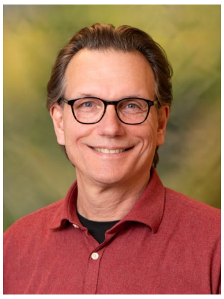
The world's first battery electric timber truck: lessons learned from the first two years of operation



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Abstract

Electromobility plays a key role on the road towards a sustainable society, where electrification of freight transports can mitigate climate change by decreasing the use of fossil fuels, reducing noise, and improving air quality. The implementation of battery electric vehicles (BEV) in freight transportation is still in an early phase. Previous research has studied implementation of BEVs in urban contexts with a focus on light commercial vehicles, whereas studies on implementation of heavy-duty battery electric vehicles (HBEV) are scarce due to the very limited number in operation. The aim of this mixed methods study is to explore the first two years of operation of the world's first battery electric timber truck. A case study of SCA that operates one battery electric timber truck is conducted. SCA is Europe's largest private forest owner annually transporting 8.5 million cubic meters of timber from forest to industry. These transports are carried out by 265 timber trucks in collaboration with 87 haulers. The battery electric timber truck has a gross vehicle weight of 64 tons on public roads, and 80 tons on private roads, and operates between SCA's timber terminal in Gimonäs and SCA's papermill at Obbola in Northern Sweden, a one-way trip of 15 km. The analysis of lessons learned is based on quantitative data from the Scania battery electric timber truck with more than 50,000 kms of operations, as well as qualitative data from semi-structured interviews with different roles within SCA. The findings indicate that the battery electric timber truck can reduce the CO_2 emissions by 55 tons annually. Data on productivity, energy consumption and cost comparison with conventional diesel trucks is reported as well as experiences of how the technology and charging work. From a driver's perspective, the working environment is improved through reduced vibrations and noise. However, the reduced noise puts more responsibility on the driver since pedestrians react to the truck at a later stage. From a strategic perspective, we will also be able to learn how battery-electric timber trucks will be an important contribution to SCA's goal of making the entire value chain fossil-free, and how SCA intends to move forward based on these experiences.

Keywords: Electrical trucks, CO2 emission, Energy consumption, Transports, Heavy truck

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1. Introduction

Electromobility plays a key role on the road towards a sustainable society, where electrification of freight transports can mitigate climate change by decreasing the use of fossil fuels, reducing noise, and improving air quality. The implementation of battery electric vehicles (BEV) in freight transportation is still in an early phase. Previous research has studied implementation of BEVs in urban contexts with a focus on cars or light commercial vehicles, whereas studies on implementation of heavy-duty battery electric vehicles (HBEV) are scarce due to the very limited number in operation.

In Sweden, road transports account for around 50% of the industry's CO_2 emissions and almost 20% of the road freight volumes. Forest industry accounts for 36% of business road transportation work, which uses roughly 250 million litres of diesel (skogsindustrierna.se). Forest timber trucks are heavy with a gross vehicle weight (GVW) of up to 74 tonnes, and are often driven on poor quality roads, usually in multiple shifts. The transports are done annually from about 200,000 new and different harvest locations in the forest, to about 1,000 receiving locations (industries and terminals). Forestry operates all over the country and uses the entire road network, transports usually start in the most peripheral parts of the road network to end at industries and terminals that are more centrally located. Due to the geographically dispersed operations, access to charging can be a challenge.

Research work on electrical vehicles is limited. Session and Lyons (2018) evaluated the potential use of electrical trucks where the loaded transport was done from a higher elevation to mills on a lower. In such an environment it is possible to keep the battery size limited due to the possibility of recover braking energy. There are hybrid trucks with a diesel and electrical motor in use and testing. Barber and Little (2024) tested a hybrid truck in British Columbia in Canada. Information collected could support the route planning to identify efficient routes given estimated energy consumption. Iyer *et al*. (2023) provides a literature review regarding costs, initiatives, energy consumption and planning tools for heavy electrical trucks.

To introduce heavy electrical trucks in forestry requires information on many things, including purchasing cost, maintenance, energy consumption, charging time, and driver scheduling. As there are no such information available from real operations, most information is based on assumptions, and behaviour on existing diesel trucks. The aim of this paper is to bridge some of this and describe the experiences from the first two years of operation of the world's first battery electric timber truck. The truck is developed by Scania and used by the Swedish pulp and paper company SCA, Europe's largest private forest owner, annually transporting 8.5 million cubic meters of timber from forest to industry. In addition, about 0.8 million cubic meters is transported from terminals to industry; this is where the truck has been used. The article describes how the truck is used within SCA and provides quantitative analysis regarding energy consumption, charging, and transportation. The analysis of lessons learned is based on quantitative data from the Scania battery electric timber truck with more than 50,000 kms of operations. It also describes a comparison with diesel trucks and discuss how the next generation of electrical trucks is being implemented.

