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Working Party on Transport Trends and Economics

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Item 8 (a) of the provisional agenda
Review and monitoring of emerging issues and sustainable development goals:
Transport trends and challenges in the road, rail, and inland waterway sectors

General trends and developments surrounding electric vehicles and their charging infrastructure – an overview of electric mobility technology developments in passenger vehicle, public transport, and road freight transport sectors

Note by the secretariat

I. Introduction

1. Further to the request of the Working Party at its previous session to designate its Transport Trends and Economics 2022–2023 publication on general trends and developments surrounding electric vehicles and their charging infrastructure, a draft publication as contained in ECE/TRANS/2023/4, ECE/TRANS/2023/5, ECE/TRANS/WP.5/2023/6, ECE/TRANS/WP.5/2023/7, and ECE/TRANS/WP.5/2023/8 has been elaborated by the secretariat and an external consultant and will be presented for feedback.

2. The curent document provides a comprehensive overview of latest trends in electric passenger vehicles and electric vehicle technology development as well as their applications in the public transport and road freight transport sectors.

3. WP.5 delegates are invited to provide feedback and suggestions for improvement of the text and to deliver presentations on national case studies and best practice examples for inclusion in the final version of the publication.

II. Electric passenger vehicles

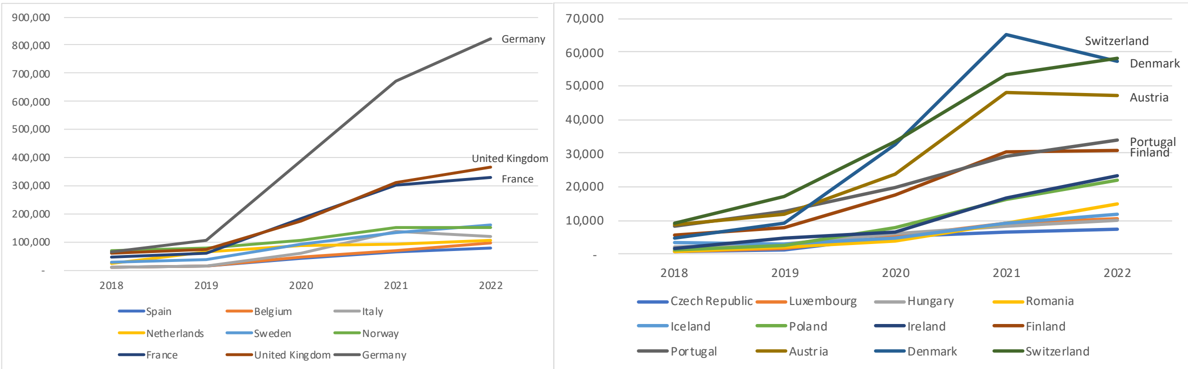
4. Both passenger and freight EVs have a role to play in the transition towards sustainable transportation. While progress has been made in the development of both, passenger EVs are currently more advanced than their freight counterparts. This is because the focus of development efforts has primarily been on passenger EVs, with numerous manufacturers offering a wide range of models to consumers. The progress of passenger EVs can be attributed to advancements in battery technology and charging infrastructure, as well

as favorable government policies and incentives aimed at promoting EV adoption. Briceno-Garmendia et al. (2022) argued that EVs will eventually come to dominate the passenger transport systems of all countries, although the timing of this transition will be determined by the economic and financial realities of each case.

A. Trends in electrification of private passenger cars

5. The electrification of passenger cars is a rapidly growing trend in the ECE region. Western European countries, such as France, Germany, and the United Kingdom, are leading the way in the number of new electric passenger car registrations each year (Figure I). In 2022, Germany registered over 800,000 battery-electric cars, followed by the United Kingdom with nearly 370,000 unit. The overall growth in electric car registrations in the ECE region has been significant, with the steepest growth is observed between 2019 and 2022. This can be attributed, in part, to European Union Regulation 2019/631,[1] which was passed in January 2020 and sets CO_2 emission standards for new passenger cars and vans. This regulation has motivated vehicle manufacturers to increase the production of EVs.

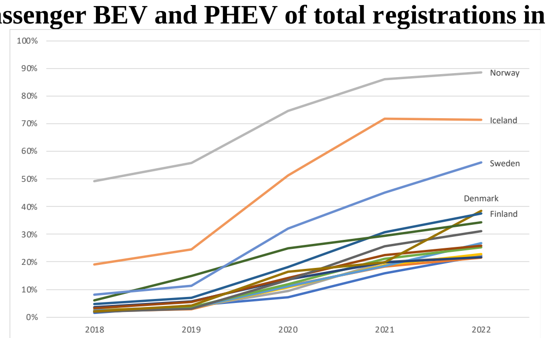
Figure I
New passenger car registrations in ECE region (BEV and PHEV)



Source: European Alternative Fuels Observatory. Available at https://alternative-fuels-observatory.ec.europa.eu/transport-mode/road/austria/vehicles-and-fleet. *Accessed on 31 May 2023.*

6. The market share of electric cars in ECE countries has also been experiencing a significant increase (Figure II). Norway continues to lead the transition with an astonishing market share of 88 per cent in 2022, rising from 49 per cent in 2018. Other countries following closely behind include Iceland, Sweden, the Netherlands and Finland, completing the top five. Finland, in particular, has experienced a dramatic surge in its market share, skyrocketing from 4.7 per cent in 2018 to 37.6 in 2022.

Figure II
Market share of passenger BEV and PHEV of total registrations in ECE region

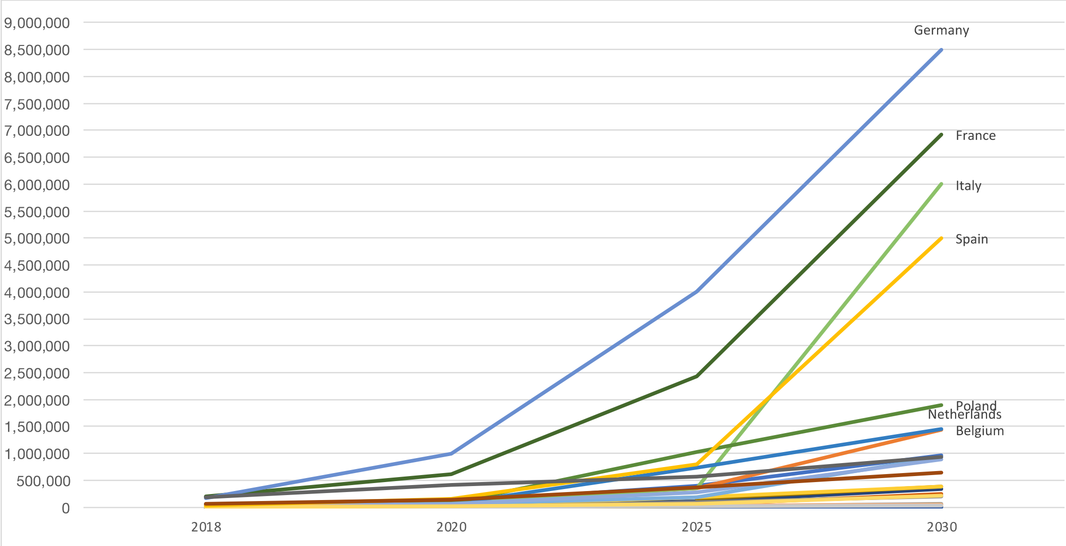


Source: European Alternative Fuels Observatory. Available at https://alternative-fuels-observatory.ec.europa.eu/transport-mode/road. Accessed on 31 May 2023.

[1] Source: https://climate.ec.europa.eu/eu-action/transport-emissions/road-transport-reducing-co2-emissions-vehicles/co2-emission-performance-standards-cars-and-vans_en

7. The European Commission staff working document regarding a detailed assessment of the Member States (MS) implementation reports on the National Policy Frameworks for the development of the market as regards alternative fuels in the transport sector and the deployment of the relevant infrastructure on the application of Directive 2014/94/EU on the deployment of alternative fuels infrastructure,[2] shows the estimates of the number of road-based EVs in each MS in 2025 and 2030 (Figure III). It should be noted that these figures encompass all types of roads based EVs, with passenger cars (BEVs and PHEVs) representing the overwhelming majority. By 2030, Germany, Spain, Italy, and France are projected to have the highest numbers of road based EVs, each exceeding 5 million. Other countries with significant estimates for 2030 include the United Kingdom, Belgium, the Netherlands, and Poland.

