Institute of Transport Economics
Norwegian Centre for Transport Research

User experiences from the first series-produced battery-electric trucks

Interviews in 2021 with the first Norwegian users

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Mobility Zero Emission Energy Systems

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Summary

While battery-electric passenger cars now make up the majority of new car sales in Norway and electric vans are quickly gaining market share, the electrification of truck transport is still in an earlier phase. After the first series-produced battery-electric trucks were introduced on the Norwegian market in June 2020, their adoption has accelerated, amounting to 75 trucks in August 2021 and 231 by August 2022. This report synthesizes the first relevant user experiences that may influence further vehicle adoption, based on interviews performed up to the summer of 2021. Feedback indicates that the adoption of electric trucks has largely been strategic and affected by (previously limited) model availability. With some adjustments in operations, much of local and regional transport can be operated with existing battery-electric vehicle technology. User experiences have largely been positive, with some exceptions and particular improvement areas. Efficient operation and larger-scale adoption requires access to fast chargers, range improvements, towbars, and stable, predictable and longer-term framework conditions.

Kort sammendrag

Mens batterielektriske personbiler nå utgjør majoriteten av nybilomsetningen i Norge og markedsandelen til batterielektriske varebiler øker raskt, ligger elektrifisering av lastebiltransport fortsatt etter i utviklingen. Etter at de første serieproduserte batterielektriske lastebiler ble introdusert på markedet i juni 2020 har innfasingen skutt mer fart, med 75 registrerte lastebiler per august 2021 og 231 ved inngangen til august 2022. Denne rapporten oppsummerer de første brukererfaringer med relevans for videre innfasing av batterielektriske lastebiler, basert på intervjuer som ble gjennomført fram til sommeren 2021. Tilbakemeldingene tyder på at investeringer i batterielektriske lastebiler i stor grad har vært strategiske valg og har vært påvirket av modelltilgjengelighet, som inntil nylig har vært svært begrenset. Med noen tilpasninger i driftsopplegg kan mye av lokal og regional transport opereres med eksisterende batterielektrisk kjøretøyteknologi. Brukererfaringer har hovedsakelig vært positive, med noen unntak og spesifikke forbedringsområder. Effektiv drift og innfasing i større skala krever tilgang til hurtigladere, økt rekkevidde, henger-feste og stabile, forutsigbare og langsiktige rammebetingelser.

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Preface

In November 2021, TØI published the report "Green Trucking? Technology status, costs, user experiences" (in Norwegian). This report built on several works carried out through MoZEES, a research center for environmentally-friendly energy, financed by the Norwegian Research Council, and led by the Institute for Energy Technology, with TØI being one of the research partners. Commissioned by the secretariat for the public-private collaboration "Green land transport program", these works and some additional analyses were synthesized and compiled into a report, serving as a knowledge base on the market and technology status for different parts of Norwegian land transports, costs for alternative propulsion technologies, and status for availability of biogas and biodiesel.

The report was supplemented with a chapter on user experiences from the first Norwegian users of series-produced battery-electric trucks, building upon similar analyses among the first users of third-party-converted battery-electric trucks in Norway (Hovi et al., 2019). This part of the work was financed by MoZEES. The current report primarily constitutes an English version of these user experiences, and includes a number of smaller updates to reflect developments in the adoption of battery-electric trucks in Norway since the analyses were performed in 2021. It should be noted that energy prices, both for electricity and diesel, have seen large increases and extraordinary volatility in 2022. At this point, it is uncertain how such developments will affect future investment decisions and choices between technologies.

Work on the current report has been carried out by Daniel Ruben Pinchasik, Erik Figenbaum and Inger Beate Hovi. Hovi initiated and carried out interviews on user experiences together with Figenbaum and, in part, Pinchasik. Pinchasik summarized the interviews and has written most of the report's contents, with input from Figenbaum and Hovi.

Oslo, September 2022
Institute of Transport Economics

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While battery-electric passenger cars now make up the majority of new car sales in Norway and electric vans are quickly gaining market share, the electrification of truck transport is still in an earlier phase. After the first series-produced battery-electric trucks were introduced on the Norwegian market in June 2020, their adoption has accelerated, amounting to 75 trucks in August 2021 and 231 by August 2022. This report synthesizes the first relevant user experiences that may influence further vehicle adoption, based on interviews performed up to the summer of 2021. Feedback indicates that the adoption of electric trucks has largely been strategic and affected by (previously limited) model availability. With some adjustments in operations, much of local and regional transport can be operated with existing battery-electric vehicle technology. User experiences have largely been positive, with some exceptions and particular improvement areas. Efficient operation and larger-scale adoption requires access to fast chargers, range improvements, towbars, and stable, predictable and longer-term framework conditions.

In November 2021, TØI published the report "Green Trucking? Technology status, costs, user experiences" (in Norwegian only). The report contained a chapter on the experiences of the first Norwegian users of series-produced battery-electric trucks. The current report constitutes an English version of these user experiences, complemented with a number of smaller updates to reflect developments since analyses were performed in 2021.

TØI previously interviewed some of the first Norwegian users of battery-electric trucks to collect real-world user experiences (Hovi et al., 2019). At that time, battery-electric trucks were generally all rebuilt from diesel to electric drivetrain by independent third-party converters, but from the summer of 2020, the first series-produced battery-electric trucks from major truck manufacturers started arriving in Norway. Although this has given a boost to their adoption, there were still only 74 Norwegian-registered battery-electric trucks as of August 2021, mainly used by major actors and in the Greater Oslo area. By August 2022, this number has increased to 231 trucks.

For the present work, we interviewed five of the first Norwegian firms that operate series-produced battery-electric trucks (three distributors and two contractors), in addition to a vehicle supplier and the Norwegian Public Roads Administration. The interviews were performed between April-June 2021 (and findings in this report must be interpreted keeping this in mind). At this point in time, the firms had recently started operating 28 series-produced battery-electric trucks from several large truck manufacturers, both 2- and 3-axled distribution trucks and 3-axled construction trucks with a distribution truck chassis. The objective of the interviews was to gain insights into their first relevant user experiences that may influence further vehicle adoption, such as the purchasing process, charging systems, use compared to diesel vehicles, incentives, challenges, and what would be necessary to attain larger scale electrification to achieve the National Public Transport Plan's target of 50 % of new trucks being zero-emission by 2030.

Drivers behind choosing battery-electric trucks

Early users state that investments in battery-electric trucks have largely been strategic. Important drivers have been the firms' own climate and environmental objectives, in addition to passionate key staff. For construction firms, the environmental weighting in public tenders, especially from the City of Oslo, has been a very important driver. Distributors report increasing demand for greener transports, but with limited willingness to pay the added cost by customers.

Choice of vehicle manufacturer and investment cost premium vs. diesel

The firms' choice of vehicle model and supplier was largely steered by availability, with choice alternatives until recently being few and delivery times long, with a preference for well-known suppliers. Price was considered, but not a decisive factor due to the investments largely being strategic.

Small and larger battery-electric distribution trucks were stated to have been 2-2.6 times and 3-4.6 times more expensive than similar diesel trucks, and battery-electric construction vehicles 3-3.5 times more expensive, respectively. Prices have gone down somewhat between 1st and 2nd generation series-production. Due to high investment costs and uncertainty about residual values, the firms interviewed often employ longer depreciation periods for battery-electric trucks than conventional vehicles or plan to use them longer. All firms received ENOVA (a national clean energy funding agency) subsidies for part of the additional investment costs (vs. a similar diesel vehicle). This is stated to be very important, even though there have been several challenges due to ENOVA's design of the grant scheme.

Use patterns for battery-electric vs. diesel trucks

Both distributors and contractors made operational adjustments for the phase-in of their battery-electric trucks. In some cases, relatively small changes were sufficient, while in other cases, larger parts of the operations were reorganized, although not all changes would strictly speaking have been necessary. Distributors mainly use their battery-electric trucks for urban distribution. Here, the battery-electric trucks approach one-on-one replacements of diesel vehicles, especially after the establishment of fast charging at depots, which allows an increase in the number of shifts and attainable annual mileages.

Use flexibility is somewhat limited due to the inability to drive with trailer and on longer routes. Bergen is stated to have more demanding topography and geographical surroundings, so that achieving fully electric city distribution will take longer than in Oslo, where separate city terminals have been established from which electric distribution transports are organized.

For construction trucks, the usage pattern for diesel vehicles varies much, making direct comparisons difficult. The battery-electric construction vehicles are mainly used for light construction work during the day in the inner city of Oslo and between construction sites and disposal sites in Oslo. Usage patterns have been somewhat adapted to increased use of local disposal sites because this fits well with the procurement policies of the municipality of Oslo.

Experiences from use

Generally, energy consumption of the battery-electric trucks is reported to be low, yielding large energy and potentially also cost savings. Both energy consumption and driving range can vary much, depending on various factors, although wintertime reductions in driving range have generally been limited. In practice, the range of battery-electric trucks lies somewhat below the manufacturer-specified range, but much closer than some of the firms previously experienced with battery-electric vans. Newer generations of battery-electric trucks have also shown noticeable efficiency improvements and better driving ranges. Other than some individual cases, the firms have not experienced major technical problems, although experiences with training, service and maintenance, and the pricing of this, are mixed. Drivers are generally satisfied with the vehicles' performance and report an improved working environment.

Even though the weight of batteries negatively affects the vehicles' payload, this is not considered a major problem in practice because capacity limitations for distribution transport are usually set by volume, while construction activities in the inner city are time-consuming, so that construction trucks often drive before they are filled up to capacity. However, the placement of batteries can yield challenges with regard to axle load, space/placement on 3-axled vehicles and uneven construction site grounds.

Charging

The distributors mainly started with nighttime depot charging, but also want to be able to use more fast-charging during daytime, although the concrete charging strategies differed. The construction firms also use nighttime charging, in addition to several fast charging solutions during the day. While depot charging infrastructure is relatively inexpensive and electricity costs are low, fast charger infrastructure is expensive. A major barrier reported by all firms is that ENOVA subsidies are only given to chargers that are made publicly available. In addition, the establishment of fast chargers may require additional costly investments such as grid upgrades. External fast charging, however, is considered expensive and entails costs for charging time, detours, waiting in queues, etc. Investments in battery-electric vehicles and the availability of charging solutions are therefore described as a “chicken-and-egg-problem”, because the competitiveness and profitability of the vehicle depends on how optimally the vehicle can be used. In this regard, it is pointed out that infrastructure deployment is going too slowly.

Incentives and framework conditions

All firms point out the importance of stable, predictable and long-term framework conditions. For the time being, subsidies for battery-electric vehicles are considered very important for investments in zero-emission vehicles, while much better schemes for charging infrastructure are called for. In particular, it is noted that maintaining road toll advantages (currently a full exemption) is critical for battery-electric vehicles to compete with other technologies. Further feedback suggests that should road toll advantages also be introduced for biogas vehicles (with an exemption entering into force for Oslo toll roads, from September 1st, 2022), this could lead to a transition to these at the expense of battery-electric solutions.

Other (existing or potential) incentives brought up by the firms are access to public transport lanes, zero/low emission zones, low noise zones and dedicated loading and unloading zones for zero emission vehicles. Such incentives allow more (time) efficient use and improve the competitiveness of zero-emission vehicles. At the same time, it can be discussed whether hybrid trucks or biogas vehicles should receive any of these advantages.

Electrification potential and other propulsion technologies

Distributors are generally positive about the potential for electrifying their fleets. Much of local distribution can already be carried out with battery-electric trucks. Fast charging and relatively small driving range improvements will enable battery-electric operation also for large shares of their regional transports. In addition to range restrictions, there are barriers associated with the (lacking) availability of vans and trucks in some vehicle classes, lack of four-wheel-drive and tow-bar, and some vehicle models not supporting fast charging. The construction firms report a need for improved driving ranges, vehicles with more than 3 axles, and for vehicles with tow-bar, so that more mass disposal sites become practically reachable. On a general note, the vehicle manufacturer states that developments are moving quickly and that larger technological developments are expected in the future. It is also expected that costs can become significantly lower once much of the large development costs has been recovered.

Of other technologies, liquid biogas is considered the most promising alternative to battery-electric operation on heavy trucks. For urban use cases, biogas is competing with battery-electric propulsion. As battery-electric solutions becomes a cheaper option, biogas can gradually be squeezed out of urban areas (although this may be affected by the road toll exemption for biogas in Oslo, starting in September 2022), while liquid biogas can have applications in long-distance heavy transport. Biodiesel has become less competitive after a Norwegian levy was introduced, so that owners of diesel vehicles have started returning to (fossil) diesel operation. This illustrates a dilemma, where large emission reductions (due to the use of biofuels) can be zeroed out quickly when framework conditions change. Hydrogen is not considered a realistic alternative by the interviewed truck operators in the short to medium term.

Hurdalsplattformen (the Norwegian Government's political platform) puts an increased focus on biobased fuels and targets tax reductions to stimulate increased use of Norwegian-made biofuels. It is uncertain what the final policy will be as the Government does not have the majority in the Parliament behind it. The EU is currently revising the Alternative Fuels Infrastructure Directive and has proposed a stronger regulation with clearer targets for refueling and charging stations. The final ruling will likely not be ready before the end of 2022.

