Alliance for Batteries Technology, Training and Skills

2019-2023

Desk Research Report III.

Other Mobile Battery Applications

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Erasmus+ Programme
of the European Union

Document Title

Delivery	D5.7 Desk research and data analysis for sub-sector IMBA - Release 3		
Title	Desk Research III: Other Mobile Battery Applications		
Responsible Project Partner:	AIA (Lukas Folbrecht)	Contributing Project Partners:	VSB TUO, ITC, CORVUS, HE3DA, ACEA

Document data:	File name:	WP5_Desk Research III.		
	Pages:	124	No. of annexes:	2 (at the end of this document)
	Status:	Final	Dissemination level:	Public use
Project title:	Alliance for Batteries Technology, Training and Skills		GA No.:	2019-612675
WP title:	Work Package 5 Intelligence in Mobile Battery Applications		Project No.:	612675-EPP-1-2019-1-SE-EPPKA2-SSA-B
			Deliverable No:	D5.7
Date:	Due date:	31. 8. 2022	Submission date:	31. 8. 2022
Keywords:	Mobile battery applications, electric trucks, electric vans, electric bikes, electric planes, drones, electric trains, electric scooters, micro-mobility, battery job roles, skills, knowledge			
Reviewed by:	Vaclav Janda, ACEA		Review date:	12. 8. 2022
Approved by:	Zdenek Petzl, AIA		Approval date:	25. 8. 2022

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List of Abbreviations

ABS	Anti-lock Brake System
AC	Alternating Current
ACC	Automotive Cells Company
ACEA	European Automobile Manufacturers Association
AFIR	Alternative Fuels Infrastructure Regulation
BaaS	Battery as a Service
BESS	Battery Energy Storage Systems
BETs	Battery Electric Trucks
BEVs	Battery Electric Vehicles
BMS	Battery Management System
BSS	Battery Swapping System
BTS	Battery Technology Source
CCS2	Combined Charging System Type 2
CO	Carbon Monoxide
CO_2	Carbon Dioxide
DC	Direct Current
EASA	European Union Aviation Safety Agency
e-bike	Electric Bike
ECV	Electrically-Chargeable Vehicles
ETS	EU Emissions Trading Scheme
EVs	Electric vehicles
FAA	US Federal Aviation Agency
FCETs	Fuel Cell Electric Trunks
HC	Hydrocarbons
HCVs	Historic Commercial Vehicles
ICCT	International Council for Clean Transport
ICE	Internal Combustion Engine
IMC	In Motion Charging
ISS	International Space Station
IWT	The European Inland Waterway Transport Platform
kWh	Kilowatt-hour
LCO	Lithium Cobalt Oxide
LCVs	Light Commercial Vehicles
LFP	Lithium Iron Phosphate
LiPo	Lithium-Polymer
$LiFEPO_4$	Lithium Iron Phosphate
LMP	Lithium Metal Polymer
LTO	Lithium Titanate Oxide
LNG	Liquified Natural Gas
LPG	Liquified Petroleum Gas
MCS	Megawatt Charging System
MCVs	Manufacturing Commercial Vehicles
MMfE	Micro-Mobility for Europe
NMC	Nickel Manganese Cobalt
NOx	Nitrogen Oxides
OBC	On-Board Battery Charger
OEMs	Original Equipment Manufacturers

PEMS	Portable Emissions Measurement System
PHEV	Plug-in Hybrid Electric Vehicle
PMDs	Personal Mobility Devices
PN	Particle Number
R&D	Research and Development
RDE	Real Driving Emission
SMEs	Small and Medium-sized Enterprises
SoC	State of Charge
TCO	Total Cost of Ownership
VECTO	Vehicle Energy Consumption Calculation Tool
WHSC	World Harmonized Stationary Cycle
WHTC	World Harmonized Transient Cycle
ZeEUS	Zero Emission Urban Bus System
ZES	Zero Emission Services

Executive Summary

EU vehicle emissions regulations are among the strictest in the world and the most vital **driver of the electrification of transport**. As part of the more comprehensive **European Green Deal**, the EU has introduced several initiatives, one of which is further tightening the CO_2 reduction targets in transport and allocating more funding and effort to **transport decarbonization**.

In 2021, the EU Commission announced the "Fit for 55" proposals to ensure a 55 % reduction in overall emissions by 2030, including e. g. a proposal for a complete ban on internal combustion engine (ICE) powertrains by 2035. After initial resistance, the **European automotive industry** joined the ranks of proponents of speedy electrification and became one of its driving forces.

Moreover, the **war in Ukraine** escalated the need to speed up the **transition from fossil fuels** and increase EU **energy security**. Transport is among the **strategic sectors** where the need to electrify within a relatively **short timeframe** intensified. A group of European countries released a joint statement asking the EU to accelerate the EU climate policy.[1] In response, the EU Commission introduced the **REPowerEU Plan** to transform the European energy system, end the dependence on fossil fuels and fight climate change.[2]

These are just one of the factors influencing the recent **explosion of interest** in batteries and their technologies and the escalation of the need to build the **battery industry in Europe** within years and ensure a **skilled workforce**.

The European Battery Alliance and many other initiatives have been launched at the EU level, accompanied by heavy private investments into "gigafactories" with other companies seeking to explore business opportunities within the emerging battery value chain. However, it needs

[1] Abnett, K. (2022, April 7). *Speed up EU climate policies to wrest free from Russia, 11 countries say*. Reuters. https://www.reuters.com/world/speed-up-eu-climate-policies-wrest-free-russia-11-countries-say-2022-04-07/ (accessed on 12.04.2022)

[2] REPowerEU: A plan to rapidly reduce dependence on Russian fossil fuels and fast forward the green transition. (2022, May 18). European Commission - European Commission. Retrieved August 20, 2022, from https://ec.europa.eu/commission/presscorner/detail/en/IP_22_3131

to be said that the **"batterization" of Europe** happens unevenly - there are regions where gigafactories and other battery-relevant establishments are mushrooming, while other countries and regions are lagging behind.

The "batterization" of **mobile applications**[3] is driven not only by regulation but, in the case of some mobile applications, quite naturally due to technological advancements, customer preferences and new innovative services in shared mobility, delivery and others. This is particularly true with electric bicycles, motorcycles, scooters and drones.

As a part of this desk research, an analysis of job roles and skills currently desired by the companies in **160 job advertisements** was undertaken by the ALBATTS project members and categorised into five groups: 1) design and development; 2) manufacturing; 3) maintenance; 4) sales, services, and support; 5) technical project management.

Across all the mobile battery applications focused on by this desk research[4], the following skills, competencies, and knowledge appeared among the most desired ones: **(vehicle) battery systems, battery management systems (BMS), manufacturing methods and processes, battery testing, maintenance and dismantling, cell design, Li-ion chemistry, knowledge of electronic circuits, legislation, safety and risk management procedures and dealing with hazardous materials.**

Nevertheless, the electrification of various mobile battery applications occurs at different speeds and has **<u>specifics</u>** concerning the drivers of changes, stakeholders involved, the technology used, and job roles and skills needed:

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[3] Another affected segment with a solid impulse to electrify in a short timeframe is **stationary** applications (e. g. households and industries switching from gas and oil to electricity). This area is being dealt with in a parallel D4.7 report by ALBATTS Work Package 4: Industrial and Stationary Battery Applications.

[4] **Heavy-duty vehicles, vans, micromobility devices, e-bikes, aerospace, trains, and inland waterways**. Passenger cars and maritime vessels were analysed in the previous ALBATTS reports, and that is why they are not included in this report.

Trucks

It remains to be seen which technology prevails in the trucks segment - the **battery technology** is going to compete with the internal combustion engine (diesel) as the currently dominant technology, but also with other alternative fuels, such as LNG (liquified natural gas) or, in particular, with fuel cell technology.

However, the pressure from the EU regulation to decarbonise freight transport is so high that heavy R&D investments can be expected to lead sooner or later to a technological breakthrough enabling to use of battery technology massively in the freight segment. **AFIR** and other legislation currently being negotiated are expected to ensure the rollout of the **charging infrastructure** across the EU, allowing for a seamless operation of the battery trucks.

Similar to the passenger cars segment, training and re- and -up-skilling of the relevant workforce needs to consider, among other areas, the **development, production and end-of-use** phrases relevant to the trucks. Qualified personnel for **servicing** electric trucks will need to be available across Europe, having a combination of **mechanic, high-voltage, battery diagnostics and IT skills**. A robust charging infrastructure with **increased power outputs** will need to be rolled out, reflecting the trucks' specific needs, potentially requiring specific skills and competencies.

In larger companies, fleet management will require **IT skills**. In addition, future technology developments such as **wireless charging** or using **pantographs** might also impact job roles and skills needs.

Buses

Like trucks and other heavy-duty vehicles, the battery technology will compete with the currently dominating diesel technology and alternatives such as fuel cell or LNG. Nevertheless, there are strong drivers of electrification, such as **EU procurement targets** or policies of individual **regions and cities** aiming to reduce **noise and air** pollution in city centres.

Alternative concepts, such as using **rails, pantographs** or static or dynamic **induction charging**, are being tested – a breakthrough in these technologies would enable a bus to carry fewer batteries and adequately **more passengers** and go to **longer routes**.

Battery-relevant job roles and skills are analogous to trucks: trained personnel must be there to deal with the **production, servicing, operation and disassembly of the batteries and high-voltage components**. **IT skills** are needed in the area of fleet management and **route planning,** and **organisation**.

Utility vehicles

Often move within city centres, and their electrification would bring many benefits to its inhabitants, such as **less noise** and **air pollution**. However, quite surprisingly, the EU legislative instruments seem to be **less strict** than in the segment of passenger cars, vans or trucks. Nevertheless, due to the policies of individual regions and cities, they are **making their way** to the market. Specific job roles and skills relevant to the utility vehicles segment are largely similar to those concerning trucks and buses.

Vans

Vans are **commercial** vehicles used for the transport of **people or goods**. The segment and the battery technology used appear similar to passenger cars. The EU CO2 emission regulation is also among the key drivers of change. However, the **total costs of ownership** (TCOs) play a more important role here.

There are some specifics – vans as commercial vehicles are expected to be **busier** and **more often charged**. They might be used by various personnel in a **company** or a **rental service,** so they need to be more **robust**. Vans used by craftsmen or maintenance need to be designed to power their **tools.**

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Relevant job roles and skills appear similar to those concerning **passenger cars** (for details, see the first ALBATTS WP5 desktop research[5]), with some specifics listed in the respective Job roles and skills chapter.

Motorbikes

The electrification of motorbikes is much more driven by **customer demand** than regulation. Electrified motorbikes and mopeds have been in everyday use in China and other countries **for years,** and they have started to find their way to the European market, especially in the **shared services** market, since they are easy to use and have low running costs.

Specifics concerning e-motorbike battery-relevant **job roles and skills** include e. g. monitoring the **state of charge (SoC**) and execution of **battery-swapping** within shared mobility services

Micromobility

E-scooters and other personal mobility devices are a fast-growing segment driven by customer demand, not regulation. Like other battery applications, Europe is heavily importing micromobility devices but is only starting to catch up with their **production**. Significant business opportunities lay not only in the area of manufacturing but also in the area of **shared services**, for example.