Figure III
Projected number of road-based EVs in selected European Union countries



Source: European Commission (2022)

B. Commercial passenger cars

8. Electrifying commercial passenger cars, which include taxi and ride-hailing service, can have a significant impact. They are high-kilometer vehicles, meaning they drive many kilometers each day, making them ideal candidates for electrification. They are also a significant source of air pollution in urban areas, and the switch to EVs can help reduce local air pollution. In addition to the environmental benefits, electric taxis can also offer an improved riding experience for passengers, with quieter rides and smoother acceleration.

9. As with electric private passenger cars, electric taxi and ride-hailing vehicles have lower operating costs than traditional gasoline-powered taxis. This is due to lower maintenance and fuel costs, resulting in significant savings for taxi drivers and companies. Additionally, the lower operating costs can lead to lower prices for passengers, which may increase ridership and benefit the broader transportation system. Affordable taxis and ride-hailing vehicles can also serve as a more accessible first- and last-mile transportation mode.

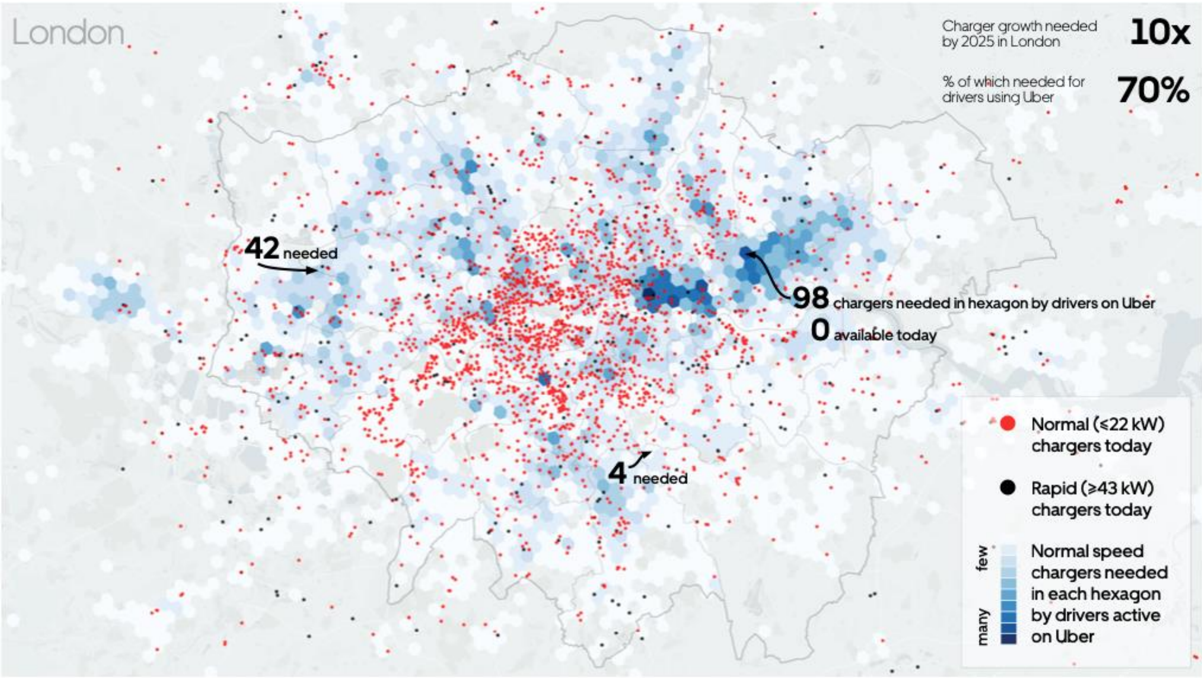
10. In the context of ride-hailing service, according to Uber (2020), providing drivers with the opportunity to charge their vehicles overnight at or near home is critical for business success. Overnight charging offers numerous benefits, including convenience, cost savings, and improved battery life. Most importantly, it eliminates the potential for a large opportunity cost of lost earnings that can be incurred while searching for and using a charge point, rather than carrying passengers. However, providing access to overnight charging has been a

[2] Source: https://eur-lex.europa.eu/resource.html?uri=cellar:e6afa54f-8003-11eb-9ac9-01aa75ed71a1.0001.02/DOC_1&format=PDF

challenge, particularly for drivers who often live in densely populated urban areas where there may be limited access to public charging infrastructure. Historically, overnight public chargers have tended to be in wealthy areas.

11. A study conducted by Uber (2020) in London highlights the need for additional public chargers to be made available for EV ride-hail drivers. The study shows that many more chargers are needed in different areas than are currently available, as depicted in Figure IV. To address this challenge, the study concludes that a central, city-level solution for the provision of widespread, affordable, public overnight charging is required. Interestingly, the approach recommended by the study of Uber (2020), which involved the expansion of the slow AC charging network, was initially adopted by the City of Amsterdam until 2019. However, Amsterdam has since revised its strategy for taxis and shifted towards expanding public fast charging points (Box 1).

Figure IV
Public chargers needed in London to serve ride-hail drivers



Source: Uber (2020)

Box 1
Amsterdam's rollout strategy for fast charging infrastructure for taxis

Previous situation:

As of December 2019, there were approximately 1,100 emission-free ATO (Authorized Taxi Organization) taxis in Amsterdam out of over 3,200 ATO drivers. Taxis relied on the charging infrastructure designed for passenger cars, with park-and-charge facilities meeting most of their charging needs. However, with more residents using charging stations, it became more challenging for drivers to charge near their homes, as the stations would be occupied for the entire evening and night. This led to a growing demand for fast charging options, which were in short supply. At that time, the city had 29 public fast chargers, with only 3 exclusively designated for taxi use at the central train station. Additionally, private entities at gas stations and restaurants offered fast chargers, and there were large charging hubs of Tesla (>40 units) near Schiphol airport.

Current situation:

Amsterdam's Action Plan for Clean Air for 2025 and 2030 outlines the following goals:

- By 2025, the aim is to transition all commercial ICEVs to electric power, with an expected fleet of 5,000 battery-electric taxis;
- By 2030, all passenger transport in Amsterdam must be emission-free. This includes an estimated 254,000 vehicles, including leased and taxi vehicles. The requirement extends not only to cars within Amsterdam but also to incoming traffic, which is projected to consist of approximately 90,000 commuters and 80,000 daily visitors in 2030.

Therefore, the expansion of public charging infrastructure plays a crucial role in this strategy. In 2020, Amsterdam initiated the implementation of a rollout strategy for public charging infrastructure, with a specific focus on supporting electric taxi fleets. Exclusive access for these target groups aims to enhance the attractiveness and reliability of the network while reducing traffic movements by these groups. Recognizing that taxis cover significant distances, making them particularly reliant on fast chargers for intermediate charging, Amsterdam has made substantial investments in installing fast chargers for taxi. These chargers are situated on the outskirts of the city, near the inner city, and other relevant locations. The network of public fast charging points, primarily intended for taxis, will expand from thirteen in 2019 to sixty-two by 2026.

Source: Gemeente Amsterdam (2019)

C. Shared mobility and public transport

12. In this study, shared mobility refers to the shared use of transportation modes, such as car-sharing programs and electric scooters. It is widely recognized that solely electrifying private vehicles will not effectively address the challenges of climate change and urban congestion. These challenges are partially caused by increased population density, limited space in metropolitan areas, and inadequate investment in transport infrastructure. The high volume of vehicles on the roads contributes to traffic congestion, diminishing the overall efficiency of transportation systems. Simply replacing ICEVs with EVs in private ownership would not address the congestion issue adequately. While transitioning private vehicles to electric powertrains is an important step, equal emphasis should be placed on electrifying shared mobility and expanding electrified public transport options, even in suburban areas. The combination of electric powertrains and shared mobility services offers a transformative opportunity to reshape urban transportation. Additionally, due to the heavier usage patterns of shared fleets, the lower operational costs of EVs could make them more cost-effective overall. Vehicle sharing programs and public transport are more conducive to electrification since fleet operators have greater control over the decision-making process. Specific efforts are required to support effective transformative policies and prevent unintended consequences, such as a shift from environmentally friendly modes of transportation to new mobility options, when the original target was private vehicle drivers. Table 1 provides basic characteristics of electric car-sharing and scooter-sharing services, two popular types of shared mobility solutions, in terms of operation, features, and use cases. Electrification of public transit buses will be discussed in the next chapter.