The structure of the paper is as follows. First, we describe the truck and its characteristics. Next, we describe the charging equipment and location. This is followed by a description of the main routes used for the truck and the driver's schedule. We then turn to the quantitative measures collected. Here we describe the transports done, transport distances and measured energy consumption from both the vehicle and measurements of the charging energy at the charging location. We describe repairs and maintenance required during the operations. Then, we provide experiences from SCA and describe the new electric truck being introduces. This is followed by some concluding remarks.

2. The battery electric truck

The battery electric timber truck, see Figure, is unique and developed by Scania. The truck is designed to handle a truck and trailer combination with a GVW of 80 tonnes, but when driven on public roads the GVW often is lower, under 74 tonnes. It is loaded by a separate loader, and operates mainly (more than 90% of the time) between SCA's railway terminal for timber in Gimonäs and SCA's papermill at Obbola in Northern Sweden, a one-way trip of about 16 km. It is also used for internal terminal relocations and transports between the port in Holmsund and the paper mill, with about 6 km one-way.

Figure 1. The Scania electrical truck where it is being unloaded. Photo by Anton Ahlinder.

The truck is a Scania 25P and started its operation in June 2022. The engine output is 612 horsepower, and it has a six-speed automatic transmission. The axle configuration is 6x2*4, which means that the first and last axle are steering, and the second axle is driving. Normal axle configuration for a heavy-duty timber truck operating under difficult conditions is 6x4 (two axles of three driven) but it was not available when ordering the truck. For the task that this truck performs, that configuration is not considered necessary.

Operating weight of the truck is 12,410 kg and maximum load weight is 17,590 kg. In operation, we have a 5-axle trailer with a weight of 7,590 kg and a maximum load of 32,410 kg. In total, a fully loaded rig weighs 70,000 kg, of which 50,000 kg is cargo. At the beginning of the operating period, the road used was classified as BK1 (Swedish road classification - load capacity class 1), which meant that the maximum GVW allowed was 64 tons, but since May 2023, the road has been reclassified to BK4, which means that truck and trailer combinations up to a GVW of 70 tons can operate on the actual road network. The battery pack weighs about 2000 kg, and the energy capacity is 319 kWh, and the SoC (state of charge) was at the time of delivery 75% which gives 319*0.75=239 kWh available energy but has since been adjusted up to 78% which gives 319*0.78=249 kWh available energy making the truck able to perform three cycles of transport instead of the original two.

According to the supplier, the charging power is limited to 130 kW. However, normally it receives charging power of 133 kW according to the charger's meter. On occasions when public chargers are used, it has sometimes been close to 140 kW according to the charger. Perhaps it is due to losses or uncertain measurement methods.

Figure 2 shows how the battery packs is mounted on the chassis of the truck. Four packs are mounted alongside the sides between axel one and two, and one pack with all the necessary control equipment is mounted underneath the truck cab where the diesel engine normally is placed.

Figure 2. The battery pack used on the truck. Photo by Anton Ahlinder.

The truck is driven like a normal truck with an automatic gearbox. One difference is the retarder system. With is an extra braking system that is used to not wear out the main brakes, which are usually disc or drum brakes and risk overheating under high load and needs a lot of maintenance.

The retarder brakes the vehicle using a hydraulic pump mounted somewhere on the driveline, an exhaust damper mounted in the manifold, a compression adjustment or some similar system. This varies between different manufacturers. The goal is to convert the vehicle's kinetic energy into heat, which can then be disposed of to the surrounding air.

On an electric vehicle, the retarder is replaced by regeneration of energy via the electric motor. In practical terms, it works in the same way as in a diesel truck, the driver has a lever behind the steering wheel where the driver can control which resistance the retarder should generate. Also, when the driver lets off the gas, the generative braking is automatically engaged if the driver has the retarder activated, or the driver can choose to "free roll" if that is more desirable for the current driving situation. The difference in this case with an electric truck is that the breaking energy can be used and fed back to the batteries instead of being vented away as heat.

3. The vehicle charger and charging location

The vehicle charger, see Figure 3, is located next to the paper mill in Obbola. The charger is an *ABB Terra CE 184* with a maximum capacity of 184 kW. Currently, the main fuse that the charger is connected to (235 A) limits the maximum power when charging to 154 kW. However, this does not constitute a limitation for the charging times because the truck can currently receive a maximum charging power of up to approx. 133 kW.