Battery-relevant job roles and skills are somewhat similar to the other mobile applications, with **Systems Engineers for BMS** and **Product Design Managers** among the most desired job roles. In addition, micromobility, related shared services, and fleet management require strong **electronics/electrical** and **IT/software engineering** skills.

Electric bikes

Electric bikes have been in everyday use in Asia for years, and their sales are **booming** in Europe, particularly Germany, Netherlands, France and Italy. The technology is considered

[5] ALBATTS project. (2020, August 31). *Intelligence in Mobile Battery Applications Desk Research Report*. ALBATTS Project Website. Retrieved August 19, 2022, from https://www.project-albatts.eu/Media/Publications/4/Publications_4_20200930_12811.pdf

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mature, and battery capacity as well as **range** (in contrast to the situation of trucks, for example) is **sufficient**. Specific job roles include servicing or **replacing** malfunctioning or end-of-life **battery packs** and **cells**.

Aerospace

The batteries used outside the earth in **spaceships** or **satellites** need specific parameters to work in extreme conditions (very cold or hot temperatures) with minimal maintenance possibilities.

Initially primarily used for military, scientific and surveillance purposes, **drones** have been making their breakthrough in the hobby and commercial areas, such as future delivery services. The use of batteries in **planes** has been somewhat limited, but there are some interesting use cases for it and relevant pilot projects.

Inland waterway vessels

Electrification of vessels is also in a relatively early stage, but there is some demand for it, particularly in city centres and areas where clean air is desired. Pilot projects are running across Europe, particularly in the **Netherlands**. One of the biggest obstacles is the lack of **charging infrastructure**.

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1 Introduction and Methodology

The **first** desktop research report[6] released in August 2020 covered all battery value chain steps and relevant job roles and skills, with some focus on electric passenger cars and maritime vessels.

The **second** desktop research report[7] released in August 2021 provided an overview of the possible future technological development of batteries, the stakeholders involved, and relevant job roles and skills. It included recommendations for education and up- and reskilling of the workforce.

<u>**This (third) report**</u> studies areas **not covered** in the previous desktop research - the application of batteries in:

- **heavy-duty vehicles** – trucks, buses, utility vehicles
- **vans**
- **motorbikes**
- **micro-mobility devices**
- **e-bikes**
- **aerospace** – drones and planes
- **trains**
- **inland waterway vessels.**

It builds on and expands knowledge gathered in the two previous reports of the project Work Package 5: Mobile Battery Applications. The purpose is to get a deeper understanding of **technological developments** and related **job roles, skills and competencies**.

[6] ALBATTS project. (2020, August 31). *Intelligence in Mobile Battery Applications Desk Research Report*. ALBATTS Project Website. Retrieved August 19, 2022, from https://www.project-albatts.eu/Media/Publications/4/Publications_4_20200930_12811.pdf

[7] ALBATTS Project. (2021, August 31). R&D and Technological Perspectives for the Battery Sector. ALBATTS Project Website. Retrieved August 19, 2022, from https://www.project-albatts.eu/Media/Publications/21/Publications_21_20210831_213355.pdf

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ALBATTS conducted detailed desktop research based on **data** available on company websites, press releases, and scientific and technical publications. In addition, some knowledge results from previous research work and individual contacts of the project partners within the industry.

Further to new findings on job roles and skills identified within the desktop research, the project partners gathered data relevant to job roles and skills from over a hundred job advertisements on the internet, which very well reflect the **actual needs** of the battery business. The data from job advertisements was combined with the desktop research findings.

The authors acknowledge the certain discrepancy between the length and level of detail in individual chapters as these were processed by different ALBATTS project **Work Package 5** members: AIA, HE3DA, ITC, and CORVUS.

2 Heavy-Duty Vehicles

2.1 TRUCKS

2.1.1 Drivers of Change

Drivers of change are factors that are key to transforming an industry. Specifically, a literature review of available reports was undertaken to create an overview of current Drivers of Change and their relevance in the sector. Like in the case of passenger cars, increasingly strict **emission regulations** and technology developments of lithium-ion batteries are among the key factors driving the truck segment towards its electrification.

The European emission standard was established in 1992 via the norm EURO I. to lower pollutants (such as NO_X, CO and PN) in exhaust emissions and improve air quality. The currently valid **pollutant emission standard** is EURO VI, which was introduced on 31 December 2012 by Regulation (EC) No 595/2009[8] and implemented and amended by Commission Regulation (EU) No 582/2011[9]. Since then, several revisions have added new, stricter conditions and measurements (the last one is the so-called Step E – see Commission Regulation (EU) 2019/1939).

EURO VI also brought new **measurement cycles**, which more accurately simulate the real operation of heavy-duty vehicles. They are the World Harmonized Transient Cycle (WHTC) and the World Harmonized Stationary Cycle (WHSC), particle number (PN) emission limits, or PEMS (portable emissions measurement system) testing.[10] Furthermore, the European Commission foresees the publication of a proposal for a new, stricter Euro VII standard for summer 2022.

[8] *REGULATION (EC) No 595/2009 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL.* (2009). https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:02009R0595-20200901 (accessed on 17.03.2022)

[9] *COMMISSION REGULATION (EU) No 582/2011.* (2011). https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:02011R0582-20180722 (accessed on 17.03.2022)

[10] *EU: Heavy-duty: Emissions | Transport Policy*.. Transport Policy. https://www.transportpolicy.net/standard/eu-heavy-duty-emissions/ (accessed on 17.03.2022)

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Heavy-duty vehicles are a source of ca **25 %** of EU CO_2 emissions from road transport and ca 6 % of total EU emissions. [11] **CO_2 emission** standards for heavy-duty vehicles were adopted in 2019 (Regulation (EU) 2019/1242[12]). They set targets for reducing the average CO_2 emissions from new trucks for 2025 by 15 % and 2030 by 30 % compared to the reference period (1 July 2019–30 June 2020). Furthermore, the announced review, which the European Commission should publish at the end of 2022, could contain the extension of the scope to other vehicle types, such as smaller trucks, buses, coaches, and trailers, asses the 2030 target, and set targets beyond 2030.[13]

Another essential piece of legislation currently being negotiated by the EU institutions is the proposal of the European Commission (document COM(2021) 559) for the Alternative Fuels Infrastructure Regulation (**AFIR**). It introduces mandatory targets for EU member states to roll out charging infrastructure for heavy-duty vehicles to enable domestic and international freight transport.

As shown in **Figure 1,** diesel-powered trucks were still dominant in 2021, with a 95.8 % market share of newly registered vehicles (255,099 units). The alternative fuels such as LPG, biofuels, ethanol, etc. have 3.6 % (9,688 units) and **battery electric trucks (BETs) 0.5 %** (1,243 units). **Figure 2** shows a **26.6 %** annual demand increase for electric medium and heavy commercial vehicles, and **Figure 3** shows a prediction of the sales worldwide, where sales of electric trucks are expected to multiple.

[11] *Reducing CO_2 emissions from heavy-duty vehicles*. (2019). Climate Action. https://ec.europa.eu/clima/eu-action/transport-emissions/road-transport-reducing-co2-emissions-vehicles/reducing-co2-emissions-heavy-duty-vehicles_en (accessed on 18.03.2022)

[12] *REGULATION (EU) 2019/1242 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL*. (2019). https://eur-lex.europa.eu/eli/reg/2019/1242/oj(accessed on 18.03.2022)

[13]*Reducing CO_2 emissions from heavy-duty vehicles*. (2019). Climate Action. https://ec.europa.eu/clima/eu-action/transport-emissions/road-transport-reducing-co2-emissions-vehicles/reducing-co2-emissions-heavy-duty-vehicles_en (accessed on 18.03.2022)

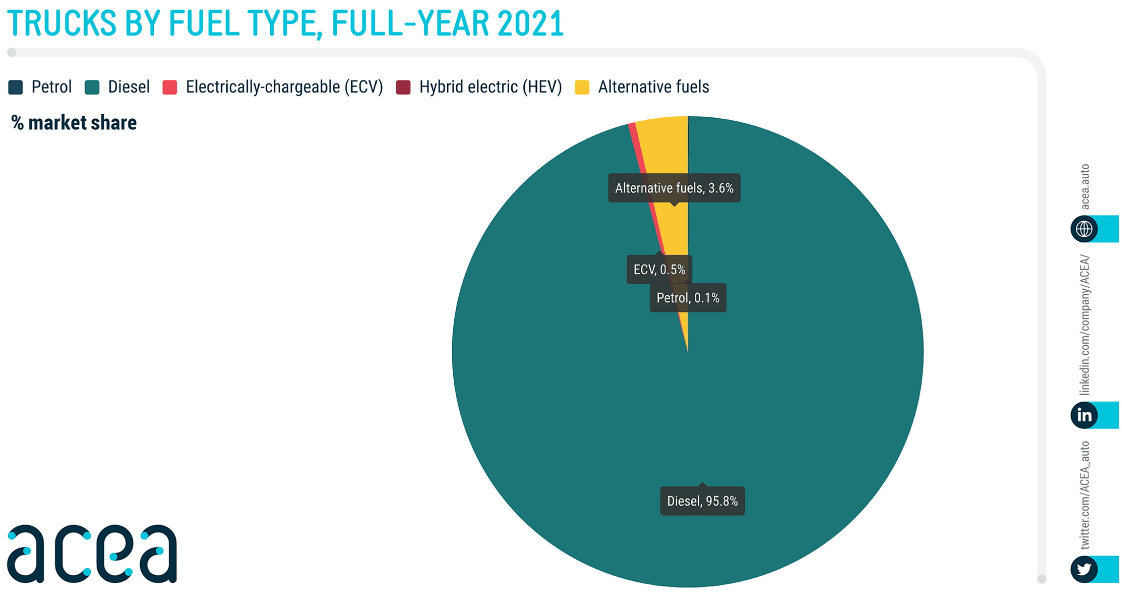

Figure 1: New medium and heavy commercial vehicle registrations by fuel type [14]

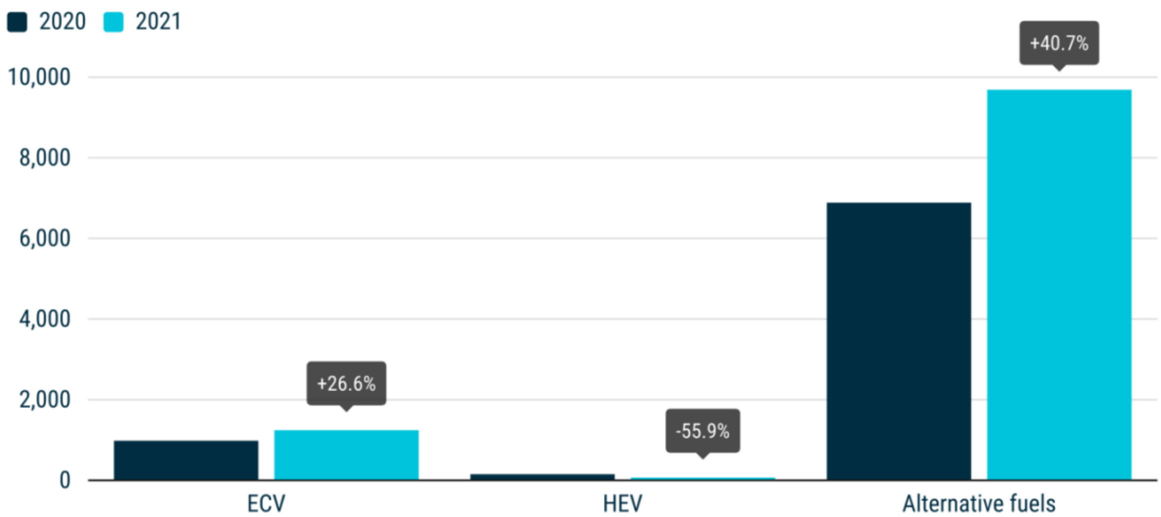

Figure 2: New medium and heavy commercial vehicle registration with alternatively powered systems[14]

