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The role of Battery Energy Storage Systems in scaling electric commercial vehicles and machines

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Executive Summary

Battery Energy Storage Systems (BESS) can play a pivotal role in mitigating local power availability, which is already at current low markets shares frequently brought up as a bottle neck for the transition to battery electric commercial vehicles and machines. By stacking a range of services, such as managing cost of power, energy, grid service revenue generation and resiliency, BESS will support the overall economics of charging and electric vehicle and machine operations. Increased cost and revenue transparency, standardization and harmonize with respect to installation, safety and data interfaces are critical to secure to be able to scale the deployment of these assess effectively. Repurposing vehicle battery packs into BESS also creates additional opportunities in supporting the transition.

Keywords: Heavy Duty electric Vehicles & Buses, Charging business models, Smart grid integration and grid management, Fast and Megawatt charging infrastructure, Energy storage systems

1 Introduction

Volvo Group has set ambitious Science Based Targets on greenhouse gas emission reductions in line with the Paris Agreement. Our ambition is to reach net-zero greenhouse gas emission-enabled products, solutions and services by 2040. We also see many of our customers, and their customers in turn, committing to similar sustainability goals. In parallel, the more forward-leaning electrification countries are also starting to put requirements in place demanding or in other ways incentivizing the use of zero emission vehicles and machines, for example urban construction sites in Norway [1] and Netherlands, Finland and Iceland, all achieving 100% battery-electric city bus sales in 2024 [2].

With an extensive range of battery electric commercial vehicles and machine options now available in the market and with our own quarterly deliveries now steadily in the 1000s [3], we are entering the scale up phase in transport and construction industry decarbonization.

According to [4]; while the current share of electric trucks in total sales remains marginal, the combination of declining costs, better infrastructure, and clear economic benefits is expected to drive rapid adoption in the coming decade, mirroring the growth trajectory seen in passenger vehicles. Concerns about charging and/or grid constraints is common in our dialogues with potential vehicle customers. This also agrees with the conclusions from a recent US outreach to more than 100 truck fleets [5]; ‘From the perspective of fleet operators, two key areas emerged as critical concerns in the transition to electrification. These include the availability of public charging infrastructure and grid readiness’. This despite that the market shares for new sales of electric trucks and buses currently still are low, in EU only at 2.3% and 18.5% respectively [6].

To increase these market share number significantly in the coming decades, affordable, reliable and quickto-deploy solutions for charging are needed. Here we and others [7-10] see that Behind-The-Meter (BTM) Battery Energy Storage Systems (BESS) can play an important role in enabling charging and silent zero-emission power in temporary locations (e.g. construction sites, events and customer trials) or in optimizing the operation of more permanent charging installations (e.g. public fast charging sites, logistic hubs, vehicle dealerships/workshops/depots).

2 Mitigating grid constraints

2.1 Off-grid

A BESS designed to mobile and possible to use in island mode (i.e. without a permanent grid connection) can in many cases replace traditional diesel generators (gen-set) in temporary, off-grid applications. Compared to a gen-set the BESS will have higher energy efficiency, no emissions during operation and will significantly reduce noise levels at the location. The rapid power response of the BESS and few moving parts will support higher reliability and productivity.

Extended off-grid use of a BESS at a specific location poses additional challenges and complexities in swap schemes and related logistics. When available, the BESS can also connect to local power generation, e.g. solar panels. This will enable longer operation between the times the BESS needs to be replaced or connected to the grid for recharging.

In a commercial vehicle and construction equipment context this type of product, especially those with integrated chargers, is an important enabler for the operation of electric vehicles and machines. Some scenarios where this is being used are:

- Events: Examples here include providing charging and/or power at larger events (e.g. FIS Cross Country ski world championships in Norway in 2025) [11], music festivals (e.g. Glastonbury, UK in 2024) [12] or supporting different electric vehicle sales activities [13].
- Construction sites: Products are currently available from several suppliers in the range from 10s-100s kWh. Some designs allow that the electric machines moving around their site during also themselves can carry with them the ‘energy’ and charger, increasing the operation flexibility, Figure 1.