Transportøkonomisk institutt
Stiftelsen Norsk senter for samferdselsforskning

NORSK Sammendrag

Brukererfaringer fra de første serieproduserte el-lastebilene
-Intervjuer i 2021 av de første norske brukerne

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Mens batterielektriske personbiler nå utgjør majoriteten av nybilomsetningen i Norge og markedsandelen til batterielektriske varebiler øker raskt, ligger elektrifisering av lastebiltransport fortsatt etter i utviklingen. Etter at de første serie-produserte batterielektriske lastebiler ble introdusert på markedet i juni 2020 har innfasingen skutt mer fart, med 75 registrerte lastebiler per august 2021 og 231 ved inngangen av august 2022. Denne rapporten oppsummerer de første brukererfaringer med relevans for videre innfasing av batterielektriske lastebiler, basert på intervjuer som ble gjennomført fram til sommeren 2021. Tilbakemeldingene tyder på at investeringer i batterielektriske lastebiler i stor grad har vært strategiske valg og har vært påvirket av modelltilgjengelighet, som inntil nylig har vært svært begrenset. Med noen tilpasninger i driftsopplegg kan mye av lokal og regional transport opereres med eksisterende batterielektrisk kjøretøyteknologi. Brukererfaringer har hovedsakelig vært positive, med noen unntak og spesifikke forbedringsområder. Effektiv drift og innfasing i større skala krever tilgang til hurtigladere, økt rekkevidde, hengerfeste og stabile, forutsigbare og langsiktige rammebetingelser.

TØI publiserte i november 2021 rapporten «Grønn lastebiltransport? Teknologistatus, kostnader og brukererfaringer». Rapporten bygget på ulike arbeider utført i regi av forskningssenteret MoZEES, herunder brukererfaringer fra de første norske brukerne av serieproduserte batterielektriske lastebiler. Foreliggende rapport utgjør en engelsk versjon av disse brukererfaringene, supplert med en rekke mindre oppdateringer for å reflektere utviklinger siden analysene ble utført i 2021.

TØI har tidligere intervjuet noen av de første norske brukerne av batterielektriske lastebiler for å samle reelle brukererfaringer (Hovi m.fl., 2019). Den gangen var batteri-elektriske lastebiler ombygd fra diesel- til elektrisk drivlinje av uavhengige ombyggere, men fra sommeren 2020 har de første serieproduserte batterielektriske lastebilene levert av de store lastebilprodusentene kommet til Norge. Selv om innfasingen har skutt fart var det per august 2021 fortsatt bare 74 norskregistrerte batterielektriske lastebiler, hovedsakelig hos større markedsaktører og hovedsakelig med bruk i Stor-Osloområdet. Ved slutten av juli 2022, hadde dette økt til 231 batterielektriske lastebiler.

Til foreliggende arbeid intervjuet vi fem av de første norske bedriftene som opererer serieproduserte batterielektriske lastebiler (tre distributører og to entreprenører), i tillegg til en kjøretøyleverandør og Statens vegvesen. Intervjuene ble utført mellom april og juni 2021 (og funnene i foreliggende rapport skal tolkes således). I denne perioden hadde bedriftene i sum 28 serieproduserte batterielektriske lastebiler levert fra flere store lastebilprodusenter, både 2- og 3-akslede skapbiler til distribusjon og 3-akslede anleggsbiler basert på distribusjonsbil-schassis. Formålet med intervjuene var å få innsikt i relevante erfaringer mht. videre innfasing, bl.a. vedr. innkjøp, lading, bruk sammenliknet med dieselbiler, insentiver, utfordringer og hva som skal til for å få til elektrifisering i større skala for å nå NTP-målet om at 50 % av nye lastebiler har nullutslipp i 2030.

Bakgrunn for elsatsningen

Tidligbrukere oppgir at satsningen på batterielektriske lastebiler i stor grad har vært strategisk. Viktige drivere har vært bedriftenes egne klima- og miljømål i tillegg til engasjerte nøkkelpersoner. For entreprenørene har miljøvektingen i offentlige anbuds-utlysninger, spesielt fra Oslo kommune, vært en svært viktig driver. Distributørene erfarer også økende etterspørsel etter grønnere transporter, men at betalingsviljen for dette er begrenset.

Valg av kjøretøyleverandør og merkostnad

Brukernes kjøretøy- og leverandørvalg er i hovedsak basert på tilgjengelighet (valgalternativene hadde vært få og leveringstiden lang), med en preferanse for kjente leverandører. Pris vektlegges, men fordi investeringene er strategiske har ikke pris vært avgjørende.

Små og større batterielektriske-distribusjonslastebiler oppgis å ha vært hhv 2-2,6 ganger og 3-4,6 ganger dyrere enn tilsvarende diesellastebiler, og batterielektriske anleggsbiler 3-3,5 ganger dyrere. Prisen er noe redusert mellom 1.- og 2.-generasjons serieproduksjon. På grunn av høy investeringskostnad og usikkerhet rundt restverdi bruker bedriftene gjerne lenger avskrivningsperioder for batterielektriske lastebiler enn ved konvensjonelle biler eller planlegger med flere bruksår. Samtlige bedrifter mottok ENOVA-tilskudd til deler av merkostnaden ved investering (vs. tilsvarende dieselbil), noe som oppgis å være svært viktig, samtidig som det har vært flere utfordringer på grunn av utformingen av tilskuddordningen.

Bruksmønster for batterielektrisk versus diesellastebil

Både distributører og entreprenørene har gjort endringer i sine driftsopplegg ved innfasing av de batterielektriske lastebilene. I noen tilfeller var det tilstrekkelig med relativt små endringer, mens i andre tilfeller ble større deler av driften lagt om, selv om ikke alle endringer ville vært strengt nødvendig for å få et fungerende opplegg med batterielektriske biler. For distributører brukes de batterielektriske lastebilene i hovedsak til bydistribusjon og nærmer seg en-til-en-erstatninger av dieselbiler, særlig etter etablering av hurtiglading på depoter slik at antall skift og årlig kjørelengde kan økes.

Bruksfleksibiliteten er noe begrenset ved at bilene foreløpig ikke kan brukes på lengre ruter og at det foreløpig ikke er mulighet for tilhenger. Bergen oppgis å ha mer krevende topografi og geografisk omland slik at det er lenger fram til fullelektrisk by-distribusjon enn i Oslo der det er opprettet egne byterminaler som den elektriske distribusjonen organiseres fra.

For anleggsbiler varierer bruksmønsteret for konvensjonelle biler i utgangspunktet mye og det er vanskelig med direkte sammenlikninger. De batterielektriske anleggsbilene brukes hovedsakelig for lettere anleggsarbeid på dagtid i indre by i Oslo og mellom anleggsplasser og massedeponier i Oslo. Bruksmønsteret er noe tilpasset ved økt bruk av lokale deponier fordi dette passer godt til Oslo kommunens innkjøps-reform.

Erfaringer fra bruk

Generelt oppgis energiforbruket til batterielektriske lastebiler å være lavt, noe som gir store energi- og kostnadsbesparelser. Både strømforbruk og rekkevidde kan variere mye avhengig av forskjellige faktorer, selv om reduksjon i rekkevidde vinterstid stort sett har vært begrenset. I praksis ligger batterielektriske lastebilers rekkevidde noe i underkant av, men nærmere, oppgitt rekkevidde enn det som noen av bedriftene erfarer ved batterielektriske varebiler. Nyere generasjoner batterielektriske lastebiler skal i tillegg ha en merkbar effektivitetsforbedring som påvirker rekkevidden positivt. Unntatt enkelttilfeller har bedriftene i liten grad opplevd større tekniske problemer, selv om erfaringer med opplæring, service og vedlikehold, og prisingen av dette, er blandet. Sjåførene er generelt fornøyde med bilenes ytelser og oppgir at arbeids-miljøet har blitt bedre.

At batterivekten reduserer bilenes lastekapasitet oppleves i praksis ikke som noe stort problem fordi kapasitetsbegrensninger vanligvis settes av volum for distribusjon, mens anleggsvirksomhet i indre by er tidkrevende slik at anleggsbilene gjerne kjører før de er helt fulle. Batteriplasseringen kan imidlertid gi utfordringer med akselbelasting og være plass-messig utfordrende på 3-akslede trekkvogner.

Lading

Distributører har hovedsakelig startet med depotlading nattestid, men ønsker også å kunne ta i bruk mer hurtiglading på dagtid, selv om konkrete ladestrategier varierer. Anleggsbe-driftene bruker også nattlading, i tillegg til ulike hurtigladeløsninger på dagtid. Mens infra-struktur for depotlading er relativt billig og strømkostnader lave, er bruk av hurtigladeinfra-struktur dyr. Det oppgis som en stor barriere at ENOVA-tilskudd bare gis til ladere som gjøres offentlig tilgjengelige, ikke minst fordi etablering av hurtiglader kan kreve ytterlige kostbare investeringer som bl.a. nettoppgradering. Ekstern hurtiglading kan medføre kostnader til ladetid, omveier, ladekøer mm. Investeringer i batterielektriske kjøretøy og tilgjengelighet av ladeløsninger oppgis derfor som et «høne-egg-problem» og infrastrukturbyggingen går for tregt, fordi lønnsomhet av investeringene er betinget av hvor optimalt kjøretøyet kan brukes.

Insentiver og rammebetingelser

Brukere påpeker viktigheten av stabile, forutsigbare og langsiktige rammebetingelser. Foreløpig anses tilskudd til batterielektriske kjøretøy som svært viktig for at nullutslipps-investeringer kan vurderes, mens for ladeinfrastruktur etterlyses mye bedre ordninger. Spesielt bemerkes det at opprettholdelse av bompengefordeler er kritisk for at batteri-elektriske biler kan konkurrere med annen teknologi. En introduksjon av bompengefordeler også for biogassbiler (som i Oslo innføres fra september 2022) kan medføre en overgang til disse på bekostning av batterielektriske løsninger.

Andre (eksisterende eller potensielle) insentiver er tilgang til kollektivfelt, null-/lavutslipps-soner, lavstøysoner og egne laste-losseplasser for nullutslippsbiler. Slike insentiver gir mer (tids)effektiv bruk og øker konkurransekraften til nullutslippsbiler. Samtidig er det diskusjon om hvorvidt hybrid-lastebiler eller biogassbiler bør få noen av disse fordelene.

Elektrifiseringspotensial og andre framdriftsteknologier

Distributører er rimelig positive vedrørende elektrifiseringspotensialet for deres flåte. En stor del av lokaltransportene kan allerede utføres med batterielektriske lastebiler og hurtig-lading. Relativt små forbedringer i rekkevidde vil muliggjøre batterielektrisk drift også for store deler av de regionale transportene. I tillegg til rekkeviddebegrensninger er det barrierer knyttet til manglende tilgjengelighet av varebiler og lastebiler i noen klasser, mangel på firehjulstrekk og hengerfeste, og at noen modeller ikke støtter hurtiglading. Anleggsbedriftene oppgir behov for økt rekkevidde, flere aksler og mulighet for å bruke tilhenger for at flere massedeponier skal kunne nås. På generelt grunnlag bemerker kjøretøyleverandøren at utviklingen går raskt og at større teknologiforbedringer er ventet framover. Det kan også forventes at kostnadene kan reduseres betydelig etter hvert som de største utviklingskostnadene blir nedbetalt.

Av andre teknologier virker flytende biogass å ha størst potensial, relativt til batteri-elektrisk drift på tunge lastebiler. For bybruk konkurrerer biogass mot batterielektrisk framdrift. Ettersom batterielektriske løsninger blir billigere kan biogass gradvis skvises ut av byene (men bompengefritaket som innfases i Oslo fra september 2022 kan endre denne utviklingen), mens flytende biogass kan finne anvendelser innenfor tungtransport over lange avstander. Biodiesel har blitt mindre konkurransedyktig etter at det ble ilagt veibruksavgift slik at eiere av dieselkjøretøy går tilbake til dieseldrift. Dette viser et dilemma ved biodrivstoff. Store utslippsreduksjoner kan bli nullet ut raskt når rammebetingelsene endres. Hydrogen anses ikke som reelt alternativ av de intervjuede lastebiloperatørene på kort til mellomlang sikt.

Hurdalsplattformen har et økt fokus på biobasert drivstoff og det tas sikte på avgifts-reduk-sjoner for å stimulere til økt bruk av norskprodusert biodrivstoff. Det er usikkert hva den endelige politikken blir, da regjeringen ikke har flertall i Stortinget bak seg. EU reviderer nå direktivet om infrastruktur for alternative drivstoff og har foreslått en sterkere regulering med klarere mål for fyll- og ladestasjoner. Den endelige regulerin-gen vil sannsynligvis ikke være klar før i slutten av 2022.

1 Introduction

In an earlier phase of the MoZEES project (Hovi et al., 2019), some of the first Norwegian users of zero-emission heavy duty vehicles (HDVs), i.e. trucks, were interviewed to gather real-world user experiences. At that time, battery-electric trucks (BE-trucks) were generally all rebuilt from diesel to electric drivetrains by independent converters. Starting in the summer of 2020, the first series-produced BE-trucks from major truck manufacturers began arriving in Norway, and additional models have been launched and announced since. Figure 1.1 illustrates that even though the phase-in of BE-trucks has accelerated with the arrival of series-produced trucks, there were still only 74 BE-trucks registered in Norway by August 2021, mainly operated by major market players and mainly used in the Greater Oslo area. By August 2022, this had increased to 231 BE-trucks.