[14] ACEA editor. (2022, March 16*). Fuel types of new trucks: diesel 95.8%, electric 0.5%, alternative fuels 3.6% share full-year 2021*. ACEA - European Automobile Manufacturers' Association. https://www.acea.auto/fuel-cv/fuel-types-of-new-trucks-diesel-95-8-electric-0-5-alternative-fuels-3-6-share-full-year-2021/ (accessed on 18.05.2022)

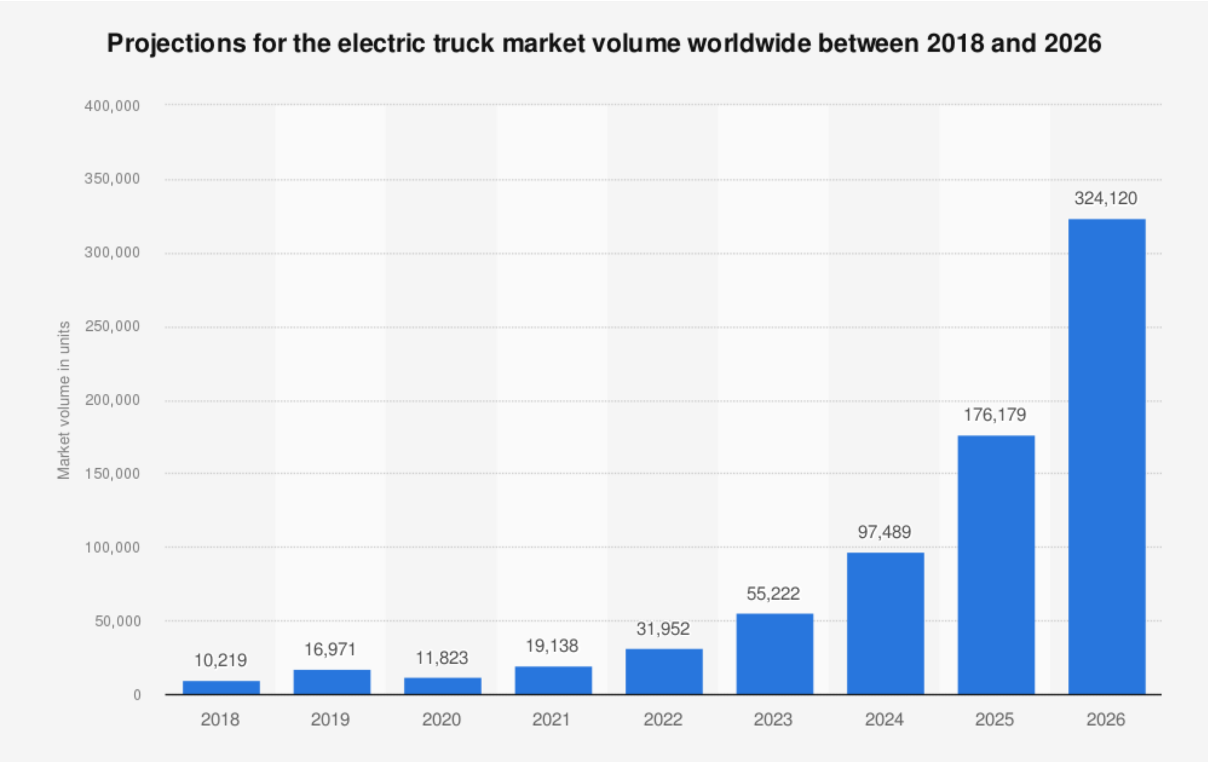

Figure 3: Prediction of worldwide sales of battery electric trucks[15]

2.1.2 Stakeholders

Figure 4: Example of battery electric truck producers

[15] Statista. (2022, January 11). *Projected global electric truck market volume 2018–2026*. https://www.statista.com/statistics/1273761/electric-truck-worldwide-market-forecast/ (accessed on 18.05.2022)

2.1.3 Technology

The battery technology of Battery Electric Trucks (BETs) is somewhat similar to BEVs. BETs use the same kind of batteries as passenger Battery Electric Vehicles (BEVs) but on a larger scale. Passenger cars typically have one big battery pack at the bottom. In the case of BETs, there are several battery packs connected to the truck platform **(see Figure 5)**.

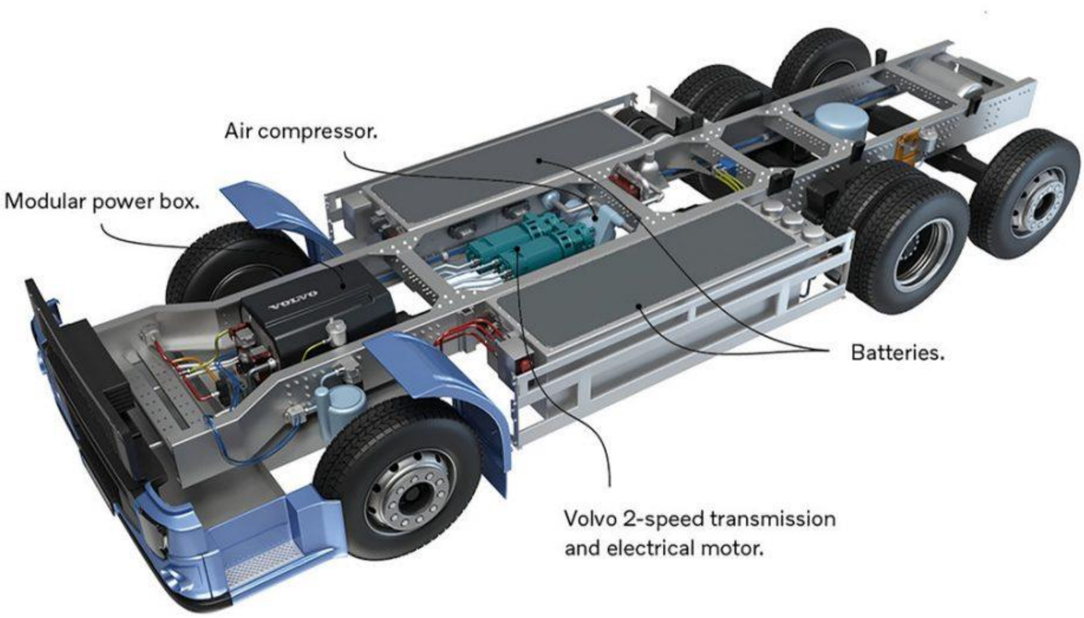

Figure 5: Volvo BET platform[16]

The current technological level in the field of batteries opens the possibility of considering batteries as a viable option to power trucks. However, there are still some **challenges** relevant to their full electrification. One of them is different regulations concerning the truck operation in individual European countries.[17,18]

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[16] *Navigating the future with electric trucks*. (2018). [Illustration]. https://www.volvotrucks.com/en-en/news-stories/magazine-online/2018/dec/electric-transition.html (accessed on 01.03.2022)
[17] Battery electric tractor-trailers in the European Union: A vehicle technology analysis. (2021). *INTERNATIONAL COUNCIL ON CLEAN TRANSPORTATION*. https://theicct.org/wp-content/uploads/2021/12/eu-tractor-trailers-analysis-aug21-2.pdf (accessed on 01.03.2022)

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Table 1: Examples of battery electric trucks (adapted to BETs model year 2022)[18]

Manufacturer	Model	Type	Maximum weight [t]	Battery capacity [kWh]	Range [km]	Consumption [kWh/ 100 km]	Charging AC/DC [kW]
Mitsubishi	eCanter	Medium duty	7.5	82.8	120	69	-
BYD	T7M	Medium duty	11.8	221.6	>261	85	100/150
Freightliner	eM2 106	Medium duty	12	325	370	88	260
Volvo	FL Electric	Rigid	16.6	200-395	Up to 300	Up to 100	22/150
Renault	D Z.E	Rigid	16.7	200-300	Up to 300	Up to 100	22/150
eMoss	EMS18	Rigid	18	120-240	100-250	100	22/44
Mercedes-Benz	eActros	Rigid	26	315-420	Up to 400	106	22/160
Renault	D WIDE Z.E	Rigid	27	200	200	100	22/150
BYD	Q3B	Semitrailer	36	348	>150	232	100/150
Freightliner	eCascadia	Semitrailer	40	475	400	119	260

As can be seen in **Table 1**, EU producers have AC charging speed limited to 22 kW, which might be fine for passenger cars but is insufficient for trucks. Furthermore, almost half of the trucks researched in this report have a maximum range of 200 km or less, meaning they are well usable for city hauling but by far not ideal for longer international journeys. For long international hauls, there is a need to have a range of at least 400-500 km for most of the vehicle's lifespan.

In the case of trucks, the maximum speed in most EU countries is 80 or 90 km/h[19], and the driver must have a break every 4.5 hours, and the break should be at least 45 minutes long. It means that a range of 400 km should be enough if there is a possibility of fast charging at the final destination, and the truck can be charged in that resting time. However, as seen in **Table 1,** Mercedes, Renault, and Volvo (trucks operating in the EU) have a maximum charging power of about 150 kW, so the battery would need at least two hours of charging. With this in mind,

[18] Liimatainen, H., van Vliet, O., & Aplyn, D. (2019). The potential of electric trucks – An international commodity-level analysis. *Applied Energy, 236*, 804–814. https://doi.org/10.1016/j.apenergy.2018.12.017 (accessed on 01.03.2022)
[19] *European Commission - Road Safety.* (2022). Going Abroad. https://ec.europa.eu/transport/road_safety/going_abroad/spain/speed_limits_en.htm

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it is clear that with this state of technology, it would be rather challenging to achieve a 100 % shift to fully electric trucks and that further technological progress in batteries is needed. [17,18,20]

Another possible technology to ensure zero-emission trucks is to power them with **hydrogen - Fuel cell electric trucks (FCETs) (see Figure 6).** They work similarly to hydrogen passenger cars but have much bigger fuel cells and batteries (even though batteries are much smaller than in BETs). According to the study made by Transport & Environment, FCETs need a battery of **10 % the size** of BETs battery.[21,22]