Figure 3. The vehicle charger beside the truck. Photo by Anton Ahlinder.

4. Truck route

The pulp and paper mill at Obbola outside Umeå has a current capacity of 450,000 tons of products meaning a demand for about a million cubic meters of logs annually. The train terminal in Gimonäs, which is located on the outskirts of Umeå, receives logs long-distance transported by timber train from the inland of Sweden. As there are no rail tracks to Obbola, there is a need to use trucks for this transport. Today, there are, on average, four timber trucks assigned to this route, and the electrical truck is a designated truck for this purpose. The journey from Gimonäs timber terminal to Obbola paper mill is about 16 km and a round of loading and unloading takes about 75 minutes to complete. The route and the vertical profile are visualized in Figure 4. The trip is generally flat and most of the route is on a highway with an 80 km/h speed limit.

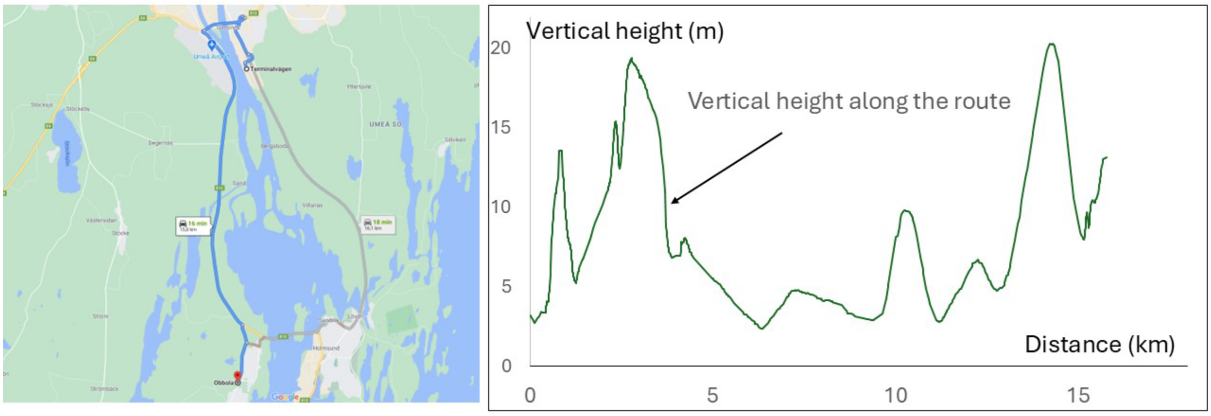

Figure 4. Left: The route used (in blue colour) between Gimonäs terminal and Obbola. Figure by Google maps. Right: Illustration of the vertical altitude of the route from the terminal to Obbola.

Biometria (biometria.com) is a logistic hub for the Swedish forest industry. Biometria provides a range of services to companies. One such service is to provide routes and energy consumption of routes for timber trucks. Based on their energy consumption models and route software, the studied trip is 15.8 km, and the loaded and empty return trip has a total fuel consumption of 17.39 litres for a diesel truck. The CO2 emission equivalent is estimated to 42.28 kg. The energy equivalent is 176.1 kWh but due to a 30% efficiency in diesel engines this represent 58.7 kWh. This means an estimated energy consumption of 1.86 kWh/km. It is important to note that this is before any losses in the electrical system and batteries.

5. Driver schedule

The vehicle is driven in single shifts four days per week (Monday – Thursday). A standard shift starts between 6:00-6:30 in the morning with the battery SoC at 100%. Then two round trips are completed before the battery pack is recharged at 9:00-9:30. This takes about 60 minutes each time. After another 2 round trips, the battery is recharged a second time connected to lunch. Afterwards another 2 roundtrips are completed before finishing the shift. The vehicle is then recharged during the night to be fully charged for the next day. The truck is parked at the charging location. This is true also during the weekend when it is connected to the charger all the time. There are sometimes changes to the schedule if there is less or more need to transport depending on the operational situation at the pulp and paper mill. Some days run until 9pm, sometimes the vehicle is used for unloading boats in Holmsund and sometimes it is used for internal transport at the Gimonäs terminal.

6. Data collection

The data collection has been done with different information systems. In the truck's fleet management system (FMS), it is possible to follow on a weekly basis distance and average energy consumption per km. The delivered volume and tonnage to the pulp and paper mill from Gimonäs terminal and harbour can be followed by the business warehouse (BW) software system used at SCA. Both systems have collected data between June 2022 and September 2024.