Table 1
Characteristics of electric car-sharing and scooter-sharing services

Characteristics	*Car-sharing service*	*Scooter-sharing service*
System type	Free-floating and hub/depot services	Predominantly free-floating
Parking flexibility	Free-floating: cars can be parked anywhere Hub/depot: cars must be left in designated parking spots	Scooters can generally be parked anywhere within the service area, though certain regulations may apply

Characteristics	*Car-sharing service*	*Scooter-sharing service*
Charging infrastructure	Free-floating: rely heavily on public fast chargers Hub/depot: can use slow charging on their own chargers during vehicle downtimes	Primarily use swappable battery systems or centralized charging depots during off-peak hours
Vehicle range	High vehicle range due to larger batteries, typically able to cover long-distance trips	Lower vehicle range, generally suitable for short to medium-distance trips

13. [PLACEHOLDER: Good practices of the deployment of electric shared vehicles to be added]

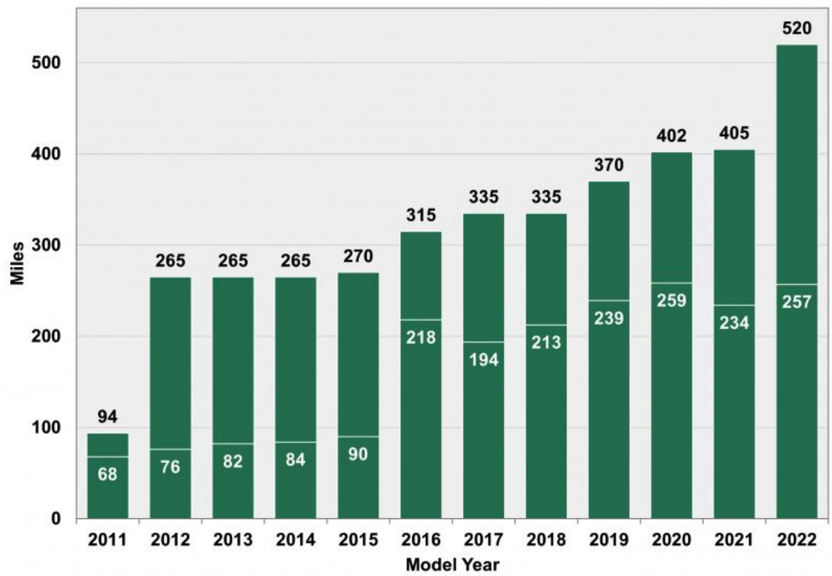
D. Electric vehicle technology development

14. The previous sections have highlighted the significant advancements in the EV industry over the past decade, leading to a rapid increase in EV adoption. Looking ahead, the EV industry is currently experiencing the following key trends, which are anticipated to persist in the future:

1. Lower vehicle price and longer driving range

15 The cost of EVs has been a major barrier to widespread adoption. Nevertheless, this situation is gradually changing as a new trend emerges. With the introduction of more affordable EV models into the market, these vehicles are becoming increasingly accessible to a broader range of consumers. Additionally, the growth of the primary EV market will inevitably lead to the expansion of the secondhand EV market. Similarly, concerns about range anxiety, which have plagued EVs since their inception, are being addressed. As shown in Figure V**Error! Reference source not found.**, the average range of EVs in the United States has dramatically improved between 2011–2022.

Figure V
Median and maximum range of EVs offered for sale in the United States

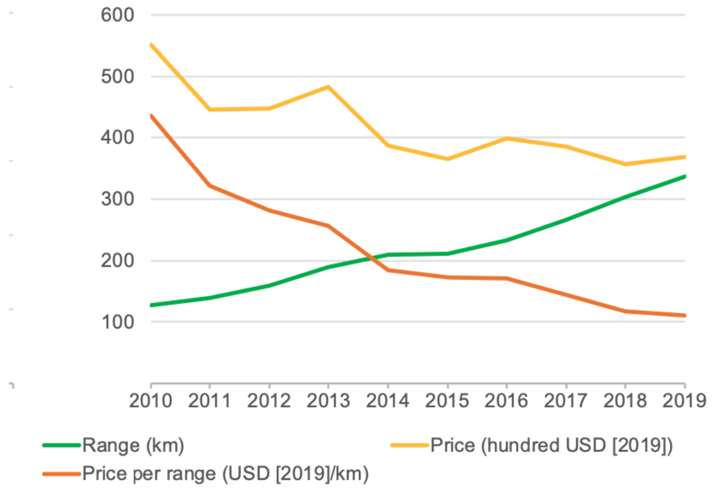


Source: Office of Energy Efficiency & Renewable Energy[3]

[3] Source: https://www.energy.gov/eere/vehicles/articles/fotw-1290-may-15-2023-model-year-2022-longest-range-ev-reached-520-miles

16. Recent trends also demonstrate a rapid enhancement in the driving range of EVs while reducing their price. Figure VI illustrates the decrease in the price of BEVs between 2010 and 2019, with the driving range increasing from just over 100 km in 2010 to nearly 350 km in 2019. According to IEA (2023), in 2022, the sales-weighted average range of small BEVs sold in the United States was nearly 350 km, compared to just under 300 km in France, Germany and the United Kingdom, and under 220 km in China. Technological innovations in battery technology, such as improvements in energy density and efficiency, have primarily driven this positive trend.

Figure VI
Average price and driving range of BEVs, 2010-2019

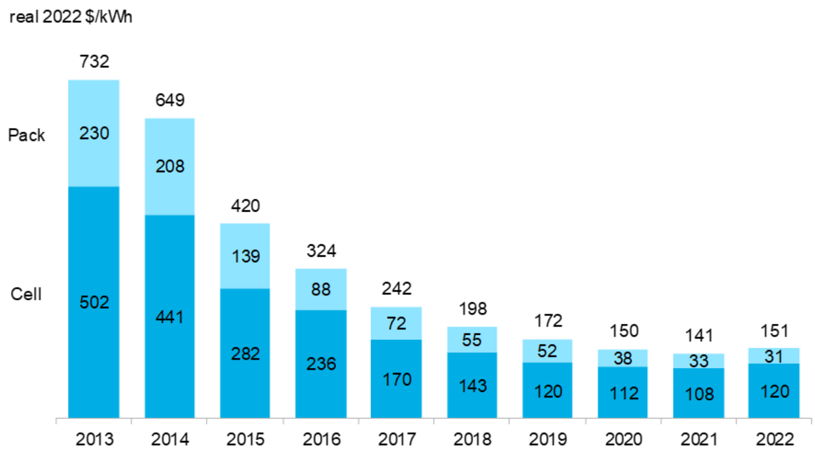


Source: IEA (2020)

2. Declining battery prices

17. The cost of batteries, which is the most expensive component of an EV, has been consistently decreasing. From over $700/kWh in 2013, battery prices have fallen to around $140/kWh in 2021, thanks to production scaling up and technological improvements. However, in 2021 and 2022, battery prices experienced a temporary increase due to various factors, including the impacts of COVID, the Ukraine war, rising raw material prices, supply chain disruptions, and related concerns (Figure VII). Nevertheless, BloombergNEF (2022) expects that average battery pack prices in 2023 will remain similar to those in 2022, and will start declining again in 2024, falling below $100/kWh by 2026.