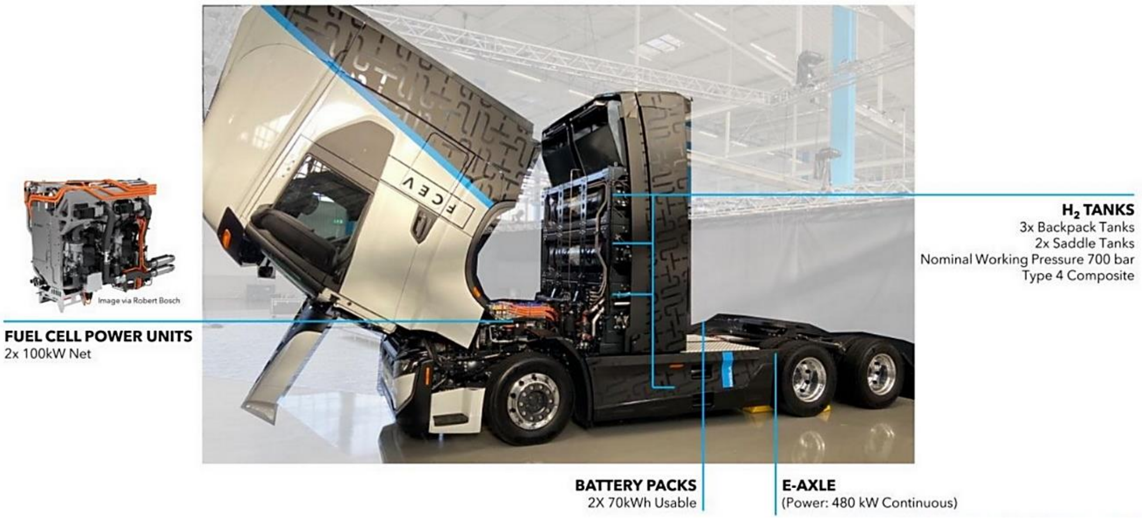

Figure 6: Construction of FCET made by Nikola[23]

[20] Furnari, E., Johnnes, L., Pfeiffer, A., & Sahdev, S. (2020, October 27). *Why most eTrucks will choose overnight charging*. McKinsey & Company. https://www.mckinsey.com/industries/automotive-and-assembly/our-insights/why-most-etrucks-will-choose-overnight-charging (accessed on 07.03.2022)

[21] *Comparing hydrogen and battery electric trucks*. (2021, August 26). Transport & Environment. https://www.transportenvironment.org/discover/comparing-hydrogen-and-battery-electric-trucks/ (accessed on 15.03.2022)

[22] *How does a hydrogen fuel cell electric truck work?* (2020). Scania Group. https://www.scania.com/group/en/home/newsroom/news/2020/how-does-a-hydrogen-fuel-cell-electric-truck-work.html (accessed on 15.03.2022)

[23] Ruffo, G. H. (2022, March 31*). Nikola Releases Interesting Technical Details of the Tre FCEV*. Autoevolution. https://www.autoevolution.com/news/nikola-releases-interesting-technical-details-of-the-tre-fcev-185304.html#agal_0 (accessed on 15.05.2022)

Charging

BETs use the same charging technology as BEVs - charging from a charging station via AC or DC charger. In the EU, BETs use the same **charging port** as BEVs: *Type 2* for AC charging and *CCS2* for DC charging. In the case of charging power, an electric EU norm defines maximal **AC** power as **22 kW**. The maximum power of *CCS2* limits **DC** charging to **500 kW.** For example, charging stations established by DAF or by IONITY for passenger cars can provide such power. Charging with a high voltage with lower ampers is more efficient and generates less heat[24,25].

Apart from the conventional way of charging, possibilities of **stationary or dynamic wireless charging** are being investigated. For example, a testing road with dynamic wireless charging is located in Gotland, Sweden. The first tests started in 2019 on a 50-meter-long track with a speed of 30 km/h and a charging power of 45 kW. This project aims to achieve 125 kW with a speed of 90 km/h.[26]

Another way of charging is by using **pantographs**. This way of powering of BETs has been tested in Sweden, Germany, and other countries. The technology well known from the railways is also suitable for highways. Trucks connect by a pantograph to the net on the highway, get electricity from the grid and charge the battery. This combination would allow for smaller batteries in the BET as they only need batteries to travel from and to the highway[27].

In March 2022, an ACEA study overviewed the required charging capacities available for BETs across Europe. According to the study, the currently used charging standard cannot cover the BETs' needs. Therefore, a new charging standard called **Megawatt Charging System (MCS)** shall be introduced, enabling charging with a speed over 1 MW, which is better suitable to charge BETs, ideally within the 45-minute resting break. According to the ACEA study, in

[24] *EV Charging Definitions, Modes, Levels, Communication Protocols and Applied Standards*. (2020). Ali Bahrami. https://doi.org/10.13140/RG.2.2.15844.53123/11 (accessed on 07.03.2022)

[25] DAF Trucks N.V. (2021, April 29). *DAF introduces charging stations for electric vehicles*. DAF Trucks. https://www.daf.com/en/news-and-media/news-articles/global/2021/q2/29-04-2021-daf-introduces-charging-stations-for-electric-vehicles (accessed on 07.03.2022)

[26] *Successful start for world's first wireless electric road for trucks*. (2020, March 18). News Powered by Cision. https://news.cision.com/electreon-ab/r/successful-start-for-world-s-first-wireless-electric-road-for-trucks,c3062153 (accessed on 07.03.2022)

[27] *A Study on E-Highway - Future of Road Transportation*. (2019). International Journal of Engineering and Advanced Technology. (accessed on 07.03.2022)

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a scenario ensuring a 30 % CO_2 reduction, there will be a need for over **40,000 public fast chargers** for electric trucks and busses and lots more in the fleet hubs[28].

2.1.4 Job, Roles and Skills

Job roles relevant to batteries in BETs include the following:

- **R&D** – developing and designing batteries and other electrical systems (e. g. BMS, BTS, OBC)
- **Manufacturing** – battery pack/modules assembly
- **Servicing** – servicing or replacement of malfunctioning or end-of-life battery cells, packs, and modules, refurbishing of the battery packs
- **Operation** – education in the field of charging for drivers
- **Disassembly** - of end-of-life vehicles and battery packs

2.2 BUSES

2.2.1 Drivers of Change

CO_2 emission limits, the critical driver of change of electrification of passenger cars and vans, do not concern the bus segment as of now. However, a revision of Regulation (EU) 2019/1242[29] is scheduled for the end of 2022. It envisages assessing the scope extension from large lorries to other vehicles (like **buses**, coaches, and trailers). The introduction of CO_2 limits to buses would be enabled by the VECTO (Vehicle Energy Consumption Calculation Tool), a simulation tool with five different mission profiles for trucks and five different mission profiles for buses and coaches.[30]

Similar to trucks, the segments of buses and coaches and their pollutants in exhaust emissions are regulated by EURO standards, currently EURO IV Step E. According to the plans of the European Commission, a proposal for **the EURO VII standard** should be published before the

[28] *European EV Charging Infrastructure Masterplan*. (2022). ACEA. https://www.acea.auto/files/Research-Whitepaper-A-European-EV-Charging-Infrastructure-Masterplan.pdf
[29] *Reducing CO_2 emissions from heavy-duty vehicles*. (2019). Climate Action. https://ec.europa.eu/clima/eu-action/transport-emissions/road-transport-reducing-co2-emissions-vehicles/reducing-co2-emissions-heavy-duty-vehicles_en (accessed on 18.03.2022)
[30] *Vehicle Energy Consumption calculation TOol - VECTO*. (2022). Climate Action. https://ec.europa.eu/clima/eu-action/transport-emissions/road-transport-reducing-co2-emissions-vehicles/vehicle-energy-consumption-calculation-tool-vecto_en (accessed on 20.04.2022)

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end of 2022. Another critical driver of change is measures adopted by **cities**, be it through **low-emission zones** or by purchasing or contracting low- and zero-emission vehicles, particularly in the area of **public transport** (low-and zero-emission busses, city trains, tramways and trolleybuses).

In the EU, specific national targets are set in the **public procurement** tenders, public service contracts and services contracts (see Directive 2019/1161/EU on the promotion of **clean and energy-efficient road transport vehicles**).[31] As for category M3 - buses and coaches (here, it applies to category M3 Class I & Class A[32] only), the definition of "clean vehicle" covers vehicles running on any of the alternative fuels listed in the Alternative Fuels Infrastructure Directive (Directive 2014/94/EU[33]), particularly the electric buses. At the same time, half of the minimum targets for the share of clean buses need to be fulfilled by procuring zero-emission buses (meaning battery electric or fuel cell).

In the Directive, the definition of "clean vehicle" in **category M2** ("minibuses", vehicles up to 5 t for more than eight passengers in addition to the driver) is stricter. These need to be vehicles with maximum CO_2 emissions of 50 g/km and below 80 % of air pollutant emissions limits (declared maximum real-driving emission (RDE) values of particles number (PN) in #/km and nitrogen oxides (NO_X)) by the end of 2025. As of 2026, only zero-emission vehicles (meaning battery electric or fuel cell) will comply with Directive 2019/1161/EU.

Last but not least, **research and development** and testing support are also drivers of change. To name just one of the projects funded by the EU research and innovation framework programme, **ZeEUS** (the Zero Emission Urban Bus System) aim was to help to spread the electric buses to urban networks.[34] In ten demonstration sites across Europe, ZeEUS was testing electric bus technology with various charging infrastructure options. It aimed to

[31] *Clean Vehicles Directive*. (2022). Mobility and Transport. https://transport.ec.europa.eu/transport-themes/clean-transport-urban-transport/clean-and-energy-efficient-vehicles/clean-vehicles-directive_en (accessed on 14.04.2022)
[32] Defined in paragraph 2.1 of UN Regulation No 107: Class I - vehicles constructed with areas for standing passengers, to allow frequent passenger movement; Class A - vehicles designed to carry standing passengers, a vehicle of this class has seats and shall have provision for standing passengers (https://unece.org/sites/default/files/2021-05/R107r7e.pdf)
[33] *EUR-Lex - 32014L0094 - EN - EUR-Lex*. (2014). Directive 2014/94/EU. https://eur-lex.europa.eu/legal-content/en/TXT/?uri=CELEX%3A32014L0094 (accessed on 14.04.2022)
[34] *Home – ZeEUS – Zero Emission Urban Bus System*. (2014). ZeEUS. https://zeeus.eu/ (accessed on 23.06.2022)

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demonstrate the electric solutions' economic, environmental, and societal viability due to the diverse geographic and topographical factors.

In 2019, all alternatively-powered buses made 4.3 % and battery and plug-in hybrids 0.6 % (over 4 thousand vehicles) of the EU fleet.[35] At the end of 2021, there were over **8,500 electric buses** in Europe (battery-electric buses, plug-in hybrids, trolleybus IMC and fuel cell).

Urban and suburban buses account for 55.7 % of all public transport journeys in the EU. Buses and coaches represent 8.5 % of all passenger land travel.[36] There are around **700,000 buses** in circulation on the EU's roads. In 2021, new bus sales comprised **31.2 %** of alternatively-powered vehicles (battery-electric, plug-in hybrid, hybrid and alternative fuels, including natural gas and LPG). Battery-electric and plug-in hybrid buses represented **10.6 %** of first registrations (3,064 units).[37] They have been gradually altering the vehicle fleet.

Due to the legislation mentioned above concerning public tendering, ING predicts a significant increase from 2023 and **by 2030** an **eight-fold growth (see Figure 7)** in the fleet of e-buses in the EU, with the average percentage of zero-emission buses rising to **67 %** of new sales.[38] Currently, Western European countries are amongst the most promising markets, especially the Netherlands (due to their national target), Germany, the UK, France, Italy and Nordic countries.