As the transport from the harbour is managed differently, we have focused on the terminal transport. The charging station is connected to an electrical meter. Since the vehicle is the only vehicle charged, it is possible to follow up on the charged energy for every charging time. The latter has data for one year, that is, September 2023 to September 2024.

7. Transports

The vehicle started in June 2022. Figure 5 gives the number of transports per week from June 2022 until September 2024. The vehicle has been in operation for most weeks. For a few weeks, it has been displayed at exhibitions and conferences. It has also been repaired and maintained several days. A total of 1,804 transports between the terminal and Obbola has been done. The total distance driven was 66,948 km. This represents a total volume of 91,175 cubic meters under bark (m^3f) and a weight of 82,518 tonnes.

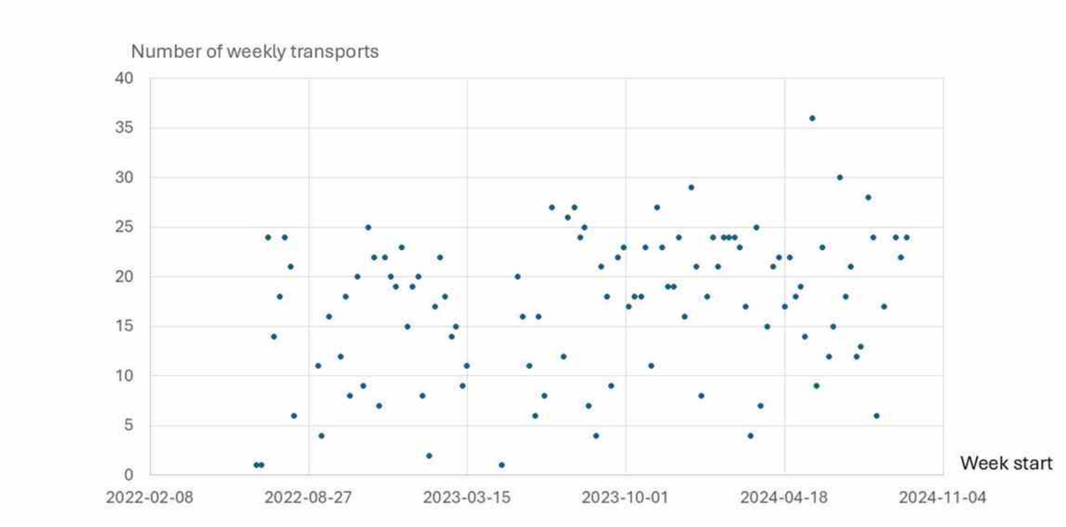

Figure 5. Number of transports per week between June 2022 and September 2024.

Figure 6 gives the average volume and payload for each transport during the operations. The main product or assortment transported is softwood pulp logs of spruce and pine. Sometimes hardwood birch is also transported. The densities are different between assortments, but the main difference in density is due to the variation over the year. During winter, the density is higher, and during summer the timber is often dryer. This explains the seasonal gaps between volume and weight. During the winter months the density is close to 1 and weight and volume is very similar.