Figure VII
Volume-weighted average lithium-ion battery pack and cell price split, 2013-2022

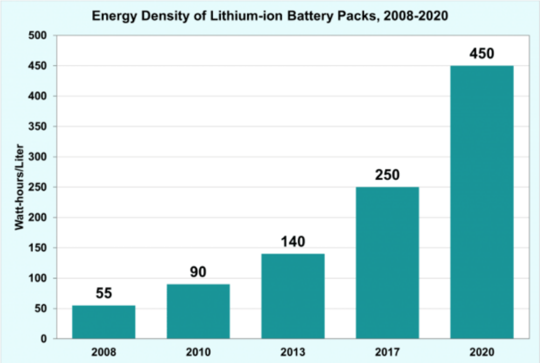


Source: BloombergNEF (2022)
Note: Weighted average survey value includes 178 data points from passenger cars, buses, commercial vehicles and stationary storage

3. Smaller battery packs

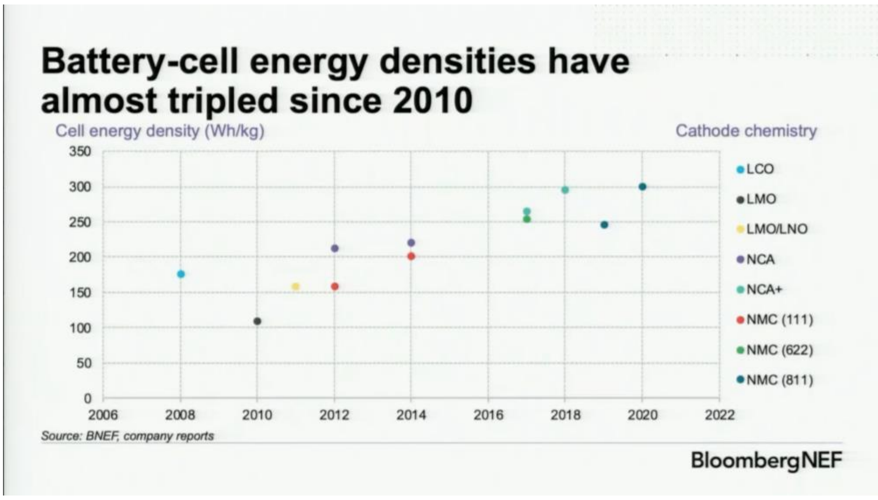
18. The pursuit of efficient and lightweight EVs has led to the development of smaller yet more energy-dense battery packs. This evolution has been driven by the demand for EVs that offer practicality and performance comparable to traditional ICEVs. Modern EV batteries are becoming increasingly energy-dense, enabling them to store more energy per unit of weight. As a result, vehicles are becoming lighter, more efficient, and facilitating innovative and flexible vehicle designs.

Figure VIII
Energy Density of Lithium-ion packs in Wh/liter



Source: US Department of Energy[4]

Figure IX
Energy Density of Lithium-ion packs in Wh/kg



Source: BloombergNEF (2020)[5]

19. With advances in battery technology, the average EVs will have less weight and will therefore be able to travel further on a single charge. Additionally, the volumetric decrease results in either smaller battery packs or a longer range with the current volume. Even innovative ways of battery placement within the vehicle can be considered to optimize the vehicle design.

4. Automated driving

20. The trend towards automated driving is becoming more prominent in the EV industry, with almost all major EV manufacturers developing or releasing some level of automated

[4] Source: https://www.energy.gov/eere/vehicles/articles/fotw-1234-april-18-2022-volumetric-energy-density-lithium-ion-batteries

[5] Source: https://cleantechnica.com/2020/02/19/bloombergnef-lithium-ion-battery-cell-densities-have-almost-tripled-since-2010/

driving capability. Tesla's Autopilot serves as an initial example followed by other EV manufacturers such as Lucid Motors or Nio who all offer some form of advance driver assistance systems. Traditional manufacturers also follow that trend, such as Mercedes-Benz who launched their flagship electric vehicle EQS with the first Automated Driving System offered for sales in series vehicles in Germany and in the United States of America. As artificial intelligence, innovation and sensor technology continue to evolve, the integration of automated driving systems into EVs is expected to increase further, moving us towards a future where self-driving EVs become the norm rather than the exception.

III. Electrification of public transit buses

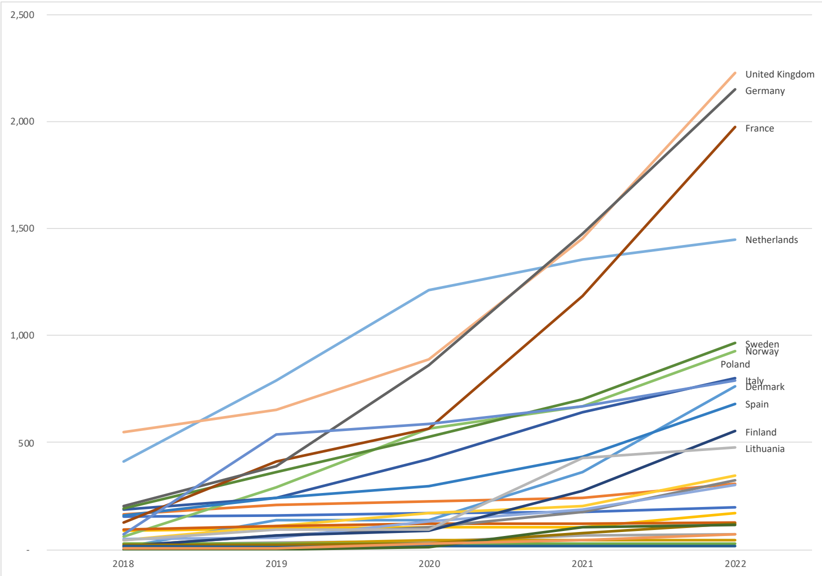
21. While the EV revolution undoubtedly presents an essential step towards sustainable mobility, it does not inherently address two of the most pressing issues plaguing urban environments: traffic congestion and parking problems. Therefore, focusing solely on EV adoption overlooks the intrinsic problems associated with single-occupancy vehicular travel, whether it is electric or not. While EVs might offer a greener ride, they still consume as much space on the road and in the parking lot as their fossil-fuel counterparts. The key to a truly sustainable urban mobility future lies not only in electrification but also in promoting efficient usage of urban space through an enhanced public transportation system. The electrification of buses presents an attractive opportunity, particularly when considering the external environmental costs in the total cost of ownership (TCO) calculation.

22. Many argue that a dual strategy of promoting and electrifying public transportation represents a readily available solution, owing to two main reasons. Firstly, public transport vehicles cover high distances, and as the kilometers increase, their cost decreases. The strongest case lies in deploying electric buses on routes with high vehicle usage, which allows for significant savings in operating costs. Secondly, public transport is predominantly under government purview, providing ample opportunity to influence its development and implementation. Since governments handle the procurement, there is no need for administratively complex subsidy schemes or regulations.

A. Trends in electrification of public transit buses

23. The transition to electric city buses is being driven by the mobility policies of major cities, as city officials aim to enhance the quality of living environments. Figure X demonstrates the growth of electric bus fleets in twenty-six ECE countries between 2018 and 2022. The data indicates that the number of electric buses has been increasing annually in most countries. In 2022, France, Germany, the Netherlands, and the United Kingdom had the highest number of electric buses are. Italy also experienced growth, albeit at a somewhat slower pace. Overall, the data suggests a rising trend towards electric buses in ECE countries, although the adoption rates vary across nation. It is important to note that the figure represents the total bus fleets, including motor coaches, buses, and trolley buses.

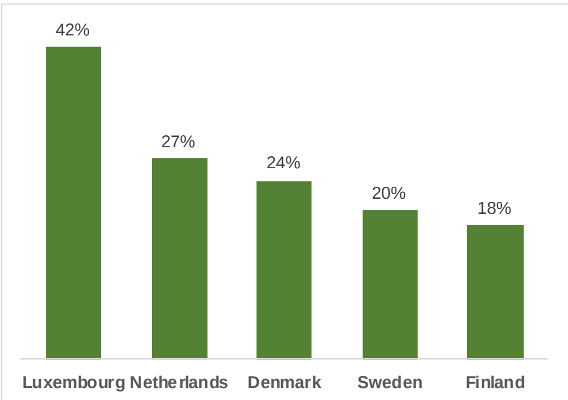
Figure X
Electric bus fleet in ECE region, 2018-2022



Source: European Alternative Fuels Observatory. Available at https://alternative-fuels-observatory.ec.europa.eu/transport-mode/road. Accessed on 31 May 2023.
Note: Fleets include motor coaches, buses and trolleybuses

24. When considering the share of electric public transit buses in urban transportation, an international study by Rabobank (FD, 2023) identifies the leading European countries as Luxembourg, the Netherlands, Denmark, Sweden, and Finland, in that order (Figure XI). Amsterdam and Stockholm have particularly high penetration of electric city transport. The acceleration in replacing diesel and other city buses with EVs was initiated by the launch of the Green Deal by the European Commission in 2019. The goal is to exclusively procure electric city buses by 2030.