Fig 1. A 40 kWh ‘Power Unit’ for charging compact construction equipment as well as for powering other site tools.

2.2 Limited grid connection

If a limited grid connection is available (typically 32-125 A), but which is not sufficient to reliably supply the output charge power needed (typically 150-400 kW), the BESS supports by charging from the grid at low power (continuously or on a schedule optimized for cost or CO2) and then discharging rapidly when so required. This ability allows for very rapid deployment of fast chargers almost anywhere and often without any need for additional permitting.

For commercial vehicles and equipment, also this is a very common scenario in construction settings. Another example is for electric truck or bus customers waiting for a grid connection upgrade to enable charging of a new or extended fleet. Here the BESS is a good temporary solution to enable charging of the fleet until the upgrade is complete. A third example is during the evaluation of electric trucks on a new, longer, transport routes where sufficient public charging infrastructure is not yet available. By deploying this type of BESS at strategic locations, charging can be secured while the public network is expanded.

Fig 2. (left) A recently launched 500 kWh 'Power Unit' which enables fast DC charging on low power grid connections. (right) Fast charging of an electric excavator at a construction site in Norway.

The limited grid connection scenario will most likely be very common in the early deployment of the new Mega Charging Standard (MCS), which will enable charge power in excess of 1 MW for commercial vehicles. MCS is also expected to be a common solution for e.g. commercial marine vessel and electric aircraft. During the roll-out of this technology, utilization of chargers is expected to be low. Low utilization in combination with very high local power peaks a pairing with local storage will most likely be very beneficial. Some integrated BESS and MCS concepts are starting to emerge in the market, Fig 3.

Fig 3. Mega Charger prototype for truck charging from Designwerk [14].

3 Optimize operations

In addition to mitigating grid constraints to enable charging, battery energy storage systems bring the potential to support the operation of charging infrastructure in several ways, Table 1.

The business case for adding a BESS to a charge site often relies on the successful stacking of several of the services highlighted, which puts high requirements on the BESS and the site Energy Management System (often called EMS). AI and machine learning play a significant role in current EMS development by enhancing capabilities predictive analysis (e.g. maintenance, power demands, market prices, weather), fault detection and cost saving/revenue optimization.

Table 1: Potential BESS contributions in optimizing the operation of charging infrastructure.

Customer benefit	Potential BESS contribution
Manage cost of power	Enable charging at power level exceeding current grid connection. Reduce cost of power for site by peak shaving. Avoid or defer investments in grid upgrade.
Manage cost of energy	Optimize self-consumption of locally generated energy (e.g. solar). Buy energy during the lowest priced hours of the day.
Generate revenue from grid service markets	*Capacity market* – Being available to deliver an agreed power to the grid if required. *Arbitrage* – Monetize difference between high and low energy prices (e.g. day-ahead, intraday, power purchase agreements). *Frequency markets* – Participate in regulations services from Transmission System Operator (TSO). *Local flexibility market* – Provide flexibility to local power markets. *Black start* – Being available to re-start grid after outage. *Future markets* – Markets for e.g. voltage control and congestion management are being considered in some countries.
Increase resiliency	Provide energy to site during shorter grid outages. Secure power quality (e.g. if equipment on site is sensitive to disturbances).
Support sustainability agenda	Buy energy when generation mix in grid most favourable. Optimize self-consumption of locally generated energy (e.g. solar). Proof-point for company brand building and sustainability communication.

4 Current BESS sales and deployment challenges

The sales and installation of BTM BESS for commercial & industrial customers comes with a range of challenges as every customer site and project is slightly different and necessary data collection often still a manual effort.

Some of the local variability includes electricity and power rates, structure of tariffs, availability of local flexibility markets, solar feed-in possibilities, rules and timelines for building and connection permits, safety and access requirements from local fire and rescue services. National and international harmonization of the permitting, installation, safety and grid connection requirements would greatly support a more rapid deployment of these solutions.