[35] *Automobile Industry Pocket Guide 2021–2022.* (2021, September 29). ACEA - European Automobile Manufacturers' Association. https://www.acea.auto/publication/automobile-industry-pocket-guide-2021-2022/ (accessed on 21.05.2022)
[36] *Fact sheet: buses*. (2021, October 26). ACEA - European Automobile Manufacturers' Association. https://www.acea.auto/fact/fact-sheet-buses/ (acccessed on 21.5.2022)
[37] *Fuel types of new buses: electric 10.6%, alternative fuels 10.5%, hybrid 10.1%, diesel 68.8% share in 2021*. (2022, March 16). ACEA - European Automobile Manufacturers' Association. https://www.acea.auto/fuel-cv/fuel-types-of-new-buses-electric-10-6-alternative-fuels-10-5-hybrid-10-1-diesel-68-8-share-in-2021/ (accessed on 21.05.2022)
[38] Luman, R. (2021, October 4). *All aboard Europe's electric bus revolution*. ING Think. https://think.ing.com/articles/all-aboard-europes-electric-bus-revolution-290921 (accessed on 26.06.2022)

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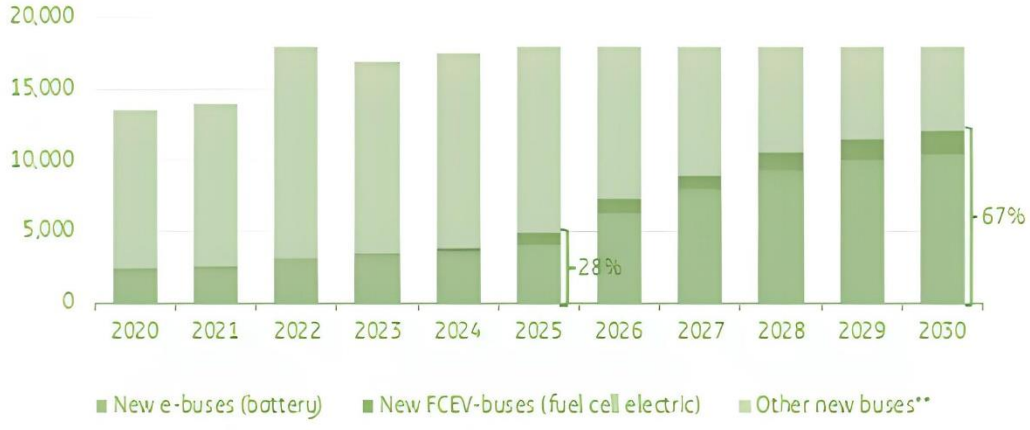

Figure 7: New registrations in Europe and zero-emission bus shares per year[38]

Gradually, similarly to passenger cars, the market will be moving to be more driven by consumers and less by policy/legislation.[39] According to BloombergNEF's Electric Vehicle Outlook 2022, electric bus sales are continuously increasing; now, **18 %** of the global fleet and **44 %** of new sales are electric buses. Even though activity is increasing in other countries, including the EU, **98 %** of the world's e-bus fleet is still in **China**.

By 2040, there should be 1.75 million electric buses operating worldwide, accounting for **62 % of all buses** on the road. Buses powered by hydrogen fuel cells also have a place in particular markets **(see Figure 8)**, especially where there is government support and interest in the technology. As for municipal buses, the development in the US is slower than in China and the EU, but there is an enormous potential to electrify **school buses**.

[39] *EVO Report 2022 | BloombergNEF | Bloomberg Finance LP*. (2022, June 1). BloombergNEF. https://about.bnef.com/electric-vehicle-outlook/ (accessed on 25.06.2022)

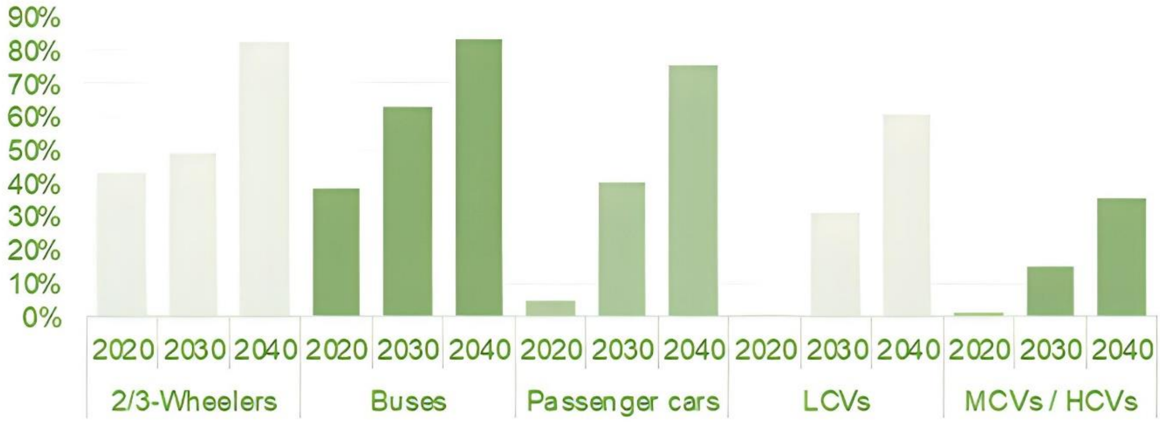

Figure 8: EV share of global new vehicle sales by segment[39]

2.2.2 Stakeholders

China is the most significant player in the electric buses segment in terms of vehicles in the fleet (as described above; in 2021, there were 685,000 electric buses[39]) as well as production. **BYD**, **Yutong** and **CRRC** are among the largest producers of electric buses globally. However, there are several European producers as well. Producers of the electric buses are shown in **Figure 9,** and producers of fuel cell buses are in **Figure 10**.

Figure 9: Producers of electric buses (selection)

Figure 10: Producers of hydrogen/fuel cell electric buses (selection)

2.2.3 Technology

The table below shows that the battery chemistry mainly used in battery electric buses is lithium nickel manganese cobalt (**NMC**) or lithium iron phosphate (**$LiFePO_4$**). The range of the buses varies between **200 km** and **400 km,** and battery packs with a capacity between **100 kWh** and up to **700 kWh**; for more detailed information on various bus models and their technical details, see **Table 7** in **Annex B**. To see how the batteries and other electric components can be applied in a bus, see **Figure 11**). Lithium titanate oxide (**LTO**) chemistry is used mainly in trolley buses´ traction batteries.

Bolloré (bluebus) and Mercedes-Benz (currently using NMC) plan to introduce solid-state (lithium metal polymer (**LMP**)) batteries; their advantage is high energy density for longer ranges, and long service life, while no battery cooling is required. However, they are not suitable for high-speed charging.[40] For construction details of a fuel cell bus, see **Figure 12**.

[40] *Mercedes-Benz Buses: eCitaro: Technology*. (2022). Mercedes-Benz Buses. p(accessed on 03.07.2022)

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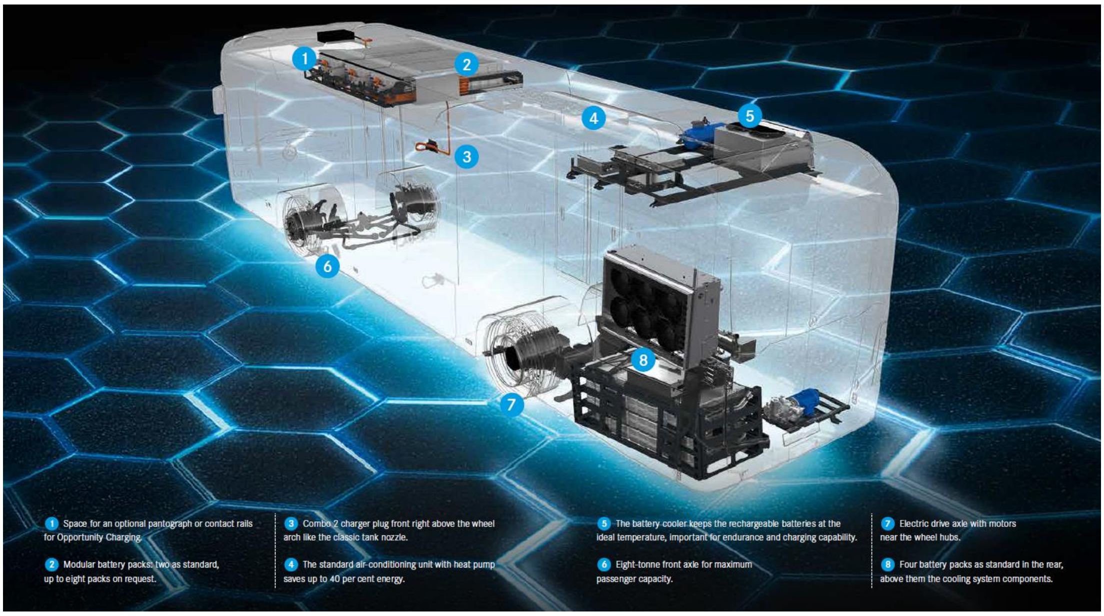

Figure 11: Example of battery electric bus model[41]

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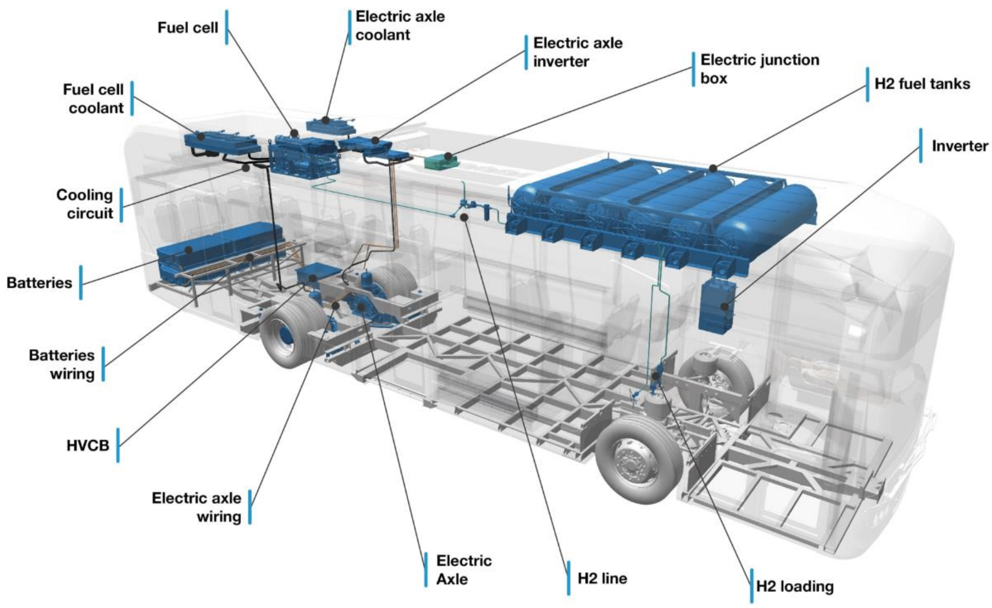

Figure 12: Example of fuel cell electric bus model[42]

41 Randall, C. (2022, June 9). *MAN to release electric bus chassis globally*. Electrive.Com. https://www.electrive.com/2022/06/09/man-to-release-electric-bus-chassis-globally/ (accessed on 04.07.2022)

42 *SAFRA, manufacturer of electric buses on the Busworld exhibition in Brussels*. Safra. https://safra.fr/en/safra-manufacturer-of-electric-buses-on-the-busworld-exhibition-in-brussels/ (accessed on 03.07.2022)

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Charging

When operating an e-bus fleet, a plan must be well prepared with places and times of charging. Additionally, the charging technology needs to be selected based on the local conditions, the route length, or the route or customer´s demand/operational plan. Three main charging technologies are available for electric buses (see also the table above):

- **Depot plug charging** (AC or DC, for slower overnight/not-in-operation charging) **(see Figure 13)**

Figure 13: Depot charging stations[43]

- **Via pantograph** - fast, high-performance charging. The pantograph can be placed on the bus's roof or the charging mast - see **Figure 14.**

[43] eCity powered by Solaris. (2022, March 16). *Transportation in Rzeszów*. https://ecity.solarisbus.com/en/e-mobility/transportation-in-rzeszow (accessed on 14.07.2022)

Figure 14: Iveco bus with pantograph charging[44]

- Charging via **charging rails** - continuous charging with less demand on the capacity of the traction battery - see **Figure 15**.