Figure XI
Market share of electric public transit buses in all propulsion systems in Europe, 2022



Source: FD (2023)

25. The following sections will primarily focus on battery electric buses (BEBs) for public transit, taking into account their technological advancements and their vital role in addressing air pollution in urban areas, as well as their social function in providing public transport for urban dwellers.

B. Vehicle models and technologies

26. BEB technology refers to buses that rely solely on on-board batteries for power, without an on-board generator. Electric buses, which have an average cost of 500,000 euros

and a lifespan of 10-15 years, are considerably more expensive than their diesel counterparts, primarily due to battery costs. In recent years, the prices of battery packs for buses have experienced a significant decline, reaching a fraction of their previous levels.[6] Table 2 presents the average battery capacity and range across transit buses, showing an increasing trend between 2019 and 2022. It is important to note that the battery capacity alone does not accurately determine the driving range, as it varies due to factors such as the bus's efficiency, driving conditions, passenger load, and other operational factors.

Table 2
Average battery capacity of transit bus vehicles

	2019	*2020*	*2021*	*2022*	*Change 2019–2022*
Average battery capacity (kWh)	264	322	225	345	31%
Estimated range*	200–250	250–300	150–200	300–350	

Source: IEA *(2023), ZET.*[7]

* Estimated range is based on declarations from various vehicle manufacturers on the ZETI website.

27. For transit agencies, battery range and sufficient bus capacity are the most crucial factors to consider. They have significant route obligations and need to travel long distances daily within fixed time constraints for refueling or recharging. When transitioning to electric fleets, transit agencies must ensure that the existing service levels are maintained or improved. However, maximizing passenger capacity can pose challenges for travel range and battery energy loss. Table 3 provides an overview of the ten original equipment manufacturers (OEMs) in Europe that offer battery-electric public transit buses with the longest range.

Table 3
Top 10 battery-electric transit buses in Europe by OEMs based on range in 2023

OEM	*Model*	*Length (m)*	*Battery capacity (kWh)*	*Maximum range (km)**	*Passenger capacity***
Ebusco	Ebusco 3.0	12	350	575	95
IVECO	E-WAY Full Electric	12	350	543	70
Quantron	Q-Bus	12	332	370	88
Temsa	Avenue Electron	12	360	350	85
Otokar	e-KENT C	12	300	300	95
Isuzu	NOVOCITI VOLT	8	211	300	52
Caetano	e.City Gold	12	385	300	87
Bozankaya	E Bus 10	10.7	230	300	80
MAN	Lion's City E	18	640	270	120
BYD	ADL Enviro200EV	10.2	348	257	80

Source: ZETI Data Explorer.[8] Accessed on 7 June 2023.

* Range values were taken from manufacturer estimates in favorable condition, which may be higher than the actual range recorded on the ground

** In some models, ZETI Data Explorer does not provide data on passenger capacity. In such cases, other sources are consulted.

[6] Source: https://www.sustainable-bus.com/components/battery-prices-2023-packs-peak/?utm_source=Sustainable+Bus+Next+Stop&utm_campaign=4234fc905c-2023_03_24_NL_NEXT_STOP_COPY_01&utm_medium=email&utm_term=0_b48eb86b72-4234fc905c-176774393

[7] Source: https://globaldrivetozero.org/tools/zeti/

[8] Source: https://globaldrivetozero.org/tools/zeti-data-explorer/

C. Contracting and business models for electrification of public transit buses

28. As buses are a vehicle category of particular interest in public policy, public authorities will bear the additional expenses of electric buses and the necessary charging infrastructure. Different to the traditional public bus contracts, electric bus contracts include new stakeholders and elements, namely charging operations and maintenance for both ownership and operations contracts.

29. Affording the higher capital cost associated with electric buses may pose challenges for public transit authorities. In such cases, experience has shown that aggregating demand across multiple urban jurisdictions to form larger procurement lots can effectively reduce the unit cost of purchasing electric buses. The FAME[9] India scheme has achieved cost reductions of up to 30 per cent. Achieving similar reductions may require national-level coordination of electric bus procurement across cities. In smaller countries, supranational coordination facilitated by regional or multilateral institutions could be a viable option.

30. All in all, the high upfront costs of battery electric buses necessitate a shift from focusing solely on purchase costs to a TCO procurement model and new financing scheme. Contracts and financing are intertwined and play a crucial role in determining possible charging strategies, bus and battery types, and the corresponding hardware, software, maintenance, and operations (ITDP, 2021).

31. Figure XII depicts various business models that are implemented in different countries across the globe. These models are commonly used in the following types of contracts:

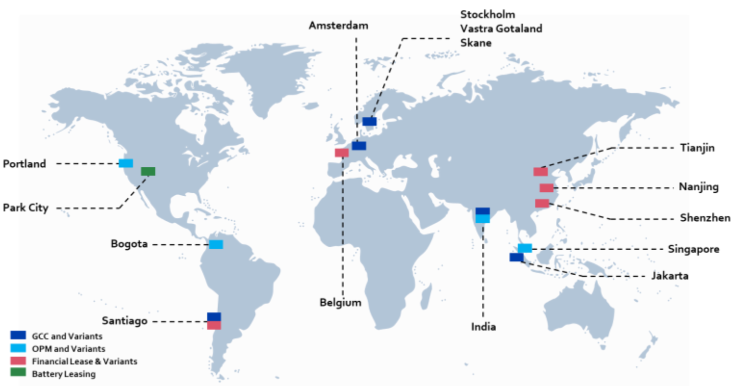
- Gross cost contract (GCC): This type of contract involves a service agreement where the operator is responsible for operating buses at a predetermined rate per kilometer. While the operator collects the revenues, the public transport authority/agency retains ownership of them.

- Outright Purchase Model (OPM): This model represents the traditional procurement arrangement employed by PT Agencies. In this approach, the agencies purchase the fleet outright instead of leasing it or hiring an operator who owns and operates the fleet.

- Financial Lease Model: In this model, the bus, and possibly the battery, are leased from a financial agent. Additionally, there is a variant of this model where the financial agent provides the charging infrastructure in exchange for a monthly payment.

- Battery Lease Model: Under this model, the procurement, operation, and maintenance of the battery are completely outsourced in exchange for a monthly payment.

Figure XII
Electric bus business model across the globe



Source: Patel (2023)

[9] FAME stands for "Faster Adoption and Manufacturing of (Hybrid &) Electric Vehicles"

32. The financial and operational difficulties of deploying public transit buses become even more pronounced in countries that lack local electric bus manufacturing capabilities. These complexities include:

- Additional import costs
- Challenges in supply chain management, leading to potential delays in obtaining the buses
- Limited availability of electric buses tailored to specific requirements, such as climatic conditions, road infrastructure, and operational demands that necessitate customized bus features
- Difficulties in accessing technical support and maintenance services.

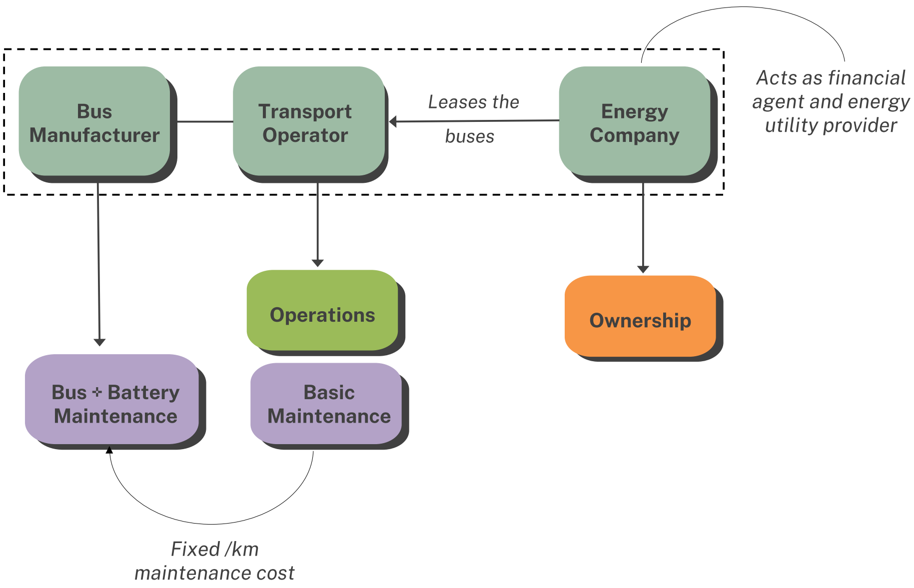
33. Santiago, however, has managed to overcome these challenges by introducing innovative financing practices and improving procurement practices. It procured over 400 electric buses in 2020, operating the first e-corridor in Latin America (Box 2).

