Sathishkumar *et al.* (2022) showed an increase of 12.5% in vehicle range was achievable when regenerative breaking was used on an electric HDT while completing the New European driving cycles test. Regenerative braking systems of all types (electrical, hydraulic, and mechanical) have been shown to have efficiencies that range from 90 to 95%, meaning much of the kinetic energy of the vehicle is captured (Midgley & Cebon, 2012).

Electric vehicles also benefit from regenerative braking due to the almost constant efficiency plateau of electric motors at all speeds. This differs from the power-band style behaviour of internal combustion engines (ICE) where efficiency changes with engine speed. Thus, where regenerative braking of an ICE may cause the engine to operate outside of its most efficient zone, this is much less likely for electric vehicles. Hu and Bauer (2021) showed that with both vehicle platooning and regenerative braking energy savings of 29% were simulated for electric HDTs with loads of 30t. Furthermore, the increased efficiency of electric engines over ICEs means the actual total amount of energy used by electric HDTs is lessened. Su et al. (2021) showed that the energy consumption of an electric HDT was less than half the equivalent diesel HDT.

The use of regenerative braking has allowed the mining industry to utilise trucks with a much smaller range, and therefore battery size, than required for other industries such as freight or end-of-line delivery services.

The forestry industry in New Zealand is in a similar position to the mining industry in that the wood resource often comes from steep, higher altitude forests or woodlots which are transported down to lower altitudes for processing. Therefore, the utilisation of the gravitational potential energy of the load is recoverable through regenerative braking, meaning the required range and battery size of the truck may be reduced. This makes the successful application and adoption of electric HDTs in New Zealand's logging industry much more promising.

Barriers to viability

Some of the prevailing barriers to the viability of electric HDTs are battery costs, charging time and relative range to battery size/payload capability (Moultak et al., 2017). Battery costs inherently play into the total cost of ownership (TCO) as the largest driver of change. Vijayagopal and Rousseau (2021) showed that at a diesel price of USD 4.00/gallon, the TCO of electric HDTs is equal to diesel HDTs when battery costs are 150 USD/kWh.

In 2021 the average battery cost was 132 USD/kWh, with companies such as Ford and Renault announcing target costs of 80 USD/kWh by 2030 (Henze, 2021). Nykvist and Olsson (2021) showed that the use of fast charging technology allows for smaller battery sizes, making electric HDTs competitive with diesel equivalents in both costs per ton, TCO, and cost per ton per km basis. It is important to note that battery cycle life can be more important than the cost per kW of the battery; this becomes more prominent with smaller batteries utilizing fast charging, resulting in more cycles.

Al-Hanahi et al. (2021) identified charging time and infrastructure availability as the most important driver for boosting the adoption of electric HDTs. Most HDTs require dedicated fast-charging infrastructure with higher power capabilities than existing infrastructure, with companies announcing charging capacities greater than 400kW, and Tesla announcing a mega charger network with >1MW capacity.

The most common model for charging HDTs is a 'Return to base' infrastructure, where the trucks return to their respective commercial facilities each night to charge; this requires a large capacity battery of which the full potential is often not utilised. Charging with public infrastructure could also be used, although the current infrastructure is not sufficient for near-term adoption.

Battery swapping is also a viable model with exchanges only taking a few minutes. This provides many benefits for batteries with the highest energy densities (with longer ranges) and places less strain on local electrical infrastructure, although they also have high adoption cost and the lack of standardisation between vehicle manufacturers limit current potential.

The use of hydrogen fuel cell technology should also be considered, with a greater energy density allowing for a comparable range between most lighter class vehicles with the same load capacity as diesel equivalents (Kast *et al*., 2017). However, to take advantage of regenerative braking the vehicle must also have a large battery pack. Forrest *et al.* (2020) found the main limitations of hydrogen-powered vehicles range were the hydrogen tank size and fuel efficiency. The other major limiting factor is access to hydrogen refuelling stations, with heavy-duty trucks requiring high-capacity refuelling stations that are very capital intensive and must be connected to a low or zero-emissions hydrogen supply to realise environmental benefits.

Other Benefits of HDTs

Tong *et al.* (2021) compared the health and climate impacts of electric and diesel HDTs in the USA, finding that transition to electric trucking reduced social costs by 80%. This was modelled using the existing freight networks and flow in the USA using advanced (future) low emission diesel trucks and no implementation of truck scheduling for charging. This study also assumed the transition of power generation in the USA to 80% renewable sources. Note: New Zealand is currently 86% renewable power sources.

If truck scheduling was implemented the health costs would increase from unusual driving schedules for truck drivers, but climate costs would decrease with reduced waiting times and better optimisation of charging services.

Modelling of an industrial gravel plant by Wanapinit and Thomsen (2021) showed that the transition to an all-electric fleet reduced carbon emissions by 70% and total costs by 14%, albeit at initially high capital investment. They also noted the improvement to the company's image as sustainable and technologically advanced, improving sales and desirability for environmentally minded customers. Weaknesses were identified as the high capital costs, the integration of relatively new technology and truck scheduling difficulty and reduced efficiency due to the relative scarcity of refuelling/charging stations.

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