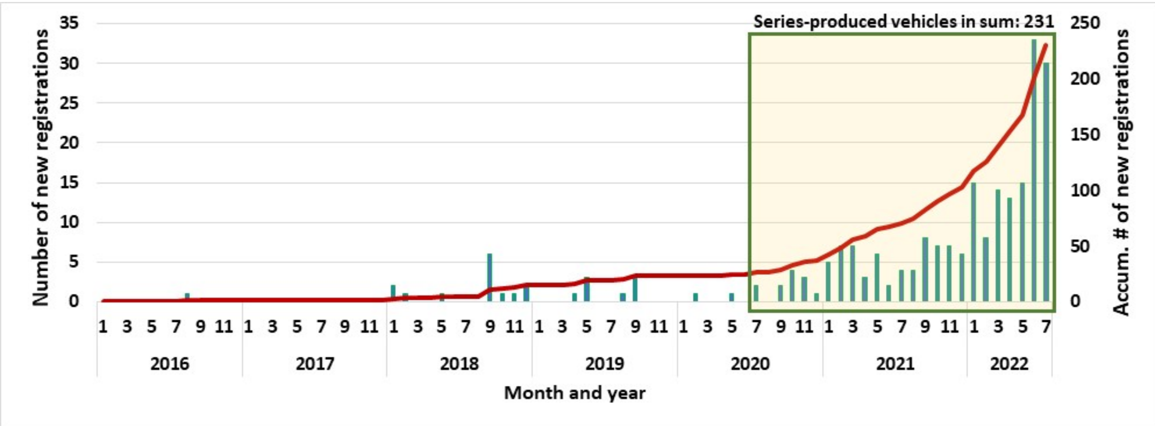

Figure 1.1:Development in the number of newly registered BE-trucks by month (left axis), and accumulated number of new registrations. Status pr. 31/07/2022. Source: Norwegian Public Roads Administration and own compilation.

2 Method and data

2.1 Interviews

For the present work, we interviewed five of the first Norwegian firms to operate *series-produced* BE-trucks (three actors within distribution transport and two actors within construction transport). The objective of the interviews was to gain insights into relevant experiences regarding further truck adoption, e.g. around purchasing and procurement, charging, operation and use compared to diesel trucks, incentives, challenges and barriers, and what it would take to achieve electrification at larger scales. In addition, we interviewed a truck supplier and the Norwegian Public Roads Administration (NPRA), who both contributed with further input, contextualization, clarification, etc.

Interviews were carried out between mid-April and mid-June 2021 and, thus, describe experiences and prospects as perceived at this time. Findings were originally published through a Norwegian TØI-report, published in November 2021 (Pinchasik et al., 2021). The current publication is primarily an English translation, but also includes several smaller updates to reflect developments in the adoption of BE-trucks in Norway over the last year, among several other developments.

2.2 Overview of the interviewed actors' fleet of BE-trucks

Table 2.1 provides a summary of the different series-produced BE-trucks in operation at the three distributors (firms A, B and C) and the two construction firms (firms D and E) at the time of the interviews. In total, the firms operated 28 series-produced BE-trucks, spanning different sizes/truck types. In addition to these trucks, some of the firms already had experience from operating battery-electric vans and/or BE-trucks from the phase where the latter were still conversions from diesel to electric drivetrains.

Table 2.1: Overview of series-produced BE-trucks operated by the 3 distributors and 2 construction firms interviewed.

Firm	Number	Make/model	Truck type	Payload capacity (if reported)	Other characteristics	Battery capacity	Time of adoption
A	2	Fuso e-Canter («Prototype 1»)	Truck with closed chapel, 2-axled		Chapel; tail lift	80-85 kWh	Late summer 2020.
	1	MAN	Truck with closed chapel, 3-axled		Chapel; side door; tail lift	185kWh	2020/2021 transition.
	1	Scania	Truck with closed chapel, 2-axled		Heated chapel (energy from HVO burner); side door; tail lift	270kWh	April 2021.
B	5	Scania	Truck with closed chapel, 3-axled			300kWh	
C	8	Fuso e-Canter («Prototype 2»)	Truck with closed chapel, 2-axled	12 pallets (80x120 cm)	Chapel (simple); tail lift	81.7kWh	Between December 2020 and March 2021.
	3	Volvo	Truck with closed chapel, 2-axled	18 pallets (80x120 cm)	Chapel (extra low); tail lift. One truck has side door.	200kWh	1 in August 2020; 2 in December 2020.
D	6	Volvo FE electric	Construction trucks, 3-axled		3x «Gen1» truck, 3x «Gen2» truck.	"Gen 1" 200kWh. "Gen 2" 260kWh.	"Gen 1" in October 2020. "Gen 2" in April/May 2021.
E	2	Volvo FE	Construction trucks, 3-axled		Both «Gen1» trucks.	200kWh.	January 2021.

3 Current experiences

3.1 Procurement process

3.1.1 Background, strategy and drivers: Why invest in BE-trucks?

For the interviewed firms, investments in BE-trucks, whether early investments in converted trucks or investments in some of the first series-produced models, were driven partly by common, and partly by different factors. In the interviews, firms were amongst others asked whether their investments were driven by a deliberate strategy and to what extent any other factors played a role in their decision to invest in BE-trucks (e.g. customer demands, national objectives, initiators/enthusiasts, PR, a desire to build up experience, etc.).

All firms stated that their investments in BE-trucks were linked to the firms' own climate or environmental strategies, albeit these strategies themselves varied between firms, e.g. with regard to when they were established, their scope, level of detail, ambition, and timeline for achieving objectives.

Overall, the firms reported that investment strategies were linked to objectives on becoming climate-neutral (both in transport and other activities), transitioning to fossil-free truck fleets, zero-emission targets, ambitions to only use renewable energy, active searches for better alternatives to fossil fuels, and/or specific emissions reduction targets.

Among the distributors, it is reported that customers increasingly demand more environmentally-friendly transport or set emission/environmental requirements in tenders. At the same time, environmental performance has so far not been weighted sufficiently in tenders to yield significant effects. In addition, tender periods for distribution transport assignments tend to be relatively short (e.g. 2-3 years), which entails a risk of purchasing BE-trucks that might not directly have a suitable alternative use once the tender period expires, often at a time that the trucks' higher investment costs are not earned back yet. The distributors further state that the willingness of customers to pay for the higher costs of environmentally-friendly transport is limited, but important for such transport to become economically feasible. While the Business-to-Consumer (B2C) segment shows some willingness to pay for environmentally-friendly transport, the Business-to-Business (B2B) segment is described as very cost-focused: Many B2B customers ask for zero-emission transport, but few are currently willing to pay a premium for it.

For the contractors, environmental requirements set by customers currently seem to be more important than for the distributors. This is related to the fact that assignments to a greater extent are carried out for the public sector, including the municipality of Oslo, which is at the forefront of weighting environment highly in tenders and has ambitious targets for reducing emissions from construction projects. The construction firms report that requirements set by the municipality of Oslo in relation to objectives for zero-emission construction sites in 2025, and award criteria in tenders, have been important or decisive drivers and that investments in electric construction machinery and trucks came as a direct response to this. Investments in BE-trucks further built on previous experiences within one of the firms' van fleet, and it was considered that electric operation also of trucks could, with relatively small changes, fit in well with parts of the firms' operations.

All interviewed firms point out that an important driver in the process of phasing in zero-emission trucks was the active role taken by at least one environmentally passionate soul in management. These people also often had good knowledge of the firms' operational transport arrangements or (previous) experience as truck drivers.

Several of the firms further mentioned that one reason for adopting new BE-trucks under their own ownership (even in cases where transport capacity is usually purchased from subcontractors), is that this contributes to an 'ownership' of the technology and to learning, experience-building and process changes. For these reasons, several of the firms also deliberately chose to introduce the trucks at several of their locations or to rotate between locations, to ensure that many drivers (employed by the firms themselves) gain experience with the trucks.

At the same time, it is noted that strategies in the future may be affected by the availability of relevant BE-trucks, stable and predictable framework conditions (e.g. road toll exceptions or discounts, financial support), and how biogas will be treated in tenders following a Parliamentary decision on treating biogas solutions the same as zero-emission solutions. This indicates that the firms' strategies to some extent may be fluid, where it is noted that biogas currently can provide greater flexibility than battery-electric alternatives.

3.1.2 Selection of manufacturer and truck model: Why were they chosen?

The approach to choosing a manufacturer differed somewhat between the firms, and different considerations were discussed. First of all, it was pointed out that with the introduction of series-produced BE-trucks, there is no longer any point in purchasing converted trucks. This is seen as an advantage, as converted trucks have often had long delivery times, have not always been sufficiently robust[1], and/or that the service offered by suppliers was insufficient for ensuring stable truck operation. Some of the firms further prefer to choose among major suppliers to the Norwegian market, if truck availability allows this. The reason for this preference is that these suppliers have systems and expertise in place and usually solve problems quickly. In this regard, one firm expressed that previous cooperation and good experiences with one supplier had been decisive for also choosing this supplier for BE-trucks.

Although several suppliers had started offering BE-trucks at the time of the interviews, it was pointed out that in practice, the choice of models was still somewhat limited. This applied to e.g. the number of suppliers that could meet the firms' needs, as for certain distribution truck classes, there were effectively only one of very few relevant suppliers. The same applied to suppliers' ability to deliver trucks at the desired time. One of the distributors further emphasized that it deliberately chose more general truck models, rather than special trucks, given the phase the market was in. Also for battery-electric construction trucks, there were, at the time of ordering, effectively only one or two suppliers. The BE-trucks purchased

[1] For example, one of the distributors already owned a BE-truck that came as a conversion from a diesel truck to electric drivetrain. Only after a long and troublesome process, this truck could finally be used without too many problems. At the time of the interview, the truck was reported to now have a decent driving range and to work well on distribution transports within Oslo and the Oslo region, and with battery (capacity) as originally intended.

by the construction firms were not originally designed for this truck segment, but were, in part due to requests and dialogue with one of the construction firms, constructed using a chassis originally designed for battery-electric distribution trucks. The battery-electric construction trucks therefore had 3 axles, of which one was a steerable rear axle, i.e. a configuration that construction trucks don't usually have. Several of the firms further pointed out that manufacturers have launched more special-purpose truck types and a broader selection of models[2], but that timelines for availability of such models are in practice often pushed back.

In the interview with the NPRA, it was noted that trucks used in Norway tend to be heavier than in much of continental Europe. For example, 3-axled tractors (max. 50 tonnes total weight) are common in Norway, while in continental Europe, 2-axled tractors are more typical (44 tonnes total weight) and the 'locomotive' behind technological and market development. In Norway, 3-axled trucks are a necessity given challenging driving conditions, particularly in winter. The three axles make it challenging to install sufficient battery capacity on these trucks, because the distance between the front and rear axles is shorter than on 2-axled trucks. This can be compensated for by increasing truck length, but this is undesirable because it would negatively affect the truck's swing radius.

With regard to price, feedback is that the firms took this into account in their investment decisions, but that price has not necessarily been the most important factor. It is stated that price was 'somewhat' a selection criterion, but that even with grants from the national clean energy funding agency ENOVA (see separate section), BE-truck prices from all suppliers were too high to provide sustainable operation. BE-trucks were nevertheless procured, highlighting the strong strategic considerations behind these investments.

3.1.3 Superstructure/bodywork

For the firms we interviewed, the choice of the truck's superstructure/bodywork, and supplier of this, did not specifically affect the decision to invest in BE-trucks. One of the distributors chose interchangeable bodies, instead of a fixed chapel, on its new BE-trucks. This choice was driven by a desire to make processes at the terminal more efficient, not necessarily because the solution fit better with BE-trucks. Despite some smaller technical challenges (see separate section), it was noted that suppliers of truck bodies/superstructures now supply electric solutions that can be coupled directly to the truck's battery, and that power units can be plugged in directly to the grid when the truck is being loaded/unloaded. The truck supplier noted that usually, the choice of superstructure supplier is made by the sales contact at the dealer, in collaboration with the customer. Superstructure/body work suppliers are said to previously have had some challenges with the power transfer between chassis and superstructure, which have largely been solved from case to case. The supplier also notes that superstructure suppliers have started to focus more on energy consumption and noise, which is more noticeable on electric trucks than on trucks with internal combustion engine and more engine noise.

[2] See, e.g.: https://www.mtlogistikk.no/elektrisk-lastebil-volvo-trucks/slik-blir-volvos-elektriskelastebiler/588190

3.2 Delivery

With regard to ordering and delivery of the trucks, interviews indicate that it often has taken a long time from BE-truck models were announced to when they could be ordered, and from the time manufacturers say they will deliver until they actually do. For some truck models, there have been waiting times of up to several years, and at the time of the interviews, it was still not possible to order the desired volumes and specifications. Only recently, developments have entailed a significantly greater freedom of choice of models and specifications. Both for distribution and construction trucks, delivery times have been long; often ranging from 7-9 months from ordering to delivery, with processes prior to ordering coming on top. Feedback from a truck supplier in May 2021 was that long delivery times were still a challenge, but that for the smaller flatbed trucks, delivery times for BE-versions had in some periods actually been shorter than for equivalent diesel models.

3.3 Investment/capital costs

Unlike for passenger cars and vans, there are no official and publicly available price lists for trucks. This is partially due to confidentiality reasons (e.g. regarding customer-specific discounts), but also because trucks in practice are tailored to the customers' specific needs, for example in terms of bodywork, equipment, different engine size specifications and comfort level desired. For BE-trucks, prices for similar models may be even more difficult to compare due to differences in e.g. battery specifications (which depend on the application that the truck is intended for) and because technological developments are rapid.

The interviews indicate that the Fuso e-Canter trucks have been between 2-2.6 times more expensive than similar diesel trucks. This provides an indication on price premiums, although it should be noted that the two distributors using this truck model, own different versions ('Prototype 1/2', where 2 is described as an almost-finished production-focused concept). Specifications between the models of the two distributors are not necessarily fully identical either, and the trucks were bought at different points in time. It was further reported that the investment cost premium for these trucks was somewhat lower than for larger BE-trucks, because the Fuso e-Canter to a larger degree employs more mature technology from the van segment and more standard components, such as battery packs from hybrid passenger cars.