Box 2
Santiago's business model for the implementation of electric buses

Santiago serves as an exemplary model for the electrification of public buses in a country without local electric bus manufacturing. The government's proactive measures in facilitating the process, streamlining approval and authorization times, and providing support for the planning and regulation of electric buses were critical to the successful transition.

The business model employed for the implementation revolves around a public-partner partnership (PPP) between the state (Ministry of Transportation and Telecommunications) and energy companies Enel and Engie. These companies have financed the provision of buses and electric charging infrastructure, leasing them to the transport operators. The leasing contracts involve monthly payments to cover three main components: fleet provision, charging infrastructure, and energy supply. By acting as the financial agent, the energy companies support their core business of energy provision and charging infrastructure installation.

The transport operators, in turn, are responsible for operating the buses and providing basic maintenance. The bus manufacturers, on the other hand, are tasked with more significant maintenance operations, including battery packs and electric drive trains. A fixed maintenance rate is agreed upon, and an availability clause ensures that the manufacturer bears responsibility for any fines incurred by buses that fail to meet frequency requirements.



Initially, the first pilot electric buses implemented in in Santiago, which were BYD buses, had a price tag of around $450,000- more than twice the cost of the diesel Euro VI buses.

However, as the electric bus fleet grew, the negotiated prices decreased significantly. Bus manufacturers BYD and Yutong recognized the opportunity to introduce electric bus technology in the Latin American market and offered a more competitive price of around $300,000 for subsequent buses, making them a more viable alternative to diesel Euro VI buses.

Key success factors

Strong political commitment

(a) The National Electric Mobility Strategy establishes a regulatory framework for the electrification of public transport in Chile by 2040.

(b) The city government has committed to exclusively procuring zero emission buses after 2025. They have actively promoted electric bus deployment through policy actions and incentives for operators.

New business models and diversification

(a) Bulk procurement strategies have been implemented to reduce purchase costs.

(b) To alleviate the risk and financial burden on transport operators, energy companies and utility firms have made investments in electric buses and charging stations. Meanwhile, bus manufacturers are responsible for vehicle and battery maintenance. This distribution of risks ensures that they are borne by parties better equipped to handle them.

(c) The public transport authority guarantees leasing payments between transport operators and utility firms.

Source: Race to Zero (2021), ZEBRA (2020)

IV. Electrification of road freight transport

34. Freight transport is a critical component of global trade and commerce, but it also accounts for a significant portion of GHG emissions. According to Gómez Vilchez et al. (2022), 36 per cent of the CO2 equivalent generated by the transport sector in the European Union (EU) and the United Kingdom in 2019 is originated from light-duty trucks and heavy-duty vehicles (HDVs). The development of freight EVs has been slower and more limited in scope when compared to that of passenger EVs. Freight is the neglected child of transport decarbonization (Council for Decarbonising Transport in Asia, 2022). While there have been some promising developments, such as the introduction of electric delivery vans and trucks in urban areas, there are still significant challenges to be overcome. These include high upfront costs, the need for more efficient battery technology, increased charging infrastructure for larger vehicles, and greater investment in research and development.

A. Light commercial vehicles

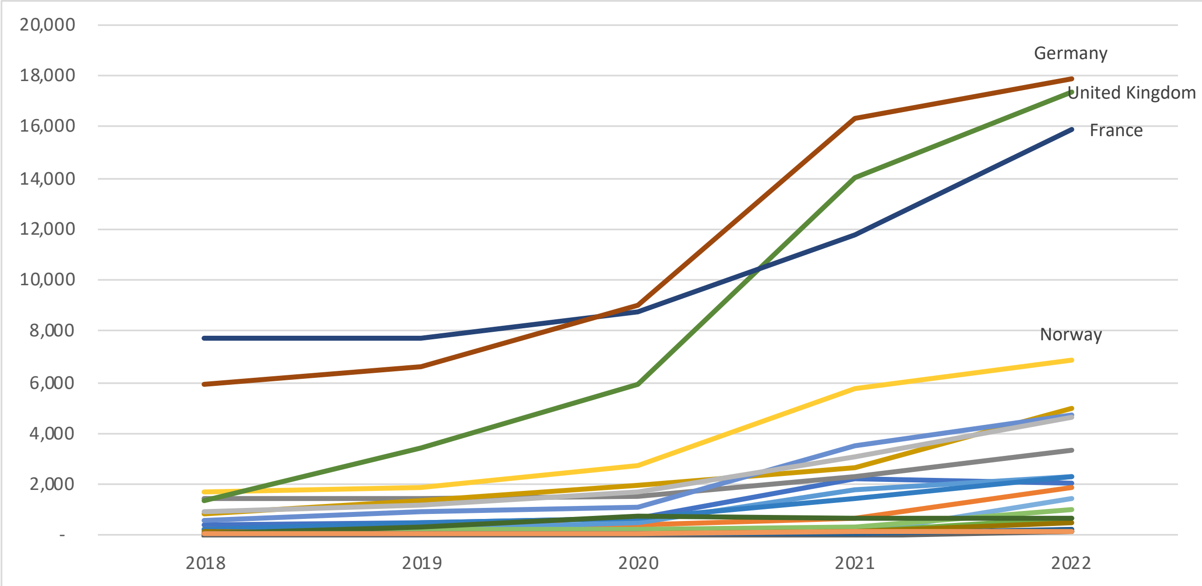
35. Light commercial vehicles (LCVs), commonly referred to as vans, are crucial component of logistic chains. They play a vital role in facilitating efficient last-mile delivery of goods within urban areas and are instrumental in providing essential services, including ambulances, postal and courier services, and municipal operations. LCVs contribute significantly to sustainable urban mobility, which is especially important given the rapid expansion of the e-commerce market.

36. Electrifying LCVs presents a more compelling economic case compared to cars, particularly in the context of urban delivery. LCV fleets are driven intensively, often operate on predictable routes and can be charged at commercial depots (IEA, 2022). Businesses place a strong emphasis on TCO, carefully considering lifecycle costs when procuring vehicles.

37. In the ECE region, sales of LCVs in selected countries have more than doubled from 2018 to 2022 (Figure XIII). During this period, the average percentage of PHEVs out of the total number of vehicles remained relatively low across the region, averaging around 2.44 per cent. Norway, with a traditionally strong EV market, had the highest proportion of electric

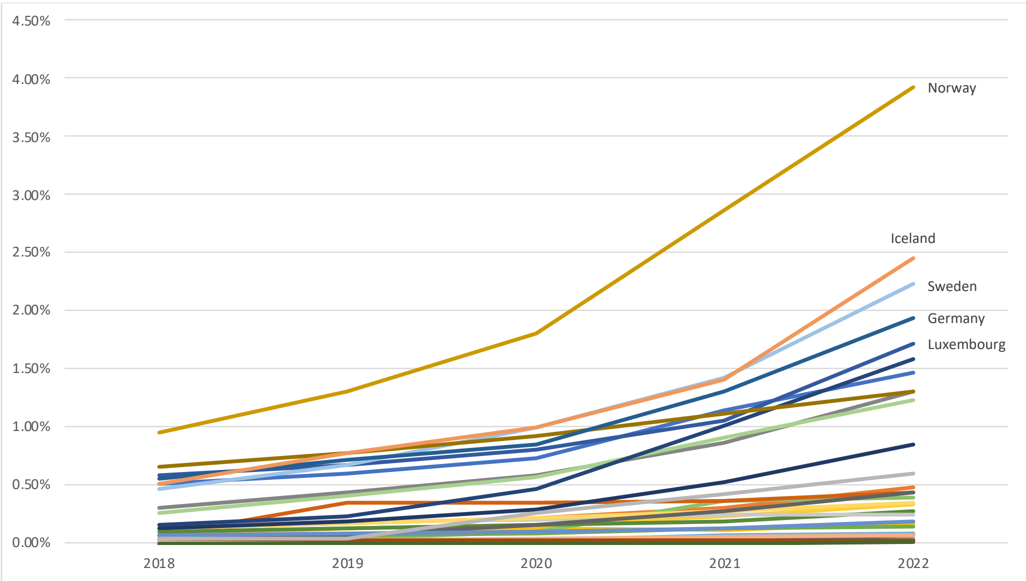
LCVs (Figure XIV). Interestingly, no new PHEVs registration were recorded in 2022, which could reflect Norway's concerted efforts to promote zero-emission vehicles over hybrids.