Figure 15: Van Hool trolleybus with rail charging[45]

[44] Editorial Staff. (2021, March 17). *Fast charging stations for electric buses installed in Milan. 170 e-buses by end 2021*. Sustainable Bus. https://www.sustainable-bus.com/electric-bus/fast-charging-station-electric-buses-atm-milano/ (accessed on 14.07.2022)

[45] ExquiCity18 Trolley | *Van Hool*. (2022, June 7). Van Hool. https://www.vanhool.com/en/vehicles/public-transport/trolley/exquicity18-trolley (accessed on 14.07.2022)

Apart from the mentioned charging possibilities, opportunity charging can also be wireless (inductive) - see **Figure 16**.[46,47] The advantage of this solution is that the battery capacity can be smaller, requiring less space and thus enabling more passengers to fit inside.

Figure 16: Wireless charging spot in Madrid located at the beginning and the end of the route

2.2.4 Job Roles and Skills

Example of job roles and skills relevant to electric busses

- Mechatronics technicians [48;49;50]
- Vehicle charging and operation¨
- Troubleshooting, repair [51]

2.3 UTILITY VEHICLES

2.3.1 Drivers of Change

Utility vehicles can be defined for the purpose of this chapter as vehicles not used for the carriage of passengers or delivery of goods. Instead, they fulfil specific tasks such as **garbage collection, road and terrain maintenance** - snow removal, sweeping or cleaning streets, salt spreading, or grass mowing **(see Figure 17)**.

[46] IPT Technology. (2020, February 13). *Wireless opportunity charging buses. As a result, smaller batteries needed*. https://ipt-technology.com/case-opportunity-charging-madrid/ (accessed on 21.07.2022)
[47] Editorial Staff. (2022, January 3). *First airport with wireless e-bus charging in the world. US: Kansas Airport turns to Momentum Dynamics*. Sustainable Bus. https://www.sustainable-bus.com/infrastructure/kansas-airport-wireless-charging-momentum-dynamics-buses/ (accessed on 21.07.2022)
[48] https://www.solarisbus.com/en/career (accessed on 24.04.2022)
[49] https://www.mantruckandbus.com/en/company/careers.html (accessed on 24.04.2022)
[50] https://www.irizar.com/en/irizar/work-with-us/ (accessed on 25.04.2022)
[51] *Training | Alexander Dennis*. (2022). Alexander Dennis. https://www.alexander-dennis.com/aftermarket/training/ (accessed on 02.07.2022)

Figure 17: Examples of lighter utility vehicles[52]

Figure 18: Example of an electric garbage truck[53]

The EU **CO_2 emission legislation** highlighted as a major driver of change in other segments (like passenger cars, vans or even specific groups of trucks) could has a **more negligible impact** on utility vehicles, as light special purpose vehicles (as defined in the EU type-approval

[52] *ZEBRA IS YOUR UTILITY SOLUTION – Užitkové vozy* ZEBRA. (2022). Zebra. http://uzitkove-vozy-zebra.cz/zebra-is-your-utility-solution/ (accessed on 03.07.2022)

[53] Edelstein, S.. (2020, May 5). *All-electric garbage truck being tested in the Netherlands*. Green Car Reports. https://www.greencarreports.com/news/1128049_all-electric-garbage-truck-being-tested-in-the-netherlands (accessed on 03.07.2022)

legislation) are exempted from the scope of the Regulation (EU) 2019/631[54] and heavy vocational vehicles are exempted from the CO_2 emission fleet targets set by Regulation (EU) 2019/1242.

In the case of heavy-duty vehicles like **garbage trucks (see Figure 18),** the declared reason for exemption has been a comparatively low mileage; also, their specific driving pattern and technical measures do not allow for reducing CO_2 emissions and fuel consumption as cost-effectively as it could be done in case of heavy-duty vehicles used for the delivery of goods.[55,56]

Moreover, some of these vehicles, such as mobile machinery, are **not included** in Directive 2019/1161[57,58]meaning they are not considered within the Member States' mandatory public procurement targets for clean vehicles. Pollutant emissions are addressed in EURO 6/VI standards for light and heavy-duty vehicles[59] or specific legislation aimed at engines of non-road mobile machinery.[60]

Even if the majority of utility vehicles are currently not subject to EU CO_2 emission targets, their frequent use in **urban conditions** or industrial parks suggests their enormous potential for improving **air quality** and noise **reduction** in cities, nature reserves and other similar areas, making it a **strong** driver to electrify these vehicles.[61] There is even a European Commission initiative called Big Buyers for Climate and Environment[62], run by ICLEI (Local Governments for

[54] *EUR-Lex - 32019R0631 - EN - EUR-Lex*. (2019). EUR-Lex. https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A32019R0631 (accessed on 15.04.2022)
[55] *Reducing CO_2 emissions from heavy-duty vehicles.* (2022). Climate Action. https://ec.europa.eu/clima/eu-action/transport-emissions/road-transport-reducing-co2-emissions-vehicles/reducing-co2-emissions-heavy-duty-vehicles_en (accessed on 15.04.2022)
[56] *EUR-Lex - 32019R1242 - EN - EUR-Lex*. (2019). EUR-Lex. https://eur-lex.europa.eu/eli/reg/2019/1242/oj (accessed on 15.04.2022)
[57] *EUR-Lex - 32019L1161 - EN - EUR-Lex*. (2019). EUR-Lex. https://eur-lex.europa.eu/eli/dir/2019/1161/oj (accessed on 15.04.2022)
[58] *Clean Vehicles Directive.* (2022). Mobility and Transport. https://transport.ec.europa.eu/transport-themes/clean-transport-urban-transport/clean-and-energy-efficient-vehicles/clean-vehicles-directive_en (accessed on 15.04.2022)
[59] *Emissions in the automotive sector*. (2022). Internal Market, Industry, Entrepreneurship and SMEs. https://single-market-economy.ec.europa.eu/sectors/automotive-industry/environmental-protection/emissions-automotive-sector_en (accessed on 15.04.2022)
[60] *Non-road mobile machinery*. (2022). Internal Market, Industry, Entrepreneurship and SMEs. https://single-market-economy.ec.europa.eu/sectors/automotive-industry/environmental-protection/non-road-mobile-machinery_en (accessed on 15.04.2022)
[61] *Looking to the future with electric garbage trucks - Eurocities*. (2020, December 16). Eurocities - Home. https://eurocities.eu/stories/looking-to-the-future-with-electric-garbage-trucks/ (accessed on 03.07.2022)
[62] *BigBuyers | Home.* (2022). BigBuyers. https://bigbuyers.eu/ (accessed on 03.07.2022)

Sustainability) and EUROCITIES, which aims to foster cooperation amongst large public purchasers to promote and implement sustainable solutions.

Support for research, development and piloting solutions are essential drivers of change. The project **REVIVE** (Refuse Vehicle Innovation and Validation in Europe)[63,64]co-funded by Horizon 2020, aimed at adopting hydrogen-powered garbage vehicles in Europe by integrating fuel-cell powertrains into 15 garbage vans and deploying them in 8 European cities or regions.

Electrification in this segment has been **lagging behind** passenger cars or urban buses, especially in the case of larger municipal vehicles, such as garbage trucks[65]. For heavier electric vehicles, the total costs of ownership (TCOs) might still be higher than for conventional vehicles with ICE.[66]

Furthermore, the battery capacity and the energy consumed by auxiliaries or used for cabin heating might be limiting factors. However, on the other hand, typical routes and charging times can be **planned** for some of these vehicles - similarly to urban electric buses. The cities like Rotterdam, Vienna[67], Copenhagen[68] and Gothenburg have started including them in their municipal services fleet. The offer of electrified utility vehicles is thus being expanded, as shown in the section below focused on stakeholders.

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[63] Revive. (2022). *Home*. https://h2revive.eu/ (accessed on 30.07.2022)
[64] Randall, C. (2020, July 12). *EU project REVIVE: fuel cell systems for garbage trucks. Electrive.Com*. https://www.electrive.com/2020/01/27/eu-project-revive-will-deliver-fuel-cell-systems-for-garbage-trucks/ (accessed on 30.07.2022)
[65] *BigBuyers | Newsbit July 2022*. (2022). BigBuyers. https://bigbuyers.eu/news/newsbit-july-2022 (accessed on 03.07.2022)
[66] Ewert, R., Grahle, A., Martins-Turner, K., Syré, A. M., Nagel, K., & Göhlich, D. (2021). Electrification of Urban Waste Collection: Introducing a Simulation-Based Methodology for Technical Feasibility, Impact and Cost Analysis. *World Electric Vehicle Journal*, 12(3), 122. https://doi.org/10.3390/wevj12030122 (accessed on 21.06.2022)
[67]GmbH, W. I. M. (2022, April 8). *Electric Trucks for Waste Collection: Let's jump on the e-Train*. WMW. https://waste-management-world.com/resource-use/electric-trucks-for-waste-collection-lets-jump-on-the-e-train/ (accessed on 22.07.2022)
[68] *Copenhagen's refuse trucks to be made fully electric*. (2021). Scania Group. https://www.scania.com/group/en/home/newsroom/news/2021/copenhagens-refuse-trucks-to-be-made-fully-electric.html (accessed on 22.07.2022)

2.3.2 Stakeholders

Chinese producers (e.g. BYD) are at the forefront also in this segment. In the **US** (e.g. Mack Trucks, a subsidiary of Volvo, Hyzon),[69] **Canada** (e.g. Ballard, Lion Electric) and **Europe** (e.g. MAN, Volvo or Daimler), the development of electric utility vehicles started several years ago. Besides that, there are specialized European manufacturers, such as Faun, Geesinknorba and Zöller. Apart from the original manufacturers, some companies **convert** ICE vehicles into hybrid or electric ones (e.g. Lunaz, XL Fleet, SEA Drive) **(see Figure 19 and Figure 20)**.