Grid service markets have during the last few years developed very rapidly, and prices have been volatile. Limited transparency in the BESS revenue potential increases the risk for the customer, and often also the willingness to invest. However, as the market matures this issue will fade and we have recently seen the launch of several BESS revenue indices, some also third party verified [15-18].

Few fully vertically integrated companies exist in the BESS eco-system today, meaning collaboration and securing local partnerships are important to provide the best customer experience.

To further de-risk installation and operation of BTM BESS, equipment and communication interoperability would benefit from harmonization. In a charging use case today, the BESS typically has to interact with DC-chargers, a local site/microgrid controller, a building energy management system, the local distribution system operator as well as one or more grid/flexibility market providers. Without more standardized solutions, scaling this technology will be slow and expensive.

5 The alluring ‘second life’ opportunity

In our view, the controlled environment and the multi-purpose use-case characteristics of a BTM BESS make this a good candidate for repurposed vehicle batteries, Fig 3. Repurposing is an attractive part of a circular business model for batteries, which is strongly supported in e.g. the EU Battery Regulation [19]. This so-called ‘second life (or 2nd life)’ significantly increases the utilization of components already produced, alleviates supply and resource constraints but also creates a higher residual value for commercial vehicle batteries. The latter in turn makes the electric vehicle more affordable and so supports the transformation in transport industry, Fig 4.

Figure 4. Details of a prototype second life BESS containing used electric bus battery packs.

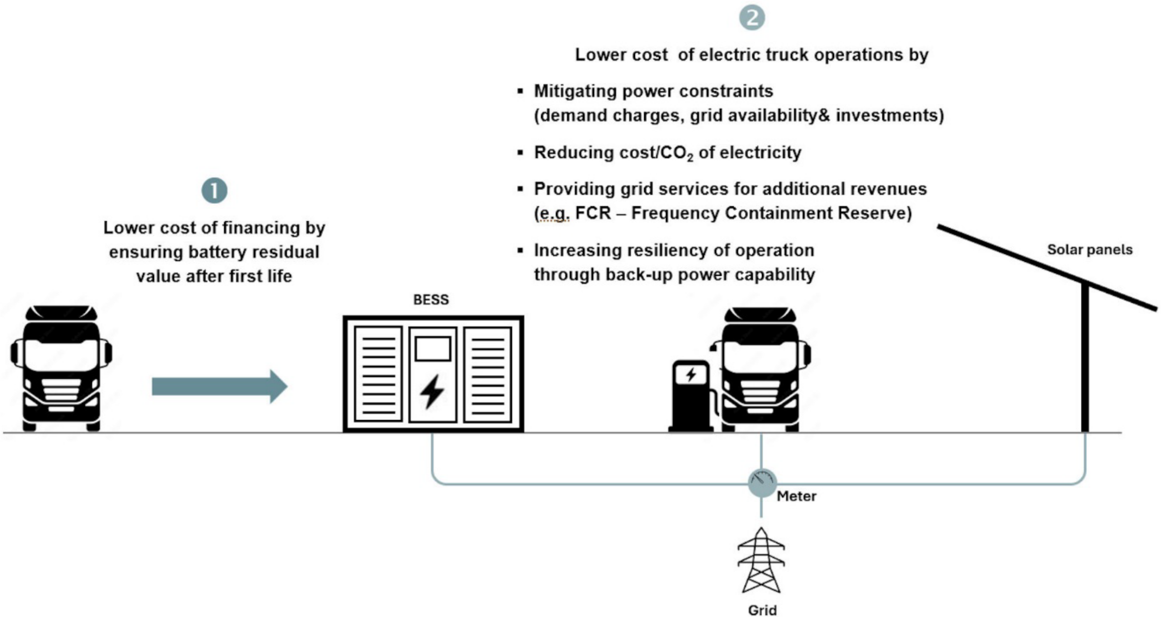

Figure 5. Schematic for how repurposing and 2nd life BESS can support the economics of electric truck operations.

It is important that upcoming BESS regulations and safety standards embrace the second life opportunity, especially since the availability of electric vehicle battery packs for repurposing into storage systems is expected to grow significantly from now on, potentially reaching up to 100 GWh by 2030 and 3 000 GWh by 2040 [20]. Thus, they can play a crucial role in supporting the energy transition beyond 2030.