Figure XIII
Number of newly registered electric LCV in ECE region, BEV and PHEV



Source: European Alternative Fuels Observatory. Available at https://alternative-fuels-observatory.ec.europa.eu/transport-mode/road. Accessed on 31 May 2023.

Figure XIV
Newly registered electric LCVs as percentage of total number of registrations in ECE region



Source: European Alternative Fuels Observatory. Available at https://alternative-fuels-observatory.ec.europa.eu/transport-mode/road. Accessed on 31 May 2023.

38. According to IEA (2023), current trends indicate that the electric LCV market is catching up with that of electric cars, suggesting that the gap in terms of EV sales shares could narrow in the future. The rapid adoption of battery electric LCVs may also be driven by the continuing expansion of low- and zero-emission zones (refer to section **Error! Reference source not found.**).

B. Development of vehicle models and technologies

39. In 2023, the global market offers nearly 100 different models of battery-electric cargo vans, as outlined in Table 4. However, this positive trend is not mirrored in the progression of the average battery capacity of these vehicles, which actually declined between 2019 and 2022 (Table 5). This might seem counterintuitive considering the advancements of electric LCVs, but several factors could contribute to this trend:

- Improved efficiency, due to innovations in vehicle design, motor efficiency, and energy management software, allowing for similar ranges with smaller batteries.
- The expansion of charging infrastructure, which makes a larger battery not be as necessary.
- Businesses opt for models with smaller batteries, which are less expensive, particularly if the delivery routes do not require extended ranges and if the vehicle's payload capacity is more important than placing large battery.

Table 4
Development of battery-electric cargo van models in the market

	2021	*2022*	*2023*
Global	59	96	99
Europe	8	15	17

Source: ZETI Data Explorer.[10] Accessed on 8 June 2023.

Table 5
Average battery capacity (kWh) in cargo van models

2019	*2020*	*2021*	*2022*	*Change 2019-2022*
69	90	57	60	-13%

Source: IEA *(2023)*

40. Table 6 lists the ten battery-electric cargo vans in Europe with the longest driving range in 2023. Arrival Van and Fiat e-Ulysse offer the maximum range of over 300 km, exceeding the typical daily requirements for urban deliveries.

Table 6
Top 10 battery-electric cargo van in Europe by OEMs based on range in 2023

OEM	*Model*	*Battery capacity (kWh)*	*Estimated maximum range (km)*	*Payload (kg)*
Arrival	Van	133	340	1,615
Fiat	e-Ulysse	75	330	1,400
Maxus	eDeliver3	89	298	860
Cenntro Electric Group	Logistar 260	44	270	1,280
Dongfeng	EC35	39	267	1,015
BYD	ETP3	45	233	780
Ford	E-Transit	68	202	2,105
Renault Trucks	Master ZE	52	200	1,600
IVECO	Daily Electric	91	200	998
GINAF	E2107	90	185	

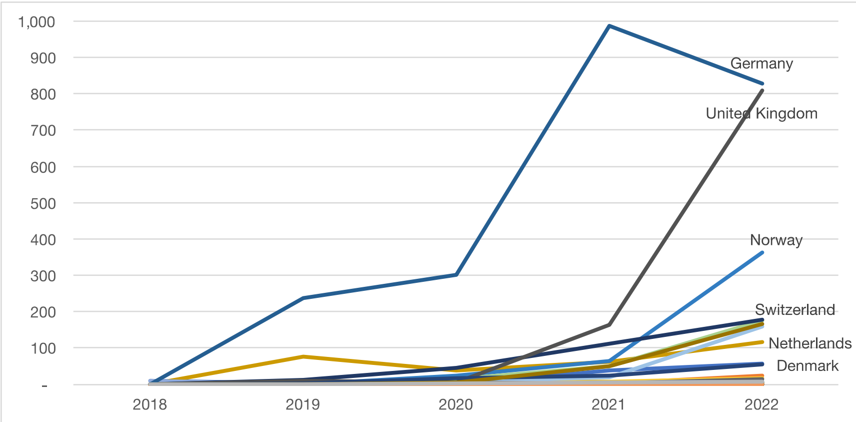
Source: ZETI Data Explorer.[11] Accessed on 8 June 2023.

[10] Source: https://globaldrivetozero.org/tools/zeti-data-explorer/
[11] Source: https://globaldrivetozero.org/tools/zeti-data-explorer/

C. Heavy-duty goods vehicles

41. Heavy-duty goods vehicles that will be discussed in this section include the medium- and heavy-duty truck segments (collectively referred to as electric trucks). In Figure XV, the fleet size of electric trucks in the ECE region is depicted. The adoption rate of these vehicles has increased considerably between 2020 and 2022. However, the number of electric trucks remains relatively low compared to electric cars and LCVs.

Figure XV
Number of newly registered MDTs and HDTs in ECE region, BEV and PHEV



Source: European Alternative Fuels Observatory. Available at https://alternative-fuels-observatory.ec.europa.eu/transport-mode/road. Accessed on 31 May 2023.

42. While battery electric truck technology has become more popular and many experts believe that electric trucks will electrify rapidly in the coming years, the following challenges still need to be overcome.

43. Upfront costs pose a significant concern for truck buyers, who often rely on loans for their purchases. These costs extend to the fast-charging infrastructure at depots necessary to support EVs, including grid upgrade costs. Given their commercial nature, electric trucks are primarily dependent on off-shift charging for most of their energy requirements. According to ICCT (2022) that undertook a study on a TCO comparison of battery-electric and diesel medium trucks in Europe for last-mile delivery, battery-electric medium trucks for last-mile delivery will reach TCO parity with their diesel counterparts today in most of the European cities considered by the study with the purchase subsidies currently available. Without these subsidies, the parity would be reached by the second half of 2030. Furthermore, adjusting the battery size to a truck's daily mileage and route-level energy needs can help to reduce the truck's purchase price gap relative to its diesel counterpart.

44. Despite continual advancements, the current battery technology is still not sufficiently capable of meeting the high energy demands of HDTs. As indicated in Table 7, the average battery capacity of HDTs does not display a clear upward trend, especially when contrasted with the increasing battery capacity observed in the transit bus market (refer to Table 2). Moreover, the availability of fast and ultra-fast charging infrastructure, crucial for extending driving ranges with less downtime, remains limited. Plans for a more widespread deployment of infrastructure for electric HDVs are set to commence gradually from 2025 onwards.[12]

[12] Source: https://www.consilium.europa.eu/en/press/press-releases/2023/03/28/alternative-fuel-infrastructure-provisional-agreement-for-more-recharging-and-refuelling-stations-across-europe/

Table 7
Average battery capacity (kWh) in medium- and heavy-duty truck models operating worldwide

Vehicle category	*2019*	*2020*	*2021*	*2022*	*Change 2019-2022*
Medium-duty truck	124	139	99	92	-26%
Heavy-duty truck	293	232	372	311	6%

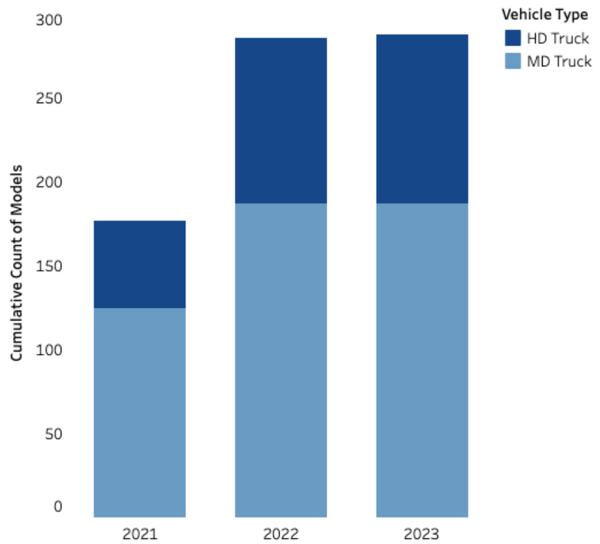
Source: IEA (2023)

45. Another way to reduce the TCO gap between battery-electric and diesel trucks is by increasing the operation costs of the latter. This can be done by factoring the environmental externalities of diesel trucks. The TCO calculation model of the above-mentioned study of ICCT (2022) concludes that imposing emissions charge between €2/day and €4/day per vehicle in low- and zero-emission zones could significantly reduce the TCO gap between battery electric and diesel trucks, allowing TCO parity before 2025.