In general, truck manufacturers will need to recover their developments costs from the early phase where volumes are small. This results in truck prices being high. The interviewed supplier stated that 'Generation 2' of most BE-trucks costs less than previous generations and less than BE-conversions did, but that prices (at early summer 2021) were still over twice as high as for similar diesel trucks (closer to 2 than to 3 times as high).

For larger distribution trucks, interview feedback indicated that BE-versions were ca. 3-4.6 times as expensive as similar diesel trucks. Battery-electric construction trucks had been ca. 3-3.5 times as expensive as comparable diesel models (including superstructure, where it is noted (see own paragraph) that this does not necessarily have to be more expensive on BE-trucks).

Due to high investment costs, uncertainty about the trucks' residual value and, in some cases, requirements to ownership arrangements in subsidy applications (see details in own paragraph), some of the firms treat capital costs somewhat differently than they usually do for diesel trucks. One of the distributors for example employs a depreciation period of 6 years for BE-trucks, while for diesel trucks, it usually employs 3 years (with repurchasing value) or 5 years (without repurchasing value). Longer depreciation periods yield lower capital costs per year, but also an increase in mileage the truck is used on. This generates a potential for additional savings on operational costs, because electric operation entails lower energy costs than diesel both in terms of energy prices, and because electric drivetrains are substantially more energy-effective than ICE-based ones.

One of the contractors typically resold fossil-fueled trucks after 3 years, but switched to repurchasing agreements (usually 3 years for diesel trucks). This was done in anticipation of the availability of BE-trucks improving and would be more in line with the firm's user needs. However, BE-trucks are considered to be such expensive investments that they must have an 8-10 year operational lifetime and have to be 'used up'. The firm employs a depreciation period of 5 years for its BE-trucks and notes that this is also related to the fact that it will first become clear in 3-5 years whether BE-trucks have been the correct choice. Further, examples were given where firms chose to finance BE-trucks with loans instead of through leasing or repurchasing agreements. One of the reasons for this was that ENOVA during a certain period did not provide subsidies when trucks were leased (see separate section on financial support).

Compared to diesel trucks, for BE-trucks (and to some extent also gas-powered trucks and other alternative propulsion technologies) there is much more uncertainty related to the trucks' residual value, mainly due to lack of experience with a secondary market, more uncertainty related to the trucks' remaining performance (e.g. the battery after several years in use), and because countries to which many Norwegian conventional trucks are commonly exported (particularly in Central and Eastern Europe) will likely have less mature charging infrastructures in place, something which can affect demand for BE-trucks. The truck supplier notes that it employs a residual value matrix, assuming that BE-trucks have a repurchase value, and envisaging that repurchasing values can be decent if zero-emission zones are starting to get introduced, as this will increase demand for BE-trucks.

Provided that firms, trucks, and investments, meet certain requirements, it has for some years been possible to obtain subsidies when investing in zero-emission trucks, mainly through schemes administered by ENOVA. Subsidies are provided for parts of the investment cost premium of BE-trucks[3] compared to equivalent diesel trucks. Operational expenses and savings are not taken into account. Because subsidies cover only parts of investment cost premiums, firms investing in BE-trucks will still need to finance sizable cost premiums themselves.

The firms we interviewed report that they received ENOVA-subsidies for all their BE-trucks. For cases where the maximum achievable subsidy was capped at 40% of the investment cost premium, the firms report subsidies of between 25-40% of the cost premium. In the other cases, firms received subsidies of between 40-48% of the investment cost premium. The firms emphasize that ENOVA-subsidies have been very important for the investments to have been made, and particularly the construction firms state that the subsidies have been

[3] As well as hydrogen-electric and (bio)gas trucks.

decisive because pricing in public tenders is often weighted highly (40-50%), even in tenders where the environment is (also) weighted relatively highly.

The firms further expected to receive similar subsidies for additional battery-electric distribution trucks that were in order at the time of the interviews, even though subsidy applications had not all been submitted yet. In this context, the truck supplier noted that ENOVA-subsidies in Norway had been reduced to 30-40% of BE-trucks' cost premium, compared to 40-50% previously[4].

Despite having received ENOVA-subsidies, the firms also pointed to a number of challenges. For example, it was noted that there had been cases where a firm had to own the BE-trucks themselves to be eligible for the subsidy, even though it had preferred a leasing arrangement to avoid binding up capital upfront. Further, an example was given by a firm simultaneously applying for subsidies towards a truck and charging infrastructure (see own paragraph). Here, ENOVA did not approve this joint application, because subsidies towards charging infrastructure establishment were not awarded, unless the charging infrastructure would be made publicly available, including to other firms. At the same time, it was noted in the interviews that ENOVA's application process has been greatly simplified and now only requires submitting details on the investment cost premium, annual mileage, and firm details. The ownership requirement (rather than leasing) has also been changed into a simplified application system, so that it has become possible to receive subsidies also for BE-trucks that are leased.

3.4 Operation and experiences

As seen in Table 2.1, the first series-produced BE-trucks were put into operation by the interviewed firms between summer 2020 and April 2021. This entails that the interviews covered experiences from a limited period, albeit with full operation for most of the firms. This section first discusses how the firms previously operated their conventional diesel trucks (operations and use pattern), how the BE-trucks trucks were intended to be used and how they are used in practice, and whether the firms made or were forced to make operational changes for battery-electric operation to be feasible. This is followed by a discussion of experiences and feedback from operation.

3.4.1 Application and use pattern for battery-electric vs. conventional trucks

One of the distributors states that the transport assignments they will use their BE-trucks on, are usually carried out by diesel trucks with annual mileages of between 50-60,000 km. The BE-trucks are intended to be driven ca. 50,000 km/year, given one-shift days without fast charging. To make this possible, transport routes had to be somewhat adapted, but other than this, the BE-trucks form one-to-one replacements of the distributor's diesel trucks. It is expected that access to a fast charger should make it possible to operate two shifts a day, and significantly higher annual mileages. Further, it is noted that for the transport

[4] It was further noted that many countries employ similar and sometimes also higher subsidy rates (up to 50% of the cost premium), with examples including Sweden (Klimatklivet) and a similar financial support scheme in Germany.

assignments the BE-trucks are used on, the lack of a towbar is not a big challenge, as trailers are only used on longer routes, such as e.g. Oslo-Sandefjord/Fredrikstad/Rudshøgda. Such distances could potentially be operated with BE-trucks, but on longer-haul transport between Norway's largest cities (Oslo-Kristiansand/Stavanger/ Bergen/Trondheim), rail transport is used extensively.

One of the other distributors primarily uses 3-axled diesel trucks for distribution driving, with annual mileages of ca. 50,000 km. Around Oslo, diesel trucks are usually operated around the clock, using three shifts, while in other regions, operations are carried out in 1-1.5 shifts. On longer distances, the firm's diesel trucks are driven with a trailer. The firm's BE-trucks, however, will initially primarily be used for urban distribution transports, although one of the trucks is used on slightly longer routes with distribution transport to Oslo. For the latter, the truck's range is sufficient to provide a one-to-one replacement of a diesel truck. The BE-trucks are operated for two shifts per day, with an aim to increase this to three shifts. In Bergen, however, only a small proportion of the firm's distribution routes can be driven with BE-trucks, because there is less city center distribution, while Bergen's topography is also more demanding than Oslo's. On longer routes, where the firm uses trailers on most of their trucks, one-to-one replacements are not yet feasible, meaning that the BE-trucks have a somewhat less flexible scope of application.

The third distributor states that with the phasing-in of BE-trucks, operations were changed. This makes it difficult to compare the performance of battery-electric and diesel trucks. The firm established a city center terminal, where deliveries from a main terminal at Alnabru, Oslo, are delivered. The objective behind this city center terminal was to allow for the phase-in of electric freight bikes and vans for distribution transport of parcels, while pallet freight and larger shipments are distributed by truck. This entails that where the firm's trucks were previously used on fixed routes, operation is now optimized day-by-day, depending on the freight volumes that are to be delivered. The BE-trucks are intended to be used ca. 250 days/year and for ca. 100 km per day, i.e. for an annual mileage of around 25,000 km. The trucks are largely driven in one-shift operation and usually do not make it back to the terminal during longer breaks. When fast charging is introduced, the trucks will be used over multiple shifts per day.

For construction trucks, it is somewhat more complex to compare usage patterns between diesel and BE-trucks, because usage patterns vary widely. One contractor typically uses its conventional trucks in one-shift operation, 8 hours per day, and ca. 230 days per year. However, operations vary, with trucks that are used a lot but with relatively short daily mileages, to trucks that drive 10 hours a day and cover 600 km. The firm's BE-trucks have so far only been used in Oslo and for lighter construction transport assignments during daytime. The trucks drive to/from construction sites and disposal sites and are only incidentally used for slightly longer trips. This is due to the fact that such operation fits in well with the municipality of Oslo's procurement incentives of later years, towards which the firm replaces transport within Ring Road 3 with electric operation, while using diesel operation on longer routes. The firm states that 3 BE-trucks have replaced 7 diesel trucks in Oslo's city center, because construction masses are driven to an intermediate disposal site at Ulven. From this site, the firm uses diesel trucks to drive masses out of Oslo and to final disposal sites, while some treated and cleaned masses are driven back to construction sites in Oslo using BE-trucks. This entails that the firm has made some adjustments in its operation in relation to the phase-in of BE-trucks.

The other contractor also states that driving patterns for BE-trucks are somewhat adapted compared to normal operation. The construction trucks usually perform transport of both masses and goods at very low average driving speeds in Oslo, and drive to landfills some distance away from Oslo. For the BE-trucks, operational routines have been adapted somewhat, because they have to be charged during the lunch break (see separate section). For construction trucks operating in the inner city, time used for loading and unloading is the dimensioning factor, meaning that construction trucks on average only drive short distances in the course of a day (the same applies to this type of operation using diesel trucks). Also this firm's BE-trucks are used for transport to intermediate disposal sites in Oslo, rather than transport to the final disposal sites.

Based on the usage patterns described above, it was noted that there are both factors in favor of, and against battery-electric operation of construction trucks, some of which are specific to Oslo. In Oslo, digging is very time-consuming due to the many cables and water and sewage networks. This means that mass extraction volumes per day are substantially smaller than for projects outside of Oslo, which in turn entails less mass transport per truck per day. These characteristics can contribute to making electric operation a feasible alternative faster. At the same time, equipment in Oslo is generally poorly utilized also for other reasons, including Oslo's geography and time constraints in relation to when and where noisy equipment can be used. These low utilization rates for equipment in Oslo decrease the savings potential in the operational phase of BE-trucks, yielding longer payback times for the trucks' initial investment costs. An advantage of BE-trucks is that they generate much less noise, and thus in theory could be used also during hours of day that conventional trucks cannot. In practice, however, this potential is limited because most of the construction works that the trucks depend on (also the BE-trucks), are inherently noisy. Another factor that was pointed out was that disposal sites and terminals for the construction industry are pushed further out of the city, while electric operation makes it important to be closer to the city center (where construction works with requirements for zero-emission operation are located), as this reduces energy consumption for driving between the landfill and construction sites.

3.5 Energy consumption

Overall, feedback from the interviews indicates that the BE-trucks have a low energy consumption in practice, and thus can yield large energy savings compared to diesel trucks. However, direct comparisons are challenging due to the changes in usage patterns the firms made, differences in what electricity is used on (in addition to driving), and the lack of sufficiently detailed data. Energy savings from battery-electric operation can translate into significant cost savings, but the size of these savings is again dependent amongst others on the extent that fast charging is used, and at what rates.

The interviews further reveal that energy consumption varies considerably, dependent on the types of transport assignments and driving that the trucks are used for. This, in turn, has implications for the trucks' driving ranges (see separate section). The truck supplier for example states that some trucks and transport assignments may have an energy consumption of less than 1 kWh/km, while for others, this can be nearer 4 kWh/km (e.g. waste collection with many starts and stops). As a rough estimate, the supplier states an average energy consumption of 1.25 kWh/km.

Feedback from the firms appears in line with this, and Table 3.1 summarizes examples of electricity consumption for different trucks at the different firms, which are then discussed in greater detail. Also for these examples, it is important to note that energy consumption can vary much, depending on what the trucks are used for, and where.

Table 3.1: Examples of electricity consumption for different trucks at different operators. Electricity consumption is highly dependent on what the trucks are used for and where they are driven.

Firm	A		B	C		D
Truck type	Fuso e-Canter, truck with closed chapel	MAN/Scania, trucks with closed chapel	Scania, closed chapel (with cooling unit)	Fuso e-Canter, truck with closed chapel	Volvo, truck with closed chapel	Volvo, construction truck
Energy consumption (kWh/km)	0.5-0.6	1.0-1.2	1.5-2.0	0.82	1.0-1.4	1.3

For the Fuso e-Canter trucks, the firms state an energy consumption of between 0.5 and 0.82 kWh/km. Here, it should be noted that the Fuso e-Canter is a small truck and that the version (‘Prototype 1/2’) and usage patterns are somewhat different between the two firms using this truck type. It was further stated that electricity consumption can be particularly low for driving in some areas in Oslo’s inner city (in which one of the firms operates) and that compared to diesel trucks, electric operation is particularly energy effective in urban areas with many starts and stops. However, the firms were unable to provide comparable energy consumption values for diesel trucks with similar usage patterns, due to the changes in usage patterns in relation to the phase-in of their BE-trucks.

The battery-electric MAN and Scania trucks at one of the distributors are stated to use ca. 1.0-1.2 kWh/km, while the Scania trucks at the other distributor are stated to use between 1.5-2.0 kWh/km (but this includes energy consumed by the cooling unit). The Volvo trucks at the third distributor use between 1.0-1.4 kWh/km.