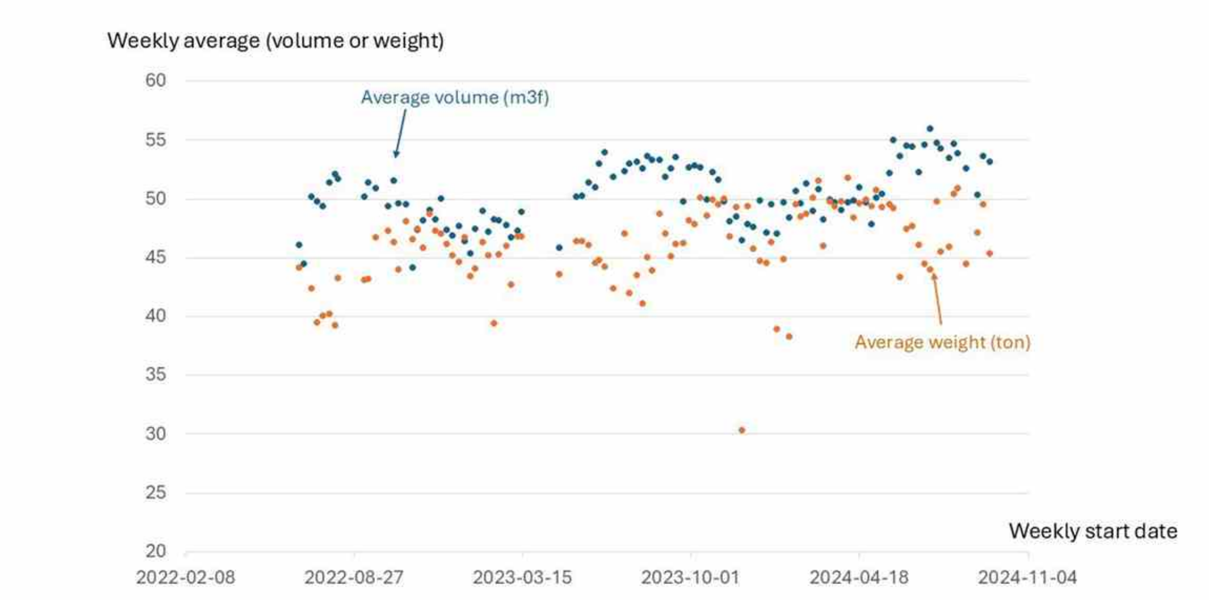

Figure 6. Average volume (m3f, blue dots) and weight (tonnes, red dots) for each transport per week between June 2022 and September 2024.

Figure 7 shows the distance travelled by the truck per week based on what is registered in the FMS and BW systems. The BW system register only the transport between terminal and Obbola, hence, the difference is explained by internal terminal and harbour transports. The weeks that have the same values are later used for more detailed energy consumption as we know where the truck has been driving.

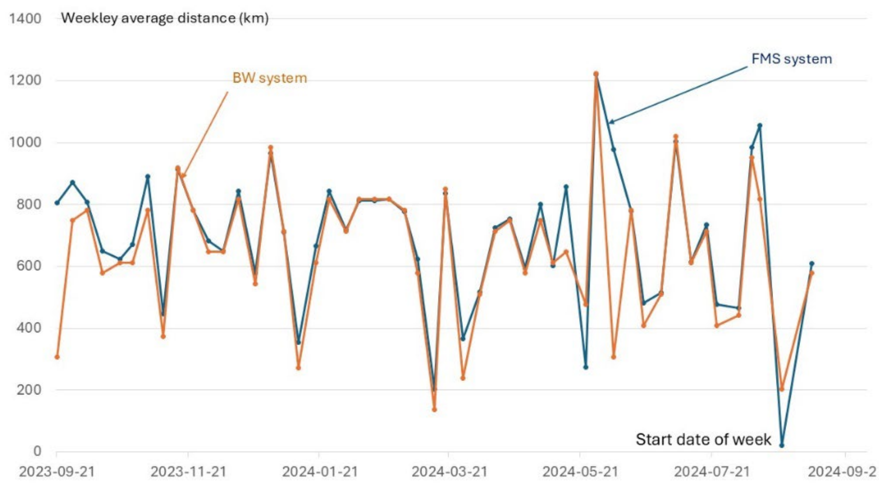

Figure 7. Distance per week (km) between June 2022 and September 2024 measured in the FMS system (blue dots) and from the BW system (red dots).

8. Energy consumption

Scania has made earlier simulations on the truck to estimate the average energy consumption during different conditions. In these simulations, a standard driving cycle has been used together with required charging times and a charging capacity of 130 kW. The results provide an estimated energy consumption of 1.75 kWh per km in a temperature of 4°C, and 1.96 kWh per km in minus 8°C. Figure 8 gives the actual energy consumption in kWh per km for the truck based on the FMS (orange) and the energy delivered by the charger in Obbola (blue). Some large differences are explained by the vehicle being repaired and charged at a garage, and that the vehicle has been on four exhibitions when a public charging station has been used. Before Christmas 2022 the charged energy was lower than used. However, later the use is higher than the charged electricity. How come there is so much difference? The charger is very accurate, so the problem should probably be found in the truck. There are two potential reasons for this behaviour. The first is that the FMS is calibrated wrongly. The second is that the use include also the charging of the batteries during generative braking that is possible on the truck.