D. Development of electric truck models and technologies

46. Over the past three years, the range of available electric truck models has significantly grown. Currently, there are nearly 300 battery-electric MDT and HDT models on the market globally, including both existing and upcoming releases (Figure XVI). It is worth noting that the number of electric truck models is nearly triple that of electric LCV models.

Figure XVI
Development of battery-electric MDT and HDT models available worldwide



Source: ZETI Data Explorer.[13] Accessed on 8 June 2023.

47. Truck manufacturers are delivering battery-electric models that are larger, heavier, and capable of carrying greater payloads (Table 8). While there are variations across models, a general trend emerges: larger battery capacities enable trucks to achieve greater ranges, providing increased flexibility for long-haul operations. In the European market, Tesla's Semi model boasts the highest battery capacity of 1,000 kWh, offering a maximum range of 805 km.

48. Payload capacity is a critical factor for commercial trucks, as it directly impacts the volume and weight of goods that can be transported. Scania's electric truck stands out with an estimated maximum payload capacity of 64,000 kg, showcasing the competitive ability of

[13] Source: https://globaldrivetozero.org/tools/zeti-data-explorer/

electric trucks to compete with traditional diesel-powered trucks in terms of payload capacity. However, the still relatively slow market adoption of electric trucks may be attributed to several factors. These include the high-upfront costs, long charging time, limited charging infrastructure, and concerns regarding reliability and unfamiliarity among fleet operators, as discussed in the previous section. The European Union's targets to deploy recharging stations for MDTs and HDTs at least every 60 km in each direction of the TEN-T core network by the end of 2030 should address some of these challenges.

Table 8
Top ten battery-electric HDTs in Europe by OEMs based on range in 2023

OEM	*Model*	*Battery capacity (kWh)*	*Maximum range (km)**	*Estimated maximum payload (kg)*
Tesla	**Semi**	1000	805	37,195
Nikola	**Tre BEV**	753	563	18,144
Quantron	**Q-Heavy**	345	500	13,000
E-Force	**EF18 SZM**	630	500	18,000
Volvo	**FM Electric**	540	380	44,000
Scania	**Scania electric truck**	624	350	64,000
Renault Trucks	**D ZE**	150	300	6,000
GINAF	**E2112**	240	280	6,000
Volta	**Zero**	225	241	15,238
DAF/VDL	**LF**	222	220	11,700

Source: ZETI Data Explorer.[14] Accessed on 8 June 2023.

* Range values were taken from manufacturer estimates based on their own methods, as currently no harmonized test procedure exists (IEA, 2023)

49. [PLACEHOLDER - Good practices of the deployment of electric shared vehicles to be added]

E. Freight consolidation to promote freight transport electrification

50. To address the challenges associated with the adoption of EVs in freight transport, freight consolidation has emerged as a viable solution. It involves combining smaller shipments into larger ones to reduce the number of vehicles needed to transport goods. By maximizing cargo capacity (more goods can be transported in a single trip) and reducing the number of trips required, freight consolidation enables more efficient use of EVs, which have a limited range and require recharging. This can help reduce the cost of EV adoption for logistic companies, while also improving the efficiency and economics of electric freight transport.

51. Since its inception in 2010, the concept of the Physical Internet has been continuously elaborated and evolved. It is a novel approach to designing open and interconnected logistics that promote more efficient and sustainable movement, storage, and use of physical goods.[15] It involves a system of interconnected logistic networks where users and service providers will collaborate, share assets, transport routes and nodes to reach a higher efficiency (Liesa, 2020).

[14] Source: https://globaldrivetozero.org/tools/zeti-data-explorer/

[15] Source: www.freightera.com/blog/physical-internet-a-vision-for-sustainable-secure-resilient-supply-chains/

Figure XVII
Physical internet increases efficiency in goods transport

Source: PierNext[16]

52. According to Pan et al. (2019), there are six classes of horizontal collaboration transport solutions: (a) Single carrier collaboration; (b) Carrier Alliance/Coalition; (c) Transport Marketplace; (d) Flow-controlling entities collaboration; (e) Logistics pooling; and (f) Physical Internet. The Physical Internet reflects the maximum potential of asset sharing and collaboration. Liesa (2020) suggests that ports, as key logistics nodes, will play a crucial role in the Physical Internet as major consolidation and deconsolidation centers, aggregating a massive variety of transport and logistics services easily accessible for end users. By leveraging technology and data, intermodal ports can facilitate the integration of different transportation modes into a single, interconnected network.

F. Conclusion

53. While the trend towards electric LCVs is on the rise, the range of models available for these vehicles is still relatively limited, especially when compared to the variety of electric passenger cars and trucks. This may be attributed to the rapidly changing dynamics surrounding LCVs, leading to solutions that are not mass-marketed and typically come with high upfront costs. This is because urban freight transport is provided as a service to a wide range of sectors, as such fleet operators can only transition to EVs if the vehicles can be operated cost-effectively while meeting the requirements of both operators and end users (ACEA, 2022).

54. The market seems to offer a broader variety of electric truck models than electric LCVs. This disparity could be driven by higher demand in the truck segment, encouraging more OEMs to invest in electric truck production. This is particularly true for HDTs, which are commonly used for long-haul and intercity transportation - sectors under significant pressure to lower carbon emissions. In conclusion, although the technology to electrify freight vehicles segments is mature, the same challenges persist, notably high upfront costs. This issue mirrors the initial hurdles encountered during the early adoption of electric passenger cars. A key solution lies in achieving production volumes that would yield significant economies of scale. The development and scaling up of electric LCV models could be advanced through collaboration between large fleet operators and OEMs, ultimately making electric LCVs more cost competitive (ITF, 2020). UPS, for instance, invested in its designated supplier, Arrival (Box 3).

[16] Source: https://piernext.portdebarcelona.cat/en/technology/introducing-the-physical-internet-the-logistics-network-of-the-future/

Box 3
UPS and Arrival – A Strategic Investment in Green Innovation

UPS demonstrated a strong commitment to green innovation by investing in Arrival, a UK-based EV manufacturer. As part of this investment, UPS placed an order for 10,000 electric vans from Arrival, which will be deployed in the United Kingdom, Europe and North America between 2020–2024. Additionally, UPS has the option to order an additional 10,000 vans within the same period. This investment signalled a key strategic direction for UPS, namely, the company's intention to transition to a zero-emissions fleet.

Arrival’s electric vans offer distinct advantages, including operational cost savings of up to 50 per cent when compared to traditional vehicles. The vehicles were designed to outperform their counterparts in terms of cost, design, and efficiency, offering compelling commercial and environmental benefits.

Arrival's unique approach to vehicle manufacturing is noteworthy. The company utilizes low capital and low footprint micro factories to assemble their vehicles. These micro factories can be strategically located to serve local communities and become profitable from the production of thousands of units. This innovative production model not only reduces capital investment and environmental impact associated with large-scale manufacturing plants, but also allows for the rapid deployment and customization of vehicles to meet local demand.

The partnership between UPS and Arrival has been crucial in developing vehicles that meet UPS's specific requirements. Arrival's flexible skateboard platforms enable the creation of vehicles to match customer requirements in terms of weight, type, size, and shape. The strong strategic partnership has led to the creation of bespoke EVs tailored to UPS's needs, from driving and loading/unloading to depot and back-office operations.

This innovative collaboration between UPS and Arrival provides valuable lessons for other companies seeking to transition to a green fleet. UPS's strategic investment in Arrival highlights the potential benefits of aligning with a dedicated supplier to create a bespoke product that is cost-effective, environmentally friendly, and efficient.

Source: Arrival (2020). Accessed on 8 June 2023.