For the construction trucks, the type of operation they are used for appears particularly important. Both contractors state that diesel consumption can vary much because of different needs of different projects. To illustrate, one of the construction firms states that from experience, diesel consumption lies at between 0.25-0.41 liter/km, but did not yet have good quality data on comparable figures under battery-electric operation. The other firm states that a project-dependent estimate for diesel consumption lies at between 0.46-5.0 litres/km, and that the BE-trucks have had an average energy consumption of ca. 1.3 kWh/km. In this context, the firm also noted the importance of the type of driving. For example, the BE-trucks do well in urban transport, but driving ranges fall rapidly when the trucks are used at higher speeds on the highway.

The truck supplier, in turn, reports that technological developments take place rapidly, with one example being improvements in energy regeneration while driving. The supplier also points out that even though 1st and 2nd generation series produced BE-trucks might be less than one year apart, the difference in driving ranges and energy regeneration is noticeable.

3.6 Battery capacity and driving range in practice

Here, the trucks' battery capacity that was summarized in Table 2.1, is described in greater detail, and related to driving ranges and energy consumption in practice (noting some uncertainty regarding this).

For the Fuso e-Canter with a battery capacity of 80-85 kWh (i.e. the trucks designated as 'Prototype 1'), no specific range is specified. For 'Prototype 2', the distributor states a range of ca. 100 km.

The battery-electric MAN truck with 185 kWh battery is stated to have a range of 120 km, where it is pointed out that this range is negatively affected by the hydraulic tail lift consuming a lot of energy. The Scania trucks from the same distributor, with 270 kWh batteries, are stated to have a range of 200 km at best.

The Volvo trucks, with gross battery capacity of 200 kWh, are reported to have a range of 140-170 km in practice. This agrees well with information that the distributor received from Volvo itself. The range is reported to be somewhat affected by the outdoor temperature. The Scania truck at the last distributor, equipped with a 300 kWh battery, is stated to have a range of 150-200 km, where it is noted that the battery also supplies power to the cooling unit.

For the construction trucks, one contractor reports a nominal/stated range of 150 km (for a 'Gen1' battery of 200 kWh). In practice, the range varies a lot with the type of driving and weather conditions, and during the coldest period in winter, the driving range fell to ca. 60 km. The construction firm keeps the batteries warm using the battery-heaters provided in the trucks, but states that it is possible that the large driving range reduction during winter may be related to the battery heater not working properly or the trucks not being charged all the time. The other contractor reports that the range of the 'Gen2' battery of 260 kWh officially lies at 200 km, but that this seems optimistic and may be achieved only under very favorable circumstances. In practice, the firm's experience is that driving ranges are shorter. However, the firm typically looks at 'up-time' in terms of operating hours, rather than distance travelled. At the same time, the firm reports that 'Gen2' trucks can go ca. 1.5 hours longer than 'Gen1' before they have to be charged. It is further mentioned that the trucks are equipped with a 9 kW battery heater, which means that some energy is used for heating in the winter. Despite a relatively cold January in 2021, the firm reports that operation largely went well and that the trucks have not stranded because of battery depletions.

The interviews indicate that there are some differences in driving ranges between summer and winter, but that these are not necessarily very large when batteries are kept warm. In addition to the above, one of the distributors comments that there do not seem to be large differences in range unless the cargo space needs to be heated, while one of the other distributors points out that their experiences are relatively robust, in that they are based on a stable and long period with winter operation. The firm adds that a possible explanation for them not having experienced any particular differences in driving range, might be that trips driven with the trucks are relatively short, that the trucks are charged during the day, and that they are mostly kept warm given that they are operated for 2 shifts a day also during winter.

In comparison, one of the distributors notes that for (smaller) battery-electric vans already in use at the firm, they cannot assume more than 50% of the stated range when planning routes due to the frequent stops and drivers getting in and out of the van. This entails substantial energy consumption for heating/cooling every time the driver opens the door. For the trucks, however, the firm expects to be able to plan routes assuming driving ranges closer to those specified by the manufacturer, amongst others because trucks make fewer stops and heat losses in the driver cabin will be much lower.

3.7 Technical and operational challenges

The firms we interviewed experienced varying degrees of technical/operational challenges. One of the distributors did not experience downtime and has mostly been operating without problems. A first-time service was mostly carried out to check that everything worked as intended. One of the other distributors experienced some minor issues in the start-up phase, but these were quickly resolved by the supplier. The third distributor reported that operation of one of the truck models has largely gone without technical challenges, but that there have been problems with one truck of the other battery-electric model that the firm operates. The truck in question has had two outages and two incidents where it became 'completely locked'. These faults were believed to be due to software errors and problems have persisted even after the truck was transferred to another geographical area. The firm's other BE-trucks of the same model have functioned significantly better.

For construction trucks, one of the contractors experienced downtime on its very first BE-truck ('Gen1'). The cause was identified to be a faulty contact point and is believed to be starting difficulty with the new technology. This downtime occurred 5 months after the truck was commissioned, and took extraordinary long time to resolve because technicians from abroad could not enter Norway due to Covid-19 traveling restrictions. The firm further experienced some challenges with hydraulic pumps of the superstructure, related to the electric trucks providing maximum power at once, where diesel trucks do this more gradually. More generally, the contractor noted that very cold weather can be a challenge for hydraulic systems in general (regardless of whether operation is diesel- or battery-electric-based), but that for the BE-trucks, things have generally gone well. The other contractor experienced some challenges with the air suspension at the front end of the truck, but believes that these challenges could just as well have occurred on a diesel truck. One of the battery-electric construction trucks has spent some time in the workshop, and problems have mostly been software-related. After an upgrade, this particular truck is reported to have worked better.

3.8 Service and maintenance

In terms of service and maintenance, both generally and in case of acute problems, the firms also paint a somewhat mixed picture. Feedback included that BE-trucks have higher service costs than similar diesel trucks and that an impression existed that suppliers were earning on this. Concrete rates that some of the firms reported for service agreements that had been offered or entered into, seem to confirm that service costs for BE-trucks, at the time of the interviews, were around the same level or somewhat higher than for diesel trucks. A challenge pointed out by one of the contractors is that, even when assuming that battery technology is sufficiently proven and a conservative charging strategy is applied, physical damage to the batteries remains the greatest risk, but is not covered by service agreements.

Further, it is pointed out in the interviews that BE-trucks have many fewer moving parts and do not require changes of oil, belts or filters, or only require oil changes on the back axle and grease on some remaining components. Several of the firms therefore express that they expect service agreements to become significantly cheaper in the future, than those for diesel trucks. Also in the scientific literature, it is often assumed that electric trucks offer a potential for significantly lower service and maintenance costs (see, for example, Hovi et al., 2019). From the supplier's side, it is pointed out that even when service costs for BE-trucks are set equal to those for diesel trucks, this would currently not cover the costs of such service. It is also pointed out that comparisons between electric trucks and electric passenger cars do not fully hold, as trucks have many more systems that need to be maintained. Service agreements can also fully cover wear and tear and 'end of life' for batteries (when the energy storage capacity of the battery falls below a certain limit, usually about 80% of full capacity), during the entire contract period of the agreement.

Other feedback on the firms' experiences with service offerings was of a more practical and operational nature. For example, it was mentioned that there were geographical restrictions with regard to where BE-trucks can be used, depending on where truck suppliers have rolled out service and follow-up in their dealer networks. For example, manufacturers may choose to certify workshops for electric trucks based on when and where trucks are sold. Feedback was also provided that there is a need for improved mechanics training for workshops in Norway. One of the firms noted that it cooperated with the truck importer to clarify how service and follow-ups can be organized when the firm wants to test BE-trucks at new locations.

Further, it is pointed out that immediate problem resolution in case of problems is critical, because the operators do not have spare capacity for their BE-trucks, and generally need to utilize them well. As mentioned before, expectations on whether suppliers are able to deliver such service has in some cases influenced which supplier was chosen. Nevertheless, even with larger suppliers, problem resolution has in some cases taken a long time and is something that several of the firms are continuously discussing with their suppliers.

As previously noted, the component in BE-trucks with the potentially largest financial risk is the battery itself. The distributors, for most of their BE-trucks, have warranties that the battery will have a certain remaining capacity (as for passenger cars). The length of these warranties varies somewhat between supplier and truck type, but lies around 8 years. It is further stated that suppliers have slightly different approaches. For example, some suppliers are more conservative with the so-called SOC-window (State-of-Charge), i.e. how much of the battery's total capacity can be used without compromising on keeping a decent battery lifetime.

For construction trucks, one of the contractors reports that the warranty on their batteries is 2 years. This limitation is probably due to construction trucks being a new area of use on a chassis made for distribution trucks. This yields uncertainties due to e.g. vibrations at construction sites. The other contractor did not state its warranty arrangements specifically, but considers that the batteries should last for 7-8 years as the technology is reasonably well-proven and because the firm employs a relatively gentle charging strategy (see separate section).

3.9 Drivers, training, use experience, interest from society

Several of the firms largely use their own drivers with fixed contracts to drive their BE-trucks. A reason behind this is that driving electrically requires a little extra and is new (e.g. focus on energy consumption, driving style, etc.), and that it helps to have motivated and enthusiastic drivers for this. Further, it is desirable that drivers have a certain ‘ownership feeling’ for their truck. Having their own, permanent, and dedicated drivers also helps the firms build up experience internally.

Most of the drivers received training/courses from the truck suppliers, but several firms note that these arrangements have not been good enough. This is partly due to challenges as a result of Covid-19 (where training sessions had to be given by other employees than the ones with most in-depth knowledge), but also because training was relatively limited, with many elements being new also for the suppliers themselves. Examples given by the firms included relatively little training when trucks were commissioned and the need for more knowledge when drivers start using the trucks, e.g. regarding recharging the batteries and on how to get the most out of the trucks. Similarly, for everyday challenges, drivers have given feedback such as ‘why has no one told me this?’. One of the firms would like to see an online safety course and in part approaches driver training by letting one of the drivers with good knowledge of all the trucks, guide other drivers. Another firm has hired a driving school to help with ‘eco-driving’, regardless of whether trucks use diesel or electricity. The firm reports that this appears to have had an effect and that energy consumption seems to be decreasing. However, a practical challenge in this regard is that it is easier to keep track of the filling of diesel trucks, as this is connected to the truck number, than for BE-trucks, for which such administrative linkages still need to be tailored.

Generally, the firms report that drivers are very happy with the trucks. The drivers say that the battery-electric distribution trucks at the different firms are nice to drive, often well-equipped, are rather silent, do not vibrate much, and don’t emit exhaust fumes. The firms state that this is greatly improved the working environment and has increased driver satisfaction. Also for construction trucks, drivers give feedback that the trucks are much more silent, nice to drive, and have improved their working environment. While noise was not a significant factor in phasing in BE-trucks, one of the contractors states that the noise reduction has been surprisingly large. In practice, this makes communication at construction sites much easier. At the same time, people working at such sites have to be a bit more careful because it is not as noticeable that a truck is approaching as it is for conventional trucks. Also from society in general, positive feedback has been received about noise reductions.

For the contractor using ‘Gen2’ electric trucks, feedback is that they work well and that improvements from ‘Gen1’ to ‘Gen2’ are noticeable. One of the contractors is positively surprised by the trucks’ efficiency and that they manage the operating pace that is expected at construction sites. The firm states that in many cases, productivity has increased, as project require fewer trucks. It is emphasized that it has been positive both for the firm and the market overall, to see an alternative solution working well under real-life conditions.

The different firms report that the BE-trucks generate attention, have aroused interest from the press, and are also used in marketing, to some extent. For some of the firms, dedicated drivers have also featured in media reports. It is further reported that the value of quieter transport in the surroundings of construction sites has not gone unnoticed. At the same time, it has been noted that in some cases it has been striking that the client ordering the construction work in some projects, has shown little interest.

3.10 Load capacity and limitations

Batteries are heavy, and all distributors indicate that this leads to a loading capacity reduction compared to similar diesel trucks. For example, the Fuso e-Canter trucks can lose around 400 kg (out of a payload of 2,600 kg), while the Volvo trucks (with a payload of 5,500 kg and registered for a maximum total weight of 16.7 tonnes) lose around 700 kg in loading capacity. Meanwhile, the Scania trucks' 3 tonnes of batteries reduce their loading capacity by ca. 2 tonnes.

However, the distributors do not experience these reductions in loading capacity to yield many restrictions in practice, as it is volume, not weight, that constrains capacity on the large majority of their transport assignments. Furthermore, it is pointed out that zero-emission trucks are given a higher total weight allowance by the authorities, to counteract the disadvantages of buying (heavier) zero-emission trucks. The increase in total weight allowance depends on the truck's characteristics and varies between 1 and 2 tonnes. In practice, the distributors have not bothered with increased total weight allowances as weight is not a problem, neither will it make much practical difference whether they are allowed 1 or 2 tonnes extra weight[5].