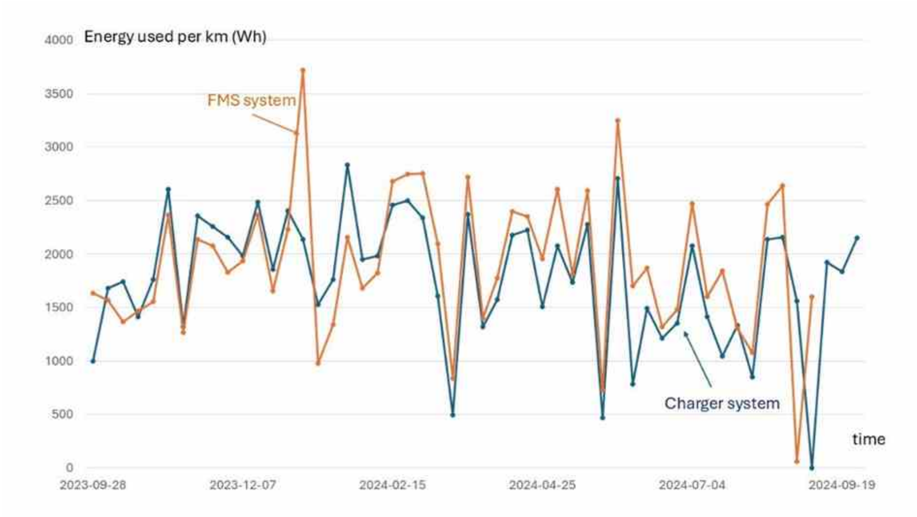

Figure 8. Energy (kWh) measured in the truck by the FMS system (orange), and energy charged at the charger (blue) per week between June 2022 and September 2024.

To analyze in more detail, we select the weeks when we know where the truck has been driving (based on Figure 7). It is well known that energy consumption depends on the temperature and wind conditions. Also, it is known that there are losses in charging and battery operational efficiency. The average daily temperature at Umeå airport which is located close to the route is given in Figure 9. This is used to estimate a temperature compensated (at 0 Celsius) energy consumption of the driving.

Figure 9. Average daily temperature (°C) at Umeå airport between June 2022 and September 2024.

We noted an energy loss during long term charging. When the vehicle is charged during the night or the weekend, there is a continuous loss that must be recharged. During a night there is an average loss of 30 kWh and during a three-day weekend 200 kWh. Biometria provides, as described earlier, an estimate of the energy consumption for any route and its profile (CRF compensated). We have used this together with a temperature compensation to estimate the energy consumption. All these are reported in Figure 10. The charger compensated energy consumption is very close to the CRF temperature compensated version. The FMS system shows a difference, and this can be explained by calibration error.

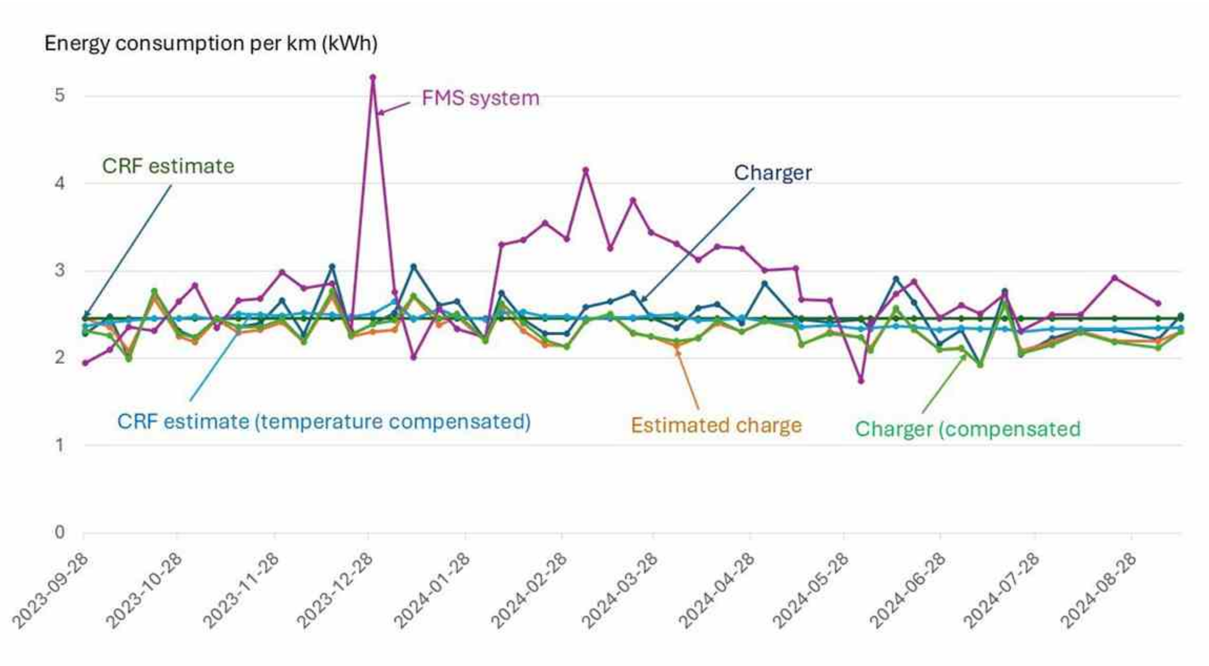

Figure 10. Average energy consumption (kWh per km) based on FMS (violet), Charger (dark blue), Estimated charge (orange), KV (green) and temperature compensated KV (light blue) between September 2023 and September 2024.