Figure 19: Electric garbage trucks producers (selection)

[69] *Electric Trash Trucks. . .It's a thing.* (2022). Berks Transfer. https://www.berkstransfer.com/electric-trash-trucksits-a-thing (accessed on 30.07.2022)

Figure 20: Smaller utility vehicles producers (selection)

2.3.3 Technology

The lithium **NMC** (Nickel Manganese Cobalt) battery technology seems to be the most common for garbage trucks. However, some manufacturers (like ALKE) also use **LFP** (Lithium Iron Phosphate) batteries, **lead-acid** batteries or **gel batteries** (maintenance-free lead batteries).[70] There are also several producers of **fuel-cell** utility vehicles.

Battery capacities range from **tens of kWh** for smaller utility vehicles to **hundreds of kWh** for large garbage trucks. The storage of the batteries is very similar to that of electric trucks - the batteries, the electric motor and other accessories are most often located in the undercarriage between the **rear axle (see Figure 21)**.

[70] *The ideal battery for your electric vehicle | Alke'*. (2022). Alke. https://www.alke.com/vehicles-lithium-lead-gel-battery#gel-battery (accessed on 1.08.2022)

Figure 21: Placement of battery packs and electric motor of Tropos Motors utility vehicle[71]

The maximum speed of most utility vehicles is around **30 km/h**; however, newer vehicles can reach speeds of around **60 km/h.** The maximum range for utility vehicles is **70 to 90 km**, corresponding to an entire working day.[72] Garbage trucks have a greater speed and maximum range compared to utility vehicles. Most garbage trucks reach a maximum speed of up to **100 km/h** with a range of approximately **200 km**, which again corresponds to the needs of an entire working day.[73]

2.3.4 Job, Roles and Skills

Battery-relevant job roles and skills are mostly similar to those relevant to trucks, busses and vans.

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[71] *Tropos Motors Electric Vehicles*. (2022). Tropos Motors. https://www.troposmotors.com/media35.html (accessed on 1.08.2022)
[72] *Which are the limits of an electric vehicle?* (2022). Alke. https://www.alke.com/limits-electric-vehicle (accessed on 1.08.2022)
[73] Anderson, N. (2022, April 13). *'Cutting edge' electric garbage truck trialled in ACT*. SEA Electric. https://www.sea-electric.com/cutting-edge-electric-garbage-truck-trialled-in-act/ (accessed on 1.08.2022)

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3 Vans

Vans are vital players in the logistics chain, enabling the 'last-mile" **delivery of goods** in urban areas. Used mainly by SMEs as business tools, vans help power the European economy, helping businesses thrive, according to ACEA. From a technological point of view, vans are relatively close to passenger cars and belong to the category of "light vehicles." Nevertheless, according to ACEA, "due to weight, size, and number of specific usage requirements, some technological solutions available for passenger cars are not directly applicable to vans, and the **lower production volumes** do not allow for the same **economies of scale**."[74]

In the ALBATTS project Deliverable D5.1 Desk Research & Data Analysis IMBA - Release 1[75], different categories of cars and relevant battery topics were addressed. This chapter goes more in detail and addresses the segment's updates since the Deliverable D5.1 Desk Research & Data Analysis IMBA publication in August 2022.

3.1 DRIVERS OF CHANGE

EU regulation

Similar to passenger cars, EU CO regulation (2019/631) is among the key drivers of change within the vans segment. Fleet CO_2 emission reduction targets for manufacturers of vans concerning newly registered vehicles are expressed as percentage reductions: **–15 % in 2025** and **–31 % in 2030** relative to the average of the specific emissions targets for 2021 determined for each manufacturer. EU vehicle **emissions regulations** are among the strictest in the world and the most vital driver of European electrification of vehicles transporting passengers and goods.

Legislation on the EU level that is also driving the vans segment towards electrification includes the revised **Clean Vehicle Directive** (EU)2019/1161[76] setting fleet procurement parameters and thus electrification targets for fleets operated by public institutions. Another

[74] *Vans: what they are and why they are so important*. (2021). ACEA - European Automobile Manufacturers' Association. https://www.acea.auto/fact/vans-what-they-are-and-why-they-are-so-important/ (accessed on 15.04.2022)
[75] https://www.project-albatts.eu/Media/Publications/4/Publications_4_20200930_12811.pdf (accessed on 05.07.2022)
[76] *EUR-Lex - 32019L1161 - EN - EUR-Lex*. (2019). EUR-Lex. https://eur-lex.europa.eu/eli/dir/2019/1161/oj (accessed on 10.04.2022)

driver is the policies of some **EU cities**, where electrified vans gain favoured **access** (lower or no city access toll etc.) or **parking** or are the only ones allowed to the **city centre**.

Furthermore, the European Commission has been preparing a new **Euro 7** standard limiting pollutants such as PN, CO and NOx emitted by newly produced road vehicles. It is expected to introduce stricter reduction targets of the pollutants and make compliance for the ICE vehicles even more complicated and expensive – another instrument to ensure manufacturers electrify faster.

Registration of **ICE vehicles** (including passenger cars and other segments) might face a complete **ban in the EU in 2035**, and the relevant legislation is now being discussed between EU institutions. Meanwhile, some countries, including those outside the EU, such as the UK or Norway, have been setting their own and sometimes even earlier dates to phase out ICE or hybrid powertrains, see **Figure 22** and **Figure 23.** [77]

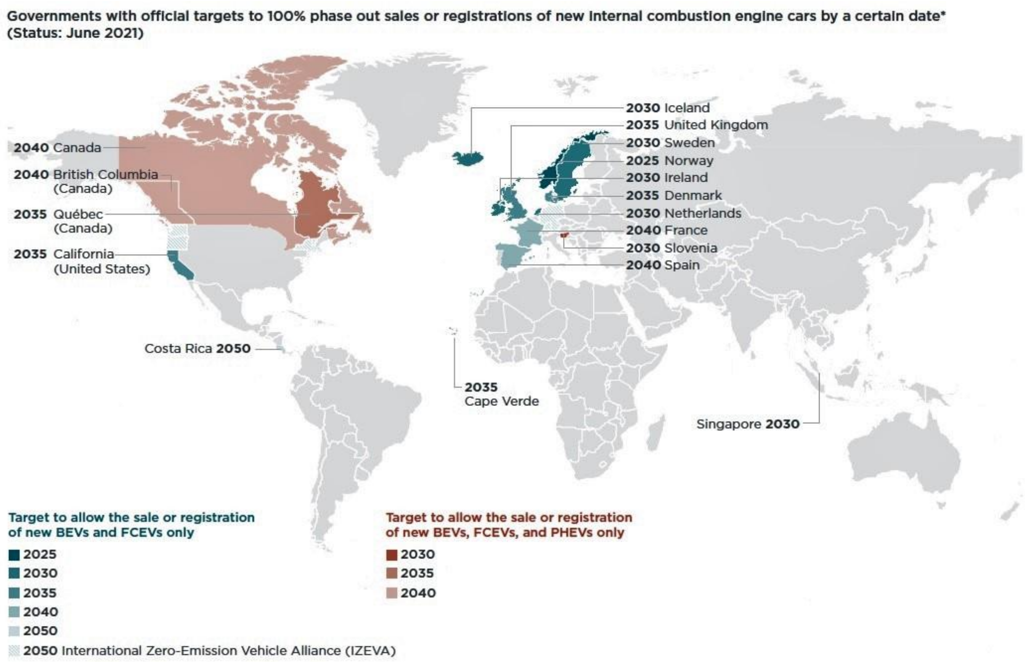

Figure 22: Countries‘ phase-out targets[78]

[77] INTERNATIONAL COUNCIL ON CLEAN TRANSPORTATION. (2021). Update on government targets for phasing out new sales of internal combustion engine passenger cars (accessed on 10.04.2022)
[78] INTERNATIONAL COUNCIL ON CLEAN TRANSPORTATION. (2021). *Update on government targets for phasing out new sales of internal combustion engine passenger cars* (accessed on 10.04.2022)

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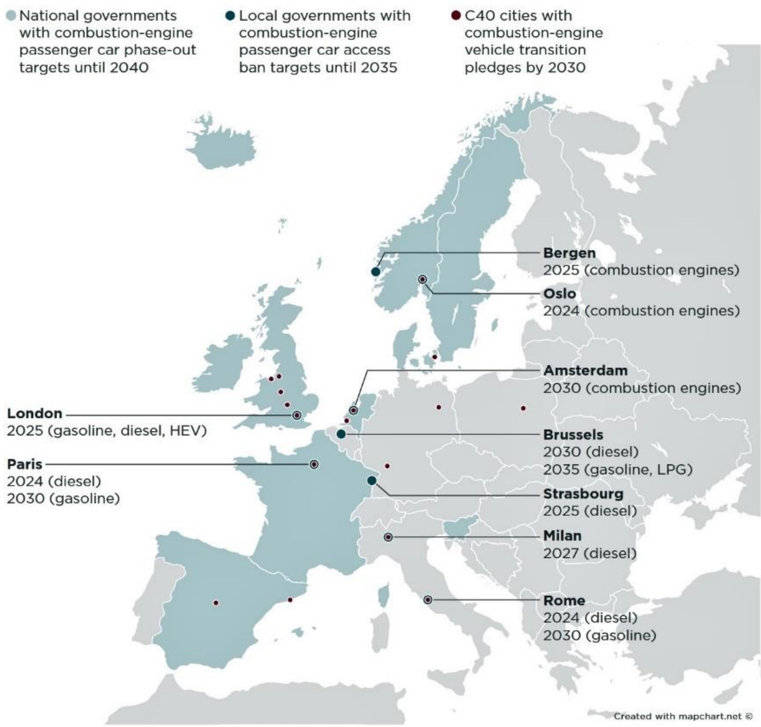


Figure 23: Local targets for ICE car bans[79]

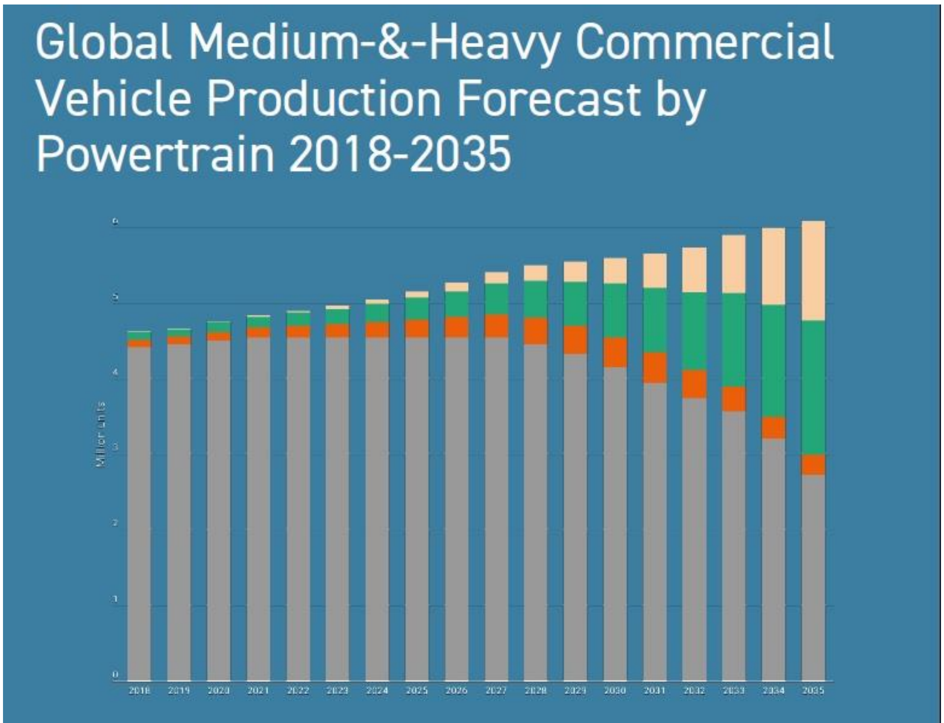
Total costs of ownership (TCOs)

According to the ICCT[80], **parity** for electric vans and pickup trucks with a range of up to 320 km will be achieved **in the next five years.** 72-97 % of vehicle miles travelled by vans could be achieved by an electric vehicle with a 320-mile (approx. 515 km) range. The total costs of ownership (TCO) analysis shows that it can be **already cheaper** to own a BEV200 van or pick-up truck than its diesel counterpart.