Although weight capacity in itself is not perceived as a problem for the operators of battery-electric distribution trucks, several other challenges related to batteries and loading capacity are highlighted. When one of the firms investigated the possibility of a larger battery (of 300 kWh) with a truck manufacturer, this was not feasible in practice, because it would reduce the remaining loading capacity on the front axle too much. A similar challenge is reported for BE-trucks from another supplier. To illustrate this, one firm explained that for 16 tonne trucks, a load distribution of 6 tonnes on the front axle and 10 tonnes on the rear axle is common. In this context, the firm also referred to MAN, which produces electric vans with flat battery packs that are spread out under the entire truck. This provides a more even weight distribution, and corresponding changes in the chassis design of distribution trucks could therefore be more desirable as well, according to the firm. The NPRA, in the same context, explained that truck manufacturers fill batteries from the front, and work their way to the back of the truck. This gives a lot of weight and axle load at the front of the truck. For 3-axled trucks, which are common in Norway due to their better suitability for winter driving conditions, it can be a challenge to find sufficient space for the batteries. This is also noted by the truck supplier. When solutions require either longer trucks or longer distances between the axles, this presents challenges with current regulations on a truck's turning radius (17.5 meters) and maximum truck length, as well as other practical challenges. The

[5] In addition to the fact that the truck itself must be approved with a max. allowed total weight, and for which the NPRA states that Norway follows EU practice (which it has to, in accordance with the EEA agreement), the truck must be approved for the roads it is to be used on. Here, Norway may have stricter requirements and restrictions than those contained in the trucks' type approval, in order to take into account that trucks can become too heavy for use on Norwegian roads/bridges.

NPRA also pointed out that Norway differs from many other European countries in that heavy trucks can drive in cities. This makes focus on and strict requirements regarding a truck's turning radius particularly important. In addition to turning radius requirements on trucks, there may also be turning radius requirements on specific roads. Therefore, it is important that (battery-electric) trucks are not sold as being 'suitable by default'. However, it is conceivable that in the future, conditional permissions for parts of the road network could be given to BE-trucks.

For construction trucks, reduced loading capacity due to the weight of batteries has not posed large challenges either. One of the contractors notes that the increased total weight allowance has actually increased the truck payload by 500 kg, while the other contractor states that the payload is slightly lower than for comparable diesel trucks, but that this difference is hardly significant. In practice, it is rare for the loading capacity of construction trucks to be fully utilized, so that the relatively small changes in payload, due to battery weight, do not typically set constraints. It is also noted that the chassis (without batteries) on BE-trucks is often a little lighter than for conventional trucks. Examples for which it is noted that some extra loading capacity would have been desirable, include when construction trucks are used to transport some types of construction equipment/machinery.

The interviews further indicate that the weight distribution of the batteries is not the largest challenge either, but that that the batteries do pose some constraints on the types of construction sites the trucks can be used at. This is because the batteries are expensive, and are installed underneath and on the side of the trucks. In order not to damage them, the firms are a bit more conservative in setting requirements to e.g. construction site surfaces.

3.11 Charging infrastructure

3.11.1 The firms' operational approach to charging and various considerations

The Scania truck of one of the distributors was delivered with a 25 kW portable DC charger. This is sufficient to charge the truck overnight and for use on one shift. Unlocking the truck's full potential, however, would require 100-150 kW chargers. The firm states that, due to this, they will probably set up a separate fast charger, but that the truck's battery system (750V) adds a slight complication. This also entails that the truck cannot use all external fast chargers either. The firm's Fuso e-Canter and MAN trucks are currently also being charged using a portable charger.

One of the other distributors always charges at the depot, where the Scania trucks are fast-charged for 30-45 minutes during the working day, in addition to slow-charging at night. The chargers that are used can provide 180 kW. In practice, charging is constrained by the Scania trucks being able to receive only 120 kW. However, the chargers do allow 2 trucks to be charged in parallel, with 2x 90 kW. According to the firm, battery capacity after a first round of deliveries is usually 35-40%, and half an hour with charging brings this up to ca. 80%. Currently, the firm uses one charger per 2-3 trucks. It is noted, however, that the need for charging infrastructure is highly dependent on the extent to which trucks charge simultaneously, and that smart planning and spreading of charging can significantly reduce the costs for charging infrastructure (see separate section).

The third distributor currently has 9 chargers of 22 kW AC at its depot, where trucks are charged at night, and may get some maintenance charging during the day. This is usually sufficient for the firm's existing operating schedule (with 1 shift). The depot will be upgraded to contain 1 charger giving 150 kW, 3 full-effect chargers yielding 22 kW AC, and 14 dynamic chargers giving 22 kW AC, where the power of the latter is adjusted dependent on the number of trucks charging. The depot upgrades take place with financial support from the municipality of Oslo. Because the firm's Fuso e-Canter trucks have a maximum charging capacity of 50 kW, these trucks will only be able to utilize part of the available power when using a fast charger.

The truck supplier outlines that most BE-trucks have a built-in AC charging capacity of 22 kW for the smallest trucks and 43 kW for the largest. Fast-charging is possible with 150 kW CCS, or 250 kW for newer trucks. The supplier expects the CCS standard to remain, and capacities between 250 kW-1 MW to become more standard in the future.

For the construction trucks, one of the contractors tries to fully charge trucks (to 100%) as much as possible, during nighttime, using normal charging (22 kW AC) with the trucks' on-board charger. During the day, battery capacity is topped-up using fast-charging. This is typically done during the lunch break, of around 45-50 minutes, and usually at chargers at Circle K facilities, using 150 kW chargers. In a pilot project, the construction trucks are sometimes also charged using a boost charger/powerbank at a construction site. This is a 20-foot container with batteries weighing approx. 11 tonnes, providing 150 kW charging, or 2x 75 kW. At the construction site where this pilot is carried out, the charger is also used by 2-3 electric excavators. Due to this and to optimize utilization of all equipment, the operating time of the site has been increased from the originally planned 4 days per week to 5 days per week. In general, the firm states that when using fast-charging, trucks are never charged to more than 80% of full capacity.

The other contractor also preferably charges its battery-electric construction trucks at the depot, during nighttime. Here, it uses an industrial contact (400V; 22 kW AC), which is sufficient to fully charge the truck. This contractor too, 'tops up' by fast-charging at Circle K facilities during lunch breaks. The firm reports that 'Gen2' of the construction trucks provides somewhat more operational time in the morning before charging is needed, compared to 'Gen1'. Charging at construction sites is currently not considered an option by the firm because it requires too much electricity.

With today's operation, electricity used for charging either comes directly from the grid, or (in part) from energy that some firms generate themselves, e.g. using solar or wind power, or a larger battery that allows charging in periods when all available grid capacity is in use. It is pointed out that electrification of the truck fleet will increase the need for electricity, whether this is self-produced or comes from other sources. In the pilot project with a 'boost charger', electricity is sourced via a large transformer nearby, with the battery bank acting as a buffer against the grid. Due to the dependence on sufficient capacity in the electricity grid/transformer, using boost chargers will not be possible everywhere in Oslo[6]. The boost charger can be equipped with solar cells to cover some of the power needs.

[6] At the time of the interviews, a pilot was being prepared where a container with fuel cells charges a battery, which in turn supplies fast chargers. This can be built as plug & play. The advantage is mobility and that electric

3.11.2 Costs for charging and investments in charging infrastructure

An advantage of BE-trucks is that their drivetrains are much more efficient than for internal combustion engines, and that the energy source (electricity) is relatively cheap. This combination therefore offers a large savings potential for energy/fuel expenses. When the trucks are charged through slow charging at a depot, preferably overnight, and both the grid capacity is sufficient and the charging covers most of the trucks' energy needs, both the charging infrastructure and electricity costs are low. This is different when grid upgrades are required, when there is a need for fast chargers, or when external fast chargers are used extensively.

With external fast charging, which some of the firms use, the costs per kWh are several times higher than the kWh price for slow charging in depots. In practice, several of the firms believe that fast-charging is too expensive, and that this is due to power tariffs being dependent on the maximum effect that is used, and a very short depreciation period used for charging infrastructure (2 years in practice, where one interviewee believes this should be 6 years). One of the firms believes that it is generally unsustainable to pay more than NOK 2/kWh for electricity for commercial transport in the current situation and therefore wants to operate fast charging itself (although it should be noted here that interviews took place before surges in both diesel and electricity prices in 2022). The firm also said that it had received an offer corresponding to a price of almost NOK 8/kWh for external fast charging. In practice, the firms that use external fast charging pay much less than NOK 8/kWh, but more than NOK 2/kWh, and often get sizable discounts compared to prices listed for other users.

For firms that invest in charging infrastructure themselves, and in particular fast charging, investment costs are situation-dependent and vary with the solution that is chosen. Generally, however, costs are significant. In the interviews, examples are given that for 150 kW fast-chargers, the charger itself costs ca. 0.5 million NOK, and if the charging capacity is split up for use with up to 3 trucks (extra charging connections), this costs an additional 0.2 million NOK per charger. Roughly speaking, fully installing a charger, including excavation work etc., can cost around 1 million NOK. Another firm states that a simple fast charger (with 1x 150 kW or 2x 75 kW) can easily cost 0.8 million NOK, excluding network upgrades and installation costs. This firm too, gives a rough estimate of 1 million NOK per fully installed charger. When establishing chargers requires upgrades to the electricity grid, this can additionally trigger a construction fee, based on the 'first-come-first-served' principle, where it is the actor needing additional capacity at the margin that has to pay for upgrades. This principle is perceived as very unfair by some of the firms. Examples were also given of it being necessary to upgrade transformers or install new cables to the firms' own facilities, which can also be very expensive[7]. Again, costs are situation-dependent, but one of the

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operation can potentially also be made possible in places where the electricity grid does not have sufficient capacity. Another potential advantage that is stated is that the container can be moved at the construction site. Excavators at today's zero-emission sites often use 6-8% of their battery capacity just to reach the boost charger, and similarly, on their way back.

[7] One of the firms had to perform such an upgrade. This cost ca. 1.5 million NOK and includes the need for (upcoming) 15 regular chargers for vans (22 kW) and a future 150 kW charger. Trucks will also be able to use these 22 kW chargers for overnight charging.

firms states that the upgrade costs for the transformer (to allow for 10 fast chargers) lie around 1 million NOK, excluding excavation. The firm also states that using a boost charger at a construction site entails sizable costs, even if the contractor does not own this charger themselves in this particular case.

3.11.3 Other challenges

Feedback from the firms indicates that high costs for charging infrastructure form one of the biggest challenges and that this creates a 'chicken-or-the-egg'-situation. In order for investments in BE-trucks to make sense, sufficient infrastructure must be available or both financially sustainable and practically possible to establish by the firm itself. Today, this leads to major barriers.

For investments in charging infrastructure to be financially sustainable, the number of trucks that costs effectively can be divided over, is a very important factor. This applies both in terms of route planning given that the trucks must be charged during the working day, and how the charging must be adapted so that the charger can be used by as many trucks as possible during the day to get the most optimal operation of both trucks and charger. For example, a firm may have space for a fast-charger at its own facility, but the question is whether the location is used by a sufficient number of trucks to make this financially sustainable. Particularly for construction trucks, it is also pointed out that these are very stationary and drive relatively little, while much of the savings potential, also for investing in chargers, lies in savings on energy costs.

Another important factor is whether public support is provided for establishing charging infrastructure, or whether the public sector takes care of such establishment (e.g. the municipality of Oslo). With regard to financial support from ENOVA, the firms pointed out that subsidies towards charging infrastructure are only awarded for chargers that are made available to other parties as well. This is usually not an option at the firms' own terminals, both for reasons of safety and space. It was further pointed out that one can get support towards a 11-22 kW AC charger per truck, but not towards larger investments in charging infrastructure or towards necessary grid upgrades. The construction firm that uses the boost charger on the construction site states that after a rule change, ENOVA could no longer provide financial support towards such chargers, and that this was decisive for the firm choosing not to purchase the boost charger itself. The boost charger is instead owned by a utility company, where part of the pilot agreement entails that the utility company receives access to a lot of data.

In addition to financial challenges and the requirement of making chargers available for others in order to be eligible for subsidies, the firms also point to other barriers. For several firms, for example, insufficient space at their own facilities is a challenge, while uncertainty about whether lease or rental agreements will be extended makes it risky to invest in charging infrastructure and grid upgrades. When establishing charging infrastructure requires grid upgrades, administrative processes with the grid managers are often slow, and it takes a long time before grid upgrades are carried out.

Regarding external fast charging, it is noted that trucks cannot use all public charging stations because the trucks are too large or too high, or they have to park in a way that renders the charging cable too short. Trucks also easily take up several charging spots for passenger cars, which already leads to challenges and sometimes conflicts. In the long run, when BE-trucks will be driven with trailers, this will set large space requirements at charging stations.

Several of the firms also note that daily operations make it difficult to charge along the way, because this entails that trucks cannot be used effectively. At the same time, charging at ramps, for example, is often challenging, since places for loading and unloading are often scarce and time at ramp spaces must be minimized. Similarly, one would need to have charging possibilities at dedicated ramps, as diesel trucks still dominate. The firms also note that availability of fast-charging in public areas would help, especially outside the cities, but that a barrier to using them would exist when this would entail detours. It is also mentioned that public charging stations must allow time slot reservations, because transporters operate with carefully planned routes, schedules and service agreements, and therefore cannot risk waiting in charging queues.

Several of the firms state that they convey their needs to the relevant authorities and that there is a lot of political will, but that there could have been more action, and that things often take much time. It is also believed that the public sector must be a major driver for the establishment of charging infrastructure. One example given is a case in which the City of Oslo was going to establish charging infrastructure at Filipstad, where the large freight forwarders Bring, DB Schenker and DHL have established hubs, but that the Port of Oslo was afraid that this would increase traffic.

3.11.4 Alternative ways of charging

In the interviews, the firms were asked whether they were involved in or looking at alternative ways of charging. This was the case only to a small extent. One of the distributors reported it would test conductive automatic stationary charging with a physical charging rail in the ramp’s surface. Induction charging was not tested, but believed to be interesting, amongst others because it would make the clearing of snow easier and not require cables around the trucks. Battery charging via overhead connections has not been specifically assessed, but it is commented that because the distributors, unlike public transport (e.g. buses), do not have fixed stops, this is difficult: Although one knows the general area that is served, one does not know how deliveries differ from one day to another. Further, it was commented that catenary charging may be relevant on roads with much traffic.