9. Repair and maintenance

We provide some examples on repair and maintenance during the last two years. Early on the truck discharged the 24-volt system when the truck was stationary for a weekend. This system provides energy to many functions such as lights, windshield wipers, fans, door locks, sound system and control system. When the 24-volt system is discharged, the truck's on-board computer with charging equipment cannot communicate with the charger or its own propulsion batteries; this makes charging impossible. This was first solved by fitting a new larger 24-volt battery, as well as installing an external charger for the battery so that it is possible to connect the truck to external power when parked for a longer time.

During a period when the electric truck was tested for a winter forest environment, it started to become more and more difficult to charge. It would not accept charging power. This situation got worse and worse for a couple of days until it could not be charged at all. Hence, it was driven to the workshop where, after troubleshooting, it was found that a battery cell in one of the battery packs was non-functioning. This cell was replaced, and the truck worked fine again. The total downtime due to troubleshooting and delivery times of special tools and spare parts was about 2 weeks.

The ABB terra 184 charger has had problems with power modules ending up in standby mode. In the charger, there are 6 power modules that deliver power to the vehicle. When the charger is not in use, the modules lie dormant. In the first six months, this happened sometimes, and it resulted in lower charging power. This is now solved with new software from ABB. The main fuse in the switchgear occasionally trips; what causes this is currently unknown. The main fuse is rated at 250 amps and the charger's internal limit is set at 235 amps. So, the amperage should never exceed that of the main fuse. This happens anywhere from several times a week to a few months apart. It is currently unclear what is causing the problem. Recovery is usually completed within an hour of the reported error.

During the cold days of winter, energy consumption increases. Also, there was a limit of about -32 Celsius. On such an extreme temperature, the truck lost connection with its batteries and indicated that they are empty even though it was fully charged at departure and has only driven a couple of kilometers. The truck had to be towed into a warm garage and after a while, there was a connection to the batteries. Currently, there is no solution to this; it is important to remember that traditional diesel trucks often have problems with these low temperatures as well. To better adapt the car for cold climates, it is desirable that the truck is fully charged just before departure so that the batteries are warmed up and ready. This cannot be achieved with ABB's software alone but requires a third party right now. The truck has also had minor problems; some sensors and some relays have had to be replaced, some plastic connected to the charging socket has broken, etc. These are normal problems that can often occur on diesel trucks as well.

10. SCA experiences

From a driver's perspective, the working environment is improved through reduced vibrations and noise. However, the reduced noise puts more responsibility on the driver since pedestrians react to the truck at a later stage. Also, drivers are often alone at the charging location during lunch instead being together with other drivers at lunch restaurants or equivalent. The Obbola electric timber truck has generally performed well, especially in terms of operation and maintenance, requiring less workshop time than diesel trucks. Drivers appreciate the quiet and comfortable driving experience, without vibrations and with smoother starts. However, the range of this early version is an issue, especially during cold periods, which leads to frequent charging. Charging is seen as the biggest challenge, as it takes time and technical problems with the charger sometimes arise. Despite initial scepticism and charging issues, the electric trucks have performed better than expected. They are viewed as a good option for shorter distances, but the cost of purchasing the vehicles remains high, and so far, production is significantly reduced due to charging time. There have been many interviews and press releases in media regarding the truck since the beginning of its use in 2022. Below, we provide some comments made in the media by key stakeholders.

Susanna Rutqvist, Climate Lead at SCA:
This collaboration between SCA and Scania is an important step in developing sustainable transport solutions for the heaviest truck transports. It is a global challenge, but where we together, in an innovative partnership, show that Swedish industry can drive sustainability development forward. Sustainability and reduced fossil emissions are important to society as a whole and this can be seen in the great interest in the electric log truck from, among others, customers, investors and employees. The fact that we have also gone ahead with another car

has received a very positive response.

Mikael Sundelin, development manager SCA Forrest:
As for the actual use of the electric log truck, it is probably the high reliability that surprised me the most. I had expected more "childhood ailments" to deal with since, after all, it is about the world's first electric timber truck to be put into operation. The electric log truck at Obbola has provided a very good basis, and great confidence, for the introduction of the next generation electric log truck at SCA.