Recent research [21] indicates that for many potential customers in the C&I segment, a second life BESS offers the lowest life-cycle CO_2 option. In the Nordics a second life BESS, in a low energy throughput use case (e.g. a mix of backup power, moderate peak shaving, frequency containment reserve) reduces lifetime CO_2 by approx. 50% versus a new Lithium Iron Phosphate cell BESS imported to EU from China. The difference between the two options is however dependent on e.g. the BESS use case and grid carbon intensity when the BESS are charged (as the 2nd life BESS will have slightly higher losses and lower round trip efficiency), so to maximize the sustainability benefits of 2nd life care should be taken to pick the right use cases and locations.

6 Business models

For several reasons we are expecting to see more as-a-Service or rental business models for battery energy storage systems in the temporary power, charging and commercial & industrial segments. These models:

- reduce the need for significant upfront capital investment.
- provide customer flexibility in terms of capacity, application and contract duration.
- mitigate risks such as revenue uncertainty, technology obsolescence and battery degradation.
- provide maximum customer convenience when coupled also with turnkey installation services.
- supports the BESS OEM in securing a circular battery business model including repair and recycling.

All-in-all, the right business model can significantly impact the customer willingness to adopt new BESS technology.

7 Recent Volvo examples

7.1 Site preparation for battery cell factory

During the ongoing initial site preparation phase of Volvo Group’s cell manufacturing facility in Mariestad, Sweden, zero emission equipment is being used, Fig 6. As this is a green field development, the DC fast charging of both truck and excavator is secured through a BESS with integrated charger. This BESS is continuously trickle-charged from a nearby low power (up to 125 A) connection, but able to discharge at much higher power when required.

Figure 6. Electric truck and excavator charging from BESS to enable zero emission operation in a temporary location with limited grid supply.

7.2 Truck MCS charging

Next to the Volvo Group headquarters in Göteborg in Sweden a new charge site for internal test vehicles as well as for selected customer trucks is in the final commissioning stage, Fig 7. The site has a new separate grid 2 MW connection with a conditional agreement in which the local Distribution System Operator (DSO) can reduce power by 50% if required for grid stability. The charger setup is 1 MCS charger (peak ~1.4 MW) and 3x CCS chargers (peak ~360 kW/each). The on-site BESS will support the operation in several ways:

- Peak shaving to reduce the cost power.
- Generating revenue by selling flexibility to a local capacity market (‘Effekthandel Väst’ [22]) and ancillary services (TSO frequency markets) outside of the scheduled windows for charging.

- Increase resiliency in operation by being able to for some time maintain site power for charging even when the DSO has been forced to reduce supply.

Figure 7. The new electric truck charge site just outside Volvo Group headquarters in Göteborg. BESS to the left in the picture, MCS charger middle-right.

7.3 Fossil free ski resort

During the 2024 winer season, ski resort operator Skistar piloted zero emission operation of the Hammarbybacken ski facility outside of Stockholm, Sweden [23]. The project aimed to show that a transition to a completely fossil-free ski resort operation is possible, to identify challenges in the transition and to inspire more companies to dare to test new initiatives for change. The test used the following electric equipment; two snowmobiles, one snow groomer, one wheel loader, one van, one quad bike, Fig 8. Charging was enabled by a BESS connected to an existing low power grid connection. The BESS was provided through a seasonal rental agreement.

Figure 8. Electric snow groomer used during the fossil free ski resort pilot in Stockholm. (left) in the slope, (right) by the charger)

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Presenter Biography

Niklas Thulin is Head of BESS Product Offer in Volvo Energy. To this role he brings 20+ years of electrification experience in different leadership positions in the Volvo Group. Niklas has his academic background at Chalmers University in Gothenburg, with an M.Sc. in Mechanical Engineering and an additional Lic.Eng. research degree in Material Science. Niklas is currently also the chairperson of the Swedish Electricity Storage and Balancing Centre.