4 Future prospects

4.1 Incentives, challenges and policy suggestions

As part of the interviews, the firms were asked to comment on the current framework conditions and incentives for the phase-in of battery-electric or other alternative technology trucks, and to give suggestions for future measures and incentives. This resulted in discussions of a number of themes. Overall, it is pointed out that it is important to have long-term, predictable and stable framework conditions.

4.1.1 ENOVA-subsidies

As mentioned before, the firms consider ENOVA-subsidies to be crucial for investments in zero-emission technology to be considered at all, even though the subsidies on their own are not enough to yield sustainable operation. The firms emphasize that it is important that the ENOVA-subsidies remain and that it is important that these framework conditions are long-term, predictable, and set up appropriately. Amongst others, the firms point to administrative requirements such as those regarding ownership vs. leasing, minimum sizes of investment projects, the application process itself, and the transparency of this process. For some of these points, it is reported that processes have become better and thresholds lower, after ENOVA implemented a simplified application process.

One remaining major challenge, mentioned in several other places, concerns support to charging infrastructure. This goes both for the scope of financial support (e.g. type of chargers, number of chargers, maximum costs, etc.), and what the firms may have to cover themselves. The latter is particularly important because the costs of establishing charging infrastructure can become very high when firms additionally have to pay for grid upgrades. While firms are eligible for subsidies towards van chargers at their own facilities, this is different for (larger) truck chargers. To be eligible for financial support, ENOVA requires such charging infrastructure to be publicly available. As previously discussed, this is considered to be a huge barrier by the firms.

4.1.2 Road toll advantages

The distributors estimate road toll expenses for diesel trucks operating in Oslo/the Oslo area at between NOK 7,000-10,000 per truck per month, or NOK 84,000-120,000 on an annual basis. This is in line with a rule of thumb mentioned by the NPRA (ca. NOK 100,000 per year per truck). The distributors consider road toll expenses to be a very important determinant of truck TCO (total costs of ownership), given current cost levels for trucks, energy prices, and ENOVA-subsidies.

At the time of the interviews, electric vans with a total weight up to 3,500 kg and trucks were fully exempt from road tolls in Oslo (and still are). According to one of the distributors, this is crucial for BE-trucks to be considered a feasible alternative. For the contractors, road toll exemptions are less important, because toll expenses are passed on to customers, albeit with some limitations. Further, feedback is given that road toll advantages are an incentive yielding significant savings both for electric vans and trucks. The firms also note that they perform much driving through Oslo's toll rings and that with today's diesel operation and 'hour rule' (multiple passages within an hour count as one), it is difficult to make cost estimates for tenders. In all, however, it is clear that toll expenses amount to significant sums. Recurring feedback concerns the importance of stable and predictable framework conditions. Should toll benefits be reduced, this could result in significant additional costs for electric trucks that have already been purchased, and thus entail a risk that the trucks will neither be used nor have much value on the second-hand market. Several of the firms point out that when road toll advantages are a decisive choice factor, but are not perceived as being predictable, this can mean that alternative technology solutions are not chosen because they entail too great a (financial) risk.

The NPRA notes that it cannot guarantee that today's road toll advantages will remain in their current form, because these are subject to political decisions, but notes that Norway has kept incentives for electric passenger cars for a long while. This suggests that road toll advantages for trucks will not fully disappear overnight. At the same time, there are indications that also electric trucks will have to pay road tolls in the longer term, but that the political motto remains that it should be financially attractive to choose green alternatives. It was further noted that road tolls are subject to national regulation which guides how decisions at the municipality level can and cannot be made, but that this leaves room for some municipality discretion, e.g. towards so-called city-agreements ('bypakker').

In addition to road toll advantages for electric trucks, several of the firms called for toll exemptions for biogas trucks. Such advantages have been discussed for a long time and decisions have been pushed back, but in May 2021 (as interviews were ongoing), Norwegian Parliament decided that biogas trucks were to be treated in the same way as zero-emission trucks, and that from 2022, there would be a road toll exemption also for biogas trucks. The NPRA also noted that biogas operation yields net reductions in CO_2, but not in local emissions, and that this has been one of the arguments against introducing road toll exemptions for biogas trucks in city toll rings. A practical challenge, which was one of the reasons for decisions on road toll exemptions having been pushed back, is how to check that trucks run on biogas, and not natural gas. Physical controls are resource-intensive, pose practical challenges (e.g. where and how to check this), and raise safety issues. Therefore, it may be more desirable to use accounting audits and checking value chains to check that the operator has purchased and been running on biogas. The end result is that gas vehicles with a total weight over 3,500 kg will be exempted from road toll charges in Oslo, as of September 1st 2022 (Fjellinjen, 2022).

4.1.3 (Public) tenders, environmental requirements, builders' role, other aspects

Interview feedback confirms that the distributors to a greater extent serve private customers than do contractors. Here, it is noted that the former currently have less focus on, or willingness to pay for, reductions in (local and global) emissions. To achieve transport emissions reductions, some of the distributors note that it would generally be desirable to allow and facilitate a greater extent of freight consolidation, but that this would require regulatory changes, amongst others because price structures are a challenge.

The above means that environmental requirements in tenders are particularly relevant and decisive for the contractors. These emphasize that it is important that environmental requirements are structured in a way that makes it financially sustainable to offer electric/zero-emission operation and that making such offers in tenders does not entail disproportional uncertainty and risks. Regarding this, the interviewees made several comments and provided both positive and negative examples from areas where this has been relevant for the construction firms (mainly Oslo and to a lesser extent Bergen).

In calls for tenders, adequate weighting of environmental performance is essential, and the contractors call for this weighting to be increased from its current practice. It is noted that the municipality of Oslo weighs environmental performance less than price, and that while it is possible to offer a mix of technologies, this affects the offer's environmental score (where 5 points are given for electric trucks, 2.5 for biogas trucks and 0 for HVO trucks). BE-trucks have therefore been favored over biogas trucks. One of the contractors points out that it is this environmental weighting that has allowed it to offer zero-emission solutions, despite their higher costs, and that as long as electric trucks remain more expensive, such favorable treatment remains necessary. The firm also points out that follow-ups to the Parliamentary decision on treating biogas in the same way as zero-emission technologies, will affect relative financial incentives between technologies.

At the same time, the contractors report a number of challenges and risks, given how calls for tenders from the municipality of Oslo are practiced, and make suggestions for improvements. To be able to offer electric operation, contractors have to check many things. This is demanding, given that there are, on average, only 32 days between calls for tenders are announced, and the deadline for submitting an offer. An example of something that contractors have to check, is whether the power supply capacity at the construction site is sufficient. The municipality has left this to contractors to find out, meaning that all parties that consider making an offer with electric operation, will try to collect the same information from the grid manager at the same time. Further, financial risks are large when an offer is made but it turns out that electric operation cannot be carried out due to power supply restrictions. In such cases, contractors can both face high daily fines in some project and risk having to bear the cost and time required to obtain sufficient power/grid upgrades. One of the contractors made an offer with provisions that it could turn to conventional operation if it turned out that power capacity available at the construction site would be insufficient. This resulted in an environmental score of 0 and indicates, according to the contractor, which party bears the full responsibility and risks for power availability. On the other hand, examples were given of projects where daily fines were so low, that it would be profitable to offer electric operation in the tender, but to carry out construction using conventional machinery and trucks.

Another risk concerning electric operation is that this can require more space, e.g. for (access to) a charger, etc. Space constraints can generally be a problem at construction sites, particularly in narrow streets in the inner city. One of the contractors was forced to lease some extra space from the municipality of Oslo for the boost charger. This entailed a significant expense which was not included in the original offer.

The truck supplier adds that in connection with large infrastructure projects in Oslo (e.g. a new drinking water supply), the municipality does not allow biogas operation because of a higher explosions risk. The supplier believes this perception stems from experience with older technologies using compressed gas and notes that trucks using liquid biogas do not yield higher explosion risk than diesel trucks. Requirements like this can result in parts of projects that could have been carried out with lower emissions (using biogas), and for which electric operation is not yet feasible, are carried out with diesel trucks instead.

The contractors also discussed several positive examples from the city of Bergen, noting that tender processes are to a larger degree a collaboration between contractors and client, than in Oslo. Examples of this include projects where a potential for emissions reductions is calculated, and which contractors have to take into account before they submit their offer. The contractor can then earn a bonus, depending on the emissions cuts it achieves in practice. It is pointed out that such arrangements ensure that both client and contractor participate actively in the process, whilst for Oslo, it is noted that the municipality sometimes shows surprisingly little interest in projects. Another positive example given is that the municipality of Bergen considers grid capacity and balancing beforehand, together with the grid manager. As such, information is obtained in advance about the approximate energy demand and available network capacity. This is pointed out as important, because it reduces the risk that otherwise ends up with the contractor, and also makes processes more efficient.

All in all, the contractors call for more cooperation with the grid manager, client, municipality, utility company, etc., and note that to achieve zero-emission construction projects, it is essential that calls for tenders become more professional and are set up in better ways. The contractors also call for a more active role of clients with regard to ensuring sufficient space is available and with regard to charging infrastructure.

One of the contractors had a meeting with Standards Norway about standards for zero-emission construction sites. From this meeting, it appeared that the municipality of Oslo was not yet prepared to pay significantly higher prices for zero-emission operation. The contractor believed that this could become a challenge in the future because electric operation is expensive both in terms of trucks, construction equipment and charging infrastructure, even though operation itself is expected to be slightly cheaper. Given the above, the contractor expressed a hope that standards designed by Standards Norway will include requirements on what clients have to prepare before a call for tenders.

Because electric operation is still new, and much is still unknown, one of the contractors notes that it is very important to arrange for data sharing and to build up experiences across suppliers/contractors so that not all players have to reinvent the wheel themselves. The firm argues that 2025 is only a few years away, and that experience-building takes a lot of time and money, especially finding out which data are relevant and which are not.

4.1.4 Incentives tailored to where and when trucks with different technologies can be used

One theme mentioned by several of the firms concerns the advantages and disadvantages of different alternative propulsion technologies with regard to noise and local and global emissions. These characteristics can be used when designing incentives that affect the efficiency with which trucks can be used, and where, when and what for.

One example is found in giving zero-emission trucks access to public transport lanes, which several of the distributors highlighted as important reason for choosing electric operation. This is particularly true for Oslo, where this advantage yields significant time savings and more efficient transport. Similarly, it was suggested that electric trucks could be given access to dedicated loading/unloading zones. In urban areas, such measures will increase the efficiency and attractiveness of electric trucks, because it is often difficult to find loading/unloading sites close to the senders or recipients of shipments.

Another example concerns zero- or low-emission zones that are currently being discussed or introduced in several European cities. Also the municipality of Oslo has ambitious plans in this regard. Such zones make investing in zero- or low-emission trucks more attractive because it makes operating diesel trucks less efficient. One question raised in the interviews is whether certain advantages should also be given to biogas or hybrid trucks. For biogas trucks, it is for example pointed out that local emissions will remain a problem and negatively affect air quality in cities. For plug-in hybrids, one of the distributors points out that geofencing technology can be used to force trucks to drive emission-free inside city boundaries, and that it can be argued that hybrid trucks should be treated advantageously, possibly also with regard to road tolls and subsidy eligibility.

Similar to zero-emission zones, the truck supplier argues that noise requirements can become a policy measure and notes that currently, many European cities still apply outdated noise regulation. The distributors point out that a major advantage of electrification is that the trucks are quiet and can be used during times of day where this is not possible or desirable for trucks with combustion engines. This means that trucks may be used more efficiently and thus improve their competitiveness versus diesel trucks. Here, too, it was pointed out that plug-in hybrid trucks with geofencing are well-suited for transport assignments in cities, and during evening or nighttime. In addition to reductions in local emissions, an additional benefit is that shifting daytime deliveries to periods with less traffic can improve traffic safety. However, a barrier is that many customers, including public institutions, require deliveries to take place during daytime.

Also for construction trucks, quieter operation offers some advantages, but does not allow many more hours of operation. In contrast to distribution trucks, construction trucks are dependent on other equipment and activities which are inherently noisy and can only be carried out during parts of the day.

4.1.5 Need for measures aimed at small actors

The battery-electric distribution trucks and construction trucks used in Norway today, are mainly owned by larger actors. This goes for the first (converted) trucks as well as the first series-produced BE-trucks. However, the firms own few trucks themselves, and mainly rely on buying transport services from smaller transport firms. It is pointed out that large parts of the market consist of small players who own only one or a few trucks (or excavators etc.) and that for these players, it is currently not at all feasible to invest in BE-trucks or equipment. It is pointed out that small players do not have the necessary financial means to make such investments. This is reinforced by the fact that both transport and construction are industries with generally low margins. While larger firms tend to have a larger financial buffer, for smaller subcontractors it can quickly become catastrophic if trucks or equipment cannot be used for a while. The interviewed firms therefore point out that to achieve electrification of substantial parts of the truck and equipment fleet, measures are needed that address these financial barriers, as well as operational risks. In this context, the firms call for incentives and facilitation from the side of public authorities. The firms state that they themselves would like trucks and machinery of subcontractors to be zero-emission. One challenge that is raised, is that this requires contracts that are more long-term than most contracts used today. It is also noted that trucks of subcontractors, in certain geographical areas, might be able to charge at the hiring firm's facilities, but that there is a need for solutions in other areas and when it is not economical or feasible for subcontractors themselves to invest in charging infrastructure.