Viktor Wasell, Logistics Manager SCA Forrest:
I think it's cool that we were at the forefront of testing new technology that brings us closer to a greener future. Transport is a large part of Sweden's emissions; to create a change in this we must dare to take on new technology. What we have learned from having this truck in operation at Gimonäs will be useful in many matters, not least now that we are taking the next step and putting an electric timber truck in the forest. Production of this truck has been in line with our expectations, proving that electric trucks have a place in the future of forestry transport.

11. Next generation truck

The truck used is special designed and its cost is not directly comparable. However, with new information on the new generations of trucks, it is possible to compare the competitiveness of an electric timber truck (BEV) compared to a conventional diesel-powered timber truck (ICE). The basic calculations have been made by SCA prior to the investment in a new electric timber truck and are based on a vehicle that will operate in two shifts. With two shifts it is possible to have an annual milage of 121,000 km (ICE) and 109,000 km (BEV) due to an estimated 9% charging downtime. The purchase price after subsidy has a relative factor 1:1.3 (ICE:BEV). The interest rate is assumed to be 6% for both and contract time 5 years. Also, the residual value of ICE is 15% whereas for the BEV it is assumed to be 0%. Moreover, due to the weight of the battery, the payload is assumed to be 46.9 and 44.5 tomes for ICE and BEV, respectively. The energy cost for the ICE is assumed to be 1.23 Euro/litre (ICE) and 0.13 Euro/kWh (BEV) (Average prices in Sweden October 2024). With these conditions, the BEV is 13% more expensive. Clearly, the diesel price may be very volatile, or the charging time could be reduced with more powerful chargers, and a sensitivity analysis would be interesting to identify when a breakeven level is found.

In October 2024, the next project began. This time it is an electric timber truck with a crane. This makes it almost identical to a normal timber truck. According to Scania, this model is called BEV3, which means "Battery electric vehicle 3". The 624-kWh battery is 95% larger than the previous model, the charging power has increased by 182% to 375 kW. The truck has a reinforced chassis and double drive axles to cope with tough forest terrain and a timber crane powered by energy from the batteries. The timber crane is estimated to consume approx. 30 kWh per load. If the timber truck had the same energy consumption as the previous timber truck, that is, an average of 2.2 kWh per km, the range would be 212 km. This truck will probably draw more energy due to a more challenging transport environment as well as loading with its own crane, so our best guess is that the truck will use a total of about 30 kWh per kilometer including crane driving. In that case, this gives a range of approx. 160 km. The truck will depart from Östavall, which is one of SCA's 13 timber terminals where timber from the forest is reloaded, from timber truck to train which then runs the rest of the way to industry. During the first period, charging will take place at a public charger in the nearest community, approx. 1.5 km from the terminal. It has also been decided to build a fast-charging station for the truck at the terminal. This project will be completed in the Spring of 2025. The reason for building this is that the price of electricity at this location will be lower, the truck does not have to drive unnecessarily to get to the charger and there is no risk of queuing.

The transports the truck will carry out are at different distances from Östavall terminal. Östavall terminal is in the middle of a large forest holding and often has relatively short transport distances compared to other areas. The average transport distance is around 50 km. On one charge, the car will be able to drive maybe 2 laps to a branch that is 40 km away, or 3 turns to a branch that is 30 km away. Or a combination of different distances. The truck will initially be operated in single shift and then move to double shift when we feel ready for it. Annual mileage is estimated to be approx. 110,000 km and annual CO2 saving is estimated to be approx. 170,000 kg of CO2.

12. Concluding remarks

The first electric vehicle was custom built, and many new situations as compared to standard diesel have been dealt with. The measurement of the energy consumption is difficult as it is a new system integrated. There are energy losses in each of the parts including from charger to battery and from battery to driveline. When the battery is fully charged there are losses to keep a battery temperature and losses from a fully charged battery. It was surprising that these were as large as identified. This can be dealt with by better software to control the charging.

The FMS has provided data of questionable quality. The equipment needs to be better calibrated or detailed for future vehicles. The findings indicate that the battery electric timber truck can reduce the CO_2 emissions by 55 tons annually. Depending on how the price per CO2 are assumed this will make the BEV more cost-effective.

From a strategic perspective, SCA has gained knowledge in how battery-electric timber trucks operate. This is an important contribution to SCA's goal of making the entire value chain fossil-free, and how SCA intends to move forward based on these experiences

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