4.1.6 Publicly available charging infrastructure

The NPRA has been working on facilitating the establishment of charging infrastructure at resting sites. It is stated that it is difficult to predict how things will develop, but that it is attempted to plan for a somewhat longer-term, e.g. with regard to location, need for cables and grid capacity, etc. A complicating factor is that resting sites can differ much. Some sites are owned by the NPRA, for some of them, the land is leased, some are part of agreements with multiple actors, and some are linked, for example, to petrol stations. In addition, some resting sites run with a profit, while some have to be subsidized. Today, resting sites are subject to a variety of different contracts, which makes things unclear and complex. At the time of the interviews, a decision on principles was in place that resting sites would have to consider charging infrastructure and that this would be rolled out when renewing or establishing new contracts. The NPRA, commissioned by the Norwegian Ministry of Transport and Communications, and together with the Norwegian Environment Agency, further worked on establishing a knowledge base for charging infrastructure, including:

- Status in different parts of the country for both passenger cars heavy trucks
- Charging power
- Framework conditions
- Need for publicly available charging stations in light of zero-emission objectives
- Assessment of market failures and other barriers for the establishment of sufficient charging infrastructure

Because the abovementioned knowledge base had only just been commissioned at the time of the interview, concrete views and analyses were not yet available. In the interview with the NPRA, it was noted that the establishment of charging infrastructure for heavy trucks so far often followed a similar recipe as for passenger cars, but that this is not necessarily the most efficient way forward. Further, it was pointed out that important considerations include ensuring that users are guaranteed a charging spot and that it should be avoided that commercial trucks end up in charging queues, something which was also pointed out in interviews with the different operators.

With regard to charging infrastructure itself, the NPRA points out the large investment costs. Resources have to be used efficiently, and there is still a lot of uncertainty regarding what types of chargers will be needed in the future. For example, it may be that a large share of resting sites will be upgraded with 50 kW chargers and that fewer resting sites are equipped with faster chargers. The basis for such decisions should be the effect required, e.g. what is needed to charge batteries to 80% during an 8-hour overnight resting period. The NPRA points out that previous experiences indicated that smaller battery packs have typically required 50 kW chargers, while larger battery packs may need up to 150 kW. If battery sizes increase, this could theoretically also make charging possibilities of up to 3 MW desirable for some of the largest long-haul trucks. Because power requirements are currently still uncertain, the NPRA initially focuses on ensuring flexibility. In March 2022, the NPRA and the

Norwegian Environment Agency jointly published the knowledge base documentation they had been working on (see NPRA, 2022).

The public-private collaboration 'Grønt landtransportprogram' ("Green land transport program") also considers the establishment of charging and filling infrastructure as comprehensive part of the transition to zero-emission transport. The program is carried out in close collaboration with relevant public authorities in order to ensure rapid and timely construction of charging and filling infrastructure for alternative technology trucks. Amongst others, the program aims at specifying what needs to be in place to achieve the authorities' objectives and action plans, including what this implies for charging infrastructure.

Further, also Nye Veier[8] is working on facilitating the development of charging infrastructure along the road network, in order to promote the transition to zero-emission trucks. A main objective is to dimension infrastructure for future charging requirements and to facilitate the construction of this by commercial developers of charging infrastructure. Nye Veier is working on assessing relevant measures for achieving this through the EL39 pilot project. In this project, charging infrastructure is established along the E39 road between Kristiansand and Ålgård. Experiences from the pilot project are then to be used along all road construction planned and carried out by Nye Veier. Thus far, the main focus has been on charging requirements for passenger cars, and to a lesser degree on requirements for heavier transport (Norconsult, 2020; Nye Veier, 2020a,b; Vista Analyse, 2020).

4.1.7 The NPRA's strategy for inducing the phase-in of zero-emission trucks

As part of the interviews, the NPRA was asked about whether it had other strategies of its own for inducing the phase-in of zero-emission trucks. The NPRA states that it is actively looking at this, especially with regard to road construction and winter maintenance (snow ploughing). During the 2020/2021 winter, some tests were carried out using electric machinery for clearing snow from pavements and the goal is to move forward to more and larger-scale testing (plow trucks), with a desire to run a full-scale electric pilot using electrical winter maintenance (in a few years' time).

The NPRA was also working on regulation regarding energy and environmental requirements in public tenders. At the time of the interviews, the NPRA had sent a proposal to the Ministry of Transport and Communications, which after some adjustments was submitted for interdepartmental consultation. It is hoped that new requirements will be implemented, primarily for public procurement of passenger cars, vans and city buses. Later versions of this regulation will likely also apply to HDVs and it is expected that such regulation will be consistent with the objectives stated in Norway's National Transport Plan.

[8] Nye Veier ('New Roads') is a construction firm created by Norwegian Parliament in 2016, and is wholly-owned by the Norwegian Ministry of Transport.

4.2 Electrification potential and technical limitations

4.2.1 Electrification

The firms are reasonably positive about the electrification potential for their truck fleets. One of the distributors expects that given the usage patterns of today's diesel trucks and the expected improvements in battery technology, a large share of the trucks they use for local and regional distribution could be electrified, provided access to fast chargers to allow more shifts per day. For transport assignments where the firm uses its Scania truck, it estimates that the current driving range of up to 200 km is sufficient to allow electrification of 50% of the firm's trucks on such assignments.

The other distributor expects that roughly 50% of its transport assignments can be carried out with BE-trucks, given the state of technology at the time of the interviews, because 60% of the firm's routes are shorter than 150 km. Further, it is considered that range increases to 250-300 km would allow large parts of its distribution transport to be electrified. The third distributor stated that already in 2021, 60-80% of its distribution transport in cities could be carried out electrically, and that in cities like Oslo and Drammen, this could soon be 100%. The distributor further noted that it had started looking also at routes to/from Skedsmo, Langhus/Ski and corridors on the west side of the Oslo fjord. However, the distributors also point out that electrifying routes for general cargo is a larger challenge than e.g. parcel delivery routes to shops, because the former routes are subject to more variation. This makes them less predictable and can cause driving range issues or concerns with drivers.

One of the contractors estimates that to replace a further 10% of construction trucks by battery-electric models, driving ranges will have to increase to 250 km, while for replacing 50% of the construction truck fleet, driving ranges should be 350-400 km. The latter is necessary in order to put important disposal sites for different types of (polluted) masses within range. The same firm also point out a need for BE-trucks with more axles and with towbar. The other contractor points out that the BE-trucks available on the market could not yet be used with trailer. This works fine for transport within/closely around cities, but for BE-trucks to become an alternative also for longer-distance transports, they should be able to drive with trailer.

Although focus has been on electric trucks, and the development of battery-electric vans has come further, it was noted that not all electrification challenges for the van segment had been resolved yet either. For example, at the time of the interviews, it was still mostly smaller vans that had come to market, with cargo capacities of up to 10.5-11 m^3. In this segment, electrification has become very feasible. However, the firms pointed to a need for electric vans with cargo capacity of 13, 15 and 17 m^3, because even when transport assignments could be solved electrically by using multiple trucks, the high costs of driver wages make this unprofitable. Further, models available so far had largely lacked 4WD. The latter is considered necessary for operation in several parts of Norway, and is standard on most diesel vans the firms had in use. Further, driving range limitations still presented challenges in some cases, where range was sufficient for operation during daytime, but not, in addition, during evenings. Examples were also given that some of the vans on the market did not allow fast-charging.

For electric trucks, the truck supplier reported much interest in Norway and describes developments as taking place rapidly. Trucks with 2 or 3 axles and maximum total weight up to 16 and 27 tonnes had been available for ordering since 2019, albeit without towbar. Two- and three-axled tractors had further been announced, specified to allow up to 44 tonnes total weight at a driving range of up to 300 km, and with production expected to start towards the end of 2022. These trucks will also come with towbar. The supplier also referred to pilots with electric modular truck combinations with up to 60 tonnes total weight, illustrating the technological possibilities in the near future, also for larger truck configurations. Further, the supplier expects that 85% of users will employ depot charging (during nighttime), and notes that for many operators, the biggest challenge is not driving range, but to organize operations such that the trucks can be used effectively throughout the day. Referring to EU statistics on road freight from 2019, it is pointed out that 45% of total transport performance in the EU (tonne-kms) is made up of transports of below 300 km/day[9]. The supplier also refers to research being carried out on charging with 600-800 kW and driving ranges that would allow 4.5 hours of driving even on the heaviest transport assignments. This would make it possible to charge the trucks during mandatory resting breaks, which is already possible for some use cases and lighter transports.

4.2.2 Battery-electric operation vs. diesel, biogas, biodiesel, and bioethanol

In addition to experiences with series-produced BE-trucks, the firms were asked about their perspectives on using other alternative propulsion technologies. Here, all distributors consider biogas operation a feasible alternative and either were looking into this, had initiated internal processes or were testing/using biogas trucks.

One of the distributors estimated, based on an example case, that biogas operation yielded ca. 25% higher TCO than diesel operation, at the time of the interviews. This additional cost is driven by biogas trucks being more expensive to purchase[10], uncertainty about their residual value, and more expensive service/maintenance. It was also noted, both through the distributor's example and by the supplier, that the introduction of a road toll exemption would result in approximately the same TCO as for diesel. However, it was also pointed out that on shorter routes, electric operation is the better solution, and that it did not make much sense to use biogas in cases where BE-trucks perform better.

For long-distance transport, it was pointed out that battery-electric operation was not yet feasible, and particularly, that it may take some time before trucks become available that are capable of driving with trailer. Currently, liquid biogas was considered to be the best and economically most attractive alternative to diesel on long-distance transport, although challenges remain on some transport assignments (e.g. to/from Northern-Norge, where trucks often drive long routes with overnight stays). Compressed biogas was not considered a real alternative for long-distance transport due to limited range. In this context, the truck supplier noted that liquid biogas operation on truck configurations of up to 60 tonnes total weight and a range over 700 km has been possible since 2017, but has not been able to gain

[9] Depending on EU definition, this number is ca. 43% in 2019, while statistics for 2020 and 2021 are not yet finalized. Details available via: https://ec.europa.eu/eurostat/web/transport/data/database

[10] The truck supplier stated that biogas trucks were usually ca. NOK 300,000 more expensive than similar diesel trucks.

substantial traction due to Norway's large focus on battery- and hydrogen-electric solutions. The supplier itself considers biogas to the key to being able to achieve Paris Agreement objectives, noting that CO_2 emissions from truck transport can roughly be divided into 15% from distribution transport, 15% from construction and waste management, and 70% from long-distance transport. For the latter, there are still few feasible alternatives in the near future, other than biogas.

The supplier also notes that the filling infrastructure for liquid biogas has been very limited in Norway, pointing to only 4 locations: Borgeskogen (Stokke/Sandefjord), Oslo, Svinesund and a newly commissioned filling station near Tillermyra in Trondheim, but not, for example, near Bergen. This is insufficient, especially in light of filling infrastructure networks observed in the rest of Europe, even given more or less concrete plans for the establishment of additional filling stations for liquid biogas in the upcoming years. In addition to filling stations, there is a need for increased production of liquid biogas. The truck supplier expressed a hope that the Parliament's decision on treating biogas trucks similarly to zero-emission trucks will lead to an increased willingness to invest in biogas. One of the distributors noted that there were plans for more filling stations for liquid biogas. It also mentioned examples of an intended collaboration with a biogas supplier, concerning the construction of biogas filling stations at locations where the distributor needed them. Such developments could be able to provide sufficient availability to cover the distributor's need, and, potentially, biogas could also be transported as return cargo from the region of the production plant, to other areas, making use of directional imbalances in the distributor's transports.

Of the contractors we interviewed, one had a biogas truck in operation. According to this firm, biogas trucks are powerful enough to carry masses out of construction site pits and powerful enough to be driven with trailer. The firm's own biogas truck is a standard 3-axles Volvo FH using liquid biogas and has more power than the firm's BE-trucks. The reason for choosing liquid, rather than compressed biogas was not driven by any differences in the performance (about which the firm stated that it had no basis to make any claims). A disadvantage that was pointed out was that biogas trucks are less flexible than diesel trucks due to limitations to where they can be filled. In the Oslo area, however, this would neither be a problem for liquid biogas, nor for compressed biogas.

The other contractor does not have gas trucks in operation and stated that it was not considering this at the moment either. One of the reasons is that the power characteristics of gas trucks are not sufficient for mass transports with trailer, outside of the city. For the firm's battery-electric construction trucks, power characteristics are sufficient for city transport and without a trailer. While such limitations have previously been used as arguments against electrification, the firm's experience is that its BE-trucks have had good performance, sufficient to carry masses out from construction pits, and with good power as soon as the tires gain traction. The construction firm considered biodiesel and biogas to currently be less feasible alternatives, especially after they had become subject to a road use level, which further reduced their financial competitiveness.

4.2.3 Hydrogen

Hydrogen, which is often considered as a possible alternative for long-distance transport, is identified as interesting by several of the firms, noting that it solves driving range challenges and can be produced locally. At the same time, neither of the firms seriously considered investing in hydrogen solutions, as this was still considered to be ‘too early’. Here, the firms pointed both to technology, maturity, the high additional costs of purchasing hydrogen trucks, and the price of hydrogen itself as fuel. So far, the supply of hydrogen trucks has been limited and prices high. For example, one of the distributors received an offer for a hydrogen-electric tractor unit, which was about 6 times more expensive than an equivalent diesel version. Such prices do not allow financially sustainable operation when the fuel itself still roughly costs the same as with diesel operation. To achieve sufficiently competitive hydrogen prices, it is pointed out that there is a need for increased demand from several sectors and in different applications.

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