According to the same study, the **fuel** costs of BEVs are more than **50 % lower**: for ICE vehicles over a 5-year ownership range between $12,800 and $15,900, while the fuel costs for BEVs are between $3,500 and $5,200/year. Total **maintenance** costs are also approx. **50 % lower**: for ICE vehicles are between $11,700-$12,300 over a 5-year ownership period, while for BEVs $6,100-$6,900.

[79] *The end of the road? An overview of combustion-engine car phase-out announcements across Europe.* (2021, November 24). International Council on Clean Transportation. https://theicct.org/publication/the-end-of-the-road-an-overview-of-combustion-engine-car-phase-out-announcements-across-europe/ (accessed on 12.04.2022)

As a result of the drivers mentioned above of change, **sales of battery vans**, as well as sales of heavy-duty vehicles, are expected to **rise (see Figure 24)**, one of the factors being that TCOs are more favourable for the segment of commercial vehicles that are expected to drive more kilometres, than the passenger cars segment.[80]



	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035
Petrol	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Diesel	4.40	4.44	4.49	4.53	4.53	4.53	4.53	4.53	4.53	4.53	4.44	4.31	4.14	3.93	3.73	3.55	3.19	2.71
NGV	0.100	0.100	0.115	0.132	0.152	0.175	0.201	0.231	0.266	0.306	0.352	0.369	0.388	0.407	0.367	0.330	0.297	0.267
HEV	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PHEV	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
EV	0.100	0.10	0.12	0.14	0.17	0.20	0.24	0.29	0.34	0.41	0.49	0.59	0.71	0.85	1.03	1.23	1.48	1.77
FCEV	0.020	0.020	0.026	0.034	0.044	0.057	0.074	0.097	0.125	0.163	0.212	0.276	0.358	0.466	0.606	0.787	1.024	1.331

Source: Automotive from Ultima Media, AAM, ACEA, ANFAC, ANFAVEA, ANFUA, CAAM, CCFA, EIA, JAMA, KAMA, OICA, SIAM, SMMT, VDA
*Medium and heavy vehicles include trucks and buses over 6 tonnes

Figure 24: Vehicle production forecast 2018 - 2035[81]

[80] *Cost of electric commercial vans and pickup trucks in the United States through 2040*. (2022, February 11). International Council on Clean Transportation. https://theicct.org/publication/cost-ev-vans-pickups-us-2040-jan22/ (accessed on 12.04.2022)

[81] *Cost of electric commercial vans and pickup trucks in the United States through 2040*. (2022, February 11). International Council on Clean Transportation. https://theicct.org/publication/cost-ev-vans-pickups-us-2040-jan22/ (accessed on 12.04.2022)

In 2021, sales of new electrically-chargeable vehicles (ECV), including pure battery-electric vans and plug-in hybrids, grew by **63.2 %** across the EU to reach **46,853** vans sold. This strong double-digit growth increased market share from 2.0 % in 2020 to **3.0 %** in 2021. ECV sales increased by **237.8 %** in Italy, **55.5** % in Spain, **44.9** % in Germany and **39.8** % in France.[82]

3.2 STAKEHOLDERS

Van manufacturers

Examples of brands **(see Figure 25)** and models available on the market (as of July 2022):

- Citroen (e-Berlingo / e-Dispatch / e-Jumpy)
- Peugeot (e-Expert / e-Traveller)
- Toyota (Proace)
- Opel / Vauxhall (Vivaro-e / Combo-e / Movano-e)
- Renault (Master ZE / Kangoo e-Tech)
- Fiat (e-Ducato)
- Mercedes (eSprinter / eVito / EQV)
- Volkswagen (e-Crafter/ e-Transporter, ID Buzz)

[82] *Fuel types of new vans: electric 3.0%, hybrid 1.6%, diesel 90.2% market share full-year 2021*. (2022, March 16). ACEA - European Automobile Manufacturers' Association. https://www.acea.auto/fuel-cv/fuel-types-of-new-vans-electric-3-0-hybrid-1-6-diesel-90-2-market-share-full-year-2021/ (accessed on 20.04.2022)

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Figure 25: Electric van producers (selection)

There are also some very active small and medium-sized companies. Canoo, for example, is an American start-up manufacturer of electric vehicles. The company plans to start selling a minivan in 2022. The company also plans to produce commercial electric vehicles, such as vans for **vehicle rental** and **ride-sharing** services.

Battery manufacturers

Car manufacturers have a clear tendency to establish a local battery supply system and use it as the leading force for future supply: VW Group, BMW Group and Volvo are strategically building plants with **Northvolt**, while Stellantis and Daimler cooperate with Automotive Cells Company (**ACC**). The current and future supply partnerships and joint ventures between automakers and battery manufacturers are shown in **Figure 26**.

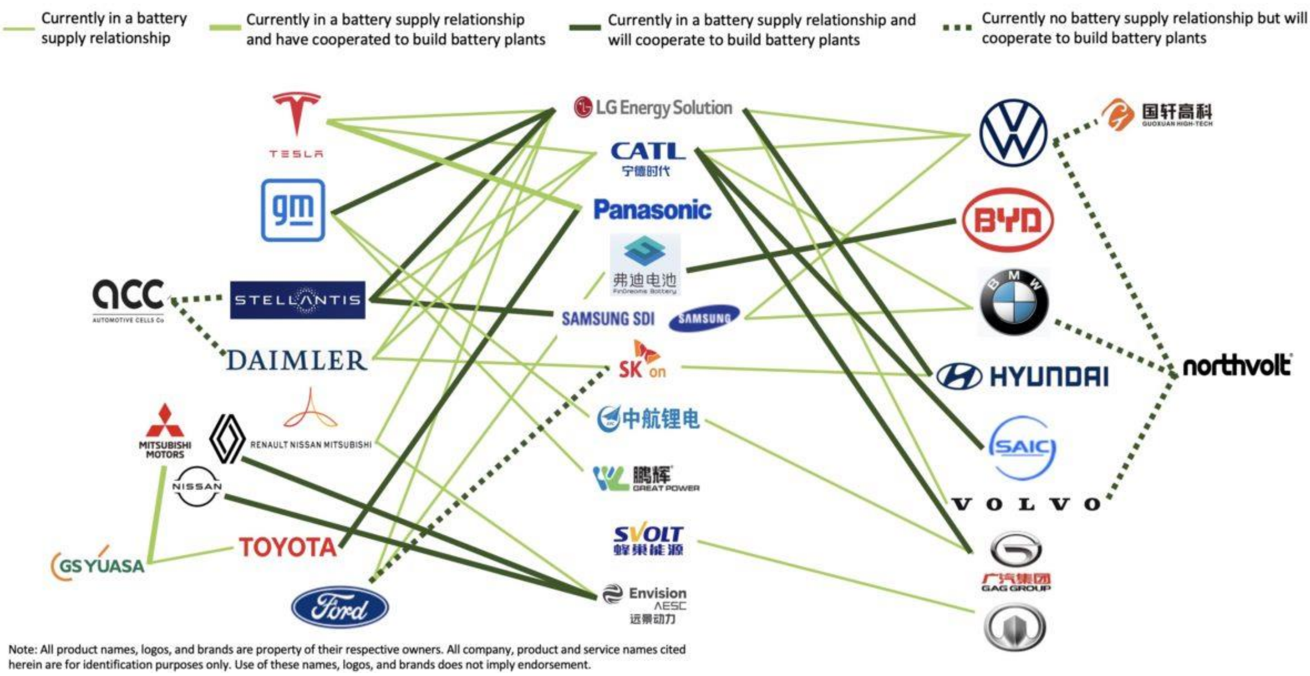

Figure 26: Strategic partnerships between leading EV manufacturers and battery suppliers [83]

Apart from the big established and emerging battery manufacturers, there are business projects with **microfactories** instead of gigafactories[84], which can deliver a microfactory in just six months. It is worth to be mentioned that Arrival[84], for example, focuses primarily on battery **factories for commercial vehicles** (vans and buses).

3.3 TECHNOLOGIES

Vans' batteries and charging systems need to be **robust** since vans and other commercial vehicles can be expected to be used and charged more often and can be expected to be used by various persons, particularly in a company or rental service. The battery technology in vans is practically the same as in passenger cars **(see Figure 27 and Table 2)**. However, there are some specifics. For example, battery vans used by craftsmen or maintenance services need to be able to provide electric power for tools.

[83] B. (2022, January 15). The Battery Report 2021 - BatteryBits. Medium. https://medium.com/batterybits/the-battery-report-2021-442ed2a06324 (accessed on 14.04.2022)

[84] *Gigafactory? How About Microfactory? Arrival Rethinks How an EV is Built*. (2020b, December 22). YouTube. https://www.youtube.com/watch?v=Z_Qyor9Yc-s (accessed on 14.04.2022)

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Figure 27: Volkswagen ID BUZZ[85]

Table 2: Some examples of e-vans[86]

Model	Range [km]	Battery [kWh]	Consumption (kWh/100 km]
Citroen e-Dispatch	339	75	22.1
Citroen e-Berlingo	195	45	23.1
Citroen e-Jumpy	250	65	26.0
Fiat e-Ducato	235-370	47-79	20-21.4
Maxeus e Deliver 3	228	52	22.8
Mercedes eSprinter	152	55	36.2
Mercedes EQV 300	205-305	60-90	29.3-29.5
Mercedes eVito	205-305	60-90	29.3-29.5
Nissan e-NV200	301	40	13.3
Opel/Vauxhall Movano-e	224	70	31.3

[85] *The technology behind Volkswagen ID BUZZ details the advantages and disadvantages of the MEB platform.* (2022, March 13). Laitimes. https://www.laitimes.com/en/article/3gca0_3x1ba.html (accessed on 12.05.2022)
[86] *Vans*. (2022b). Auto Express. https://www.autoexpress.co.uk/vans accessed on 12.05.2022

Opel Vivaro-e, Zafira-e	180-250	45-65	25-26
Peugeot e-Expert/e-Traveller	175-260	45-68	25.7-26.2
Renault Kangoo E-Tech	186	45	24.2
Renault Master ZE	120-244	33-52	27.5-21.3
Toyota Proace	180-250	45-65	25-26
VW e-Transporter	132	37	28.0
VW ID BUZZ	340	77	22.6

3.4 JOB ROLES AND SKILLS

A wide range of skills will be needed to meet the sector's demands, see **Figure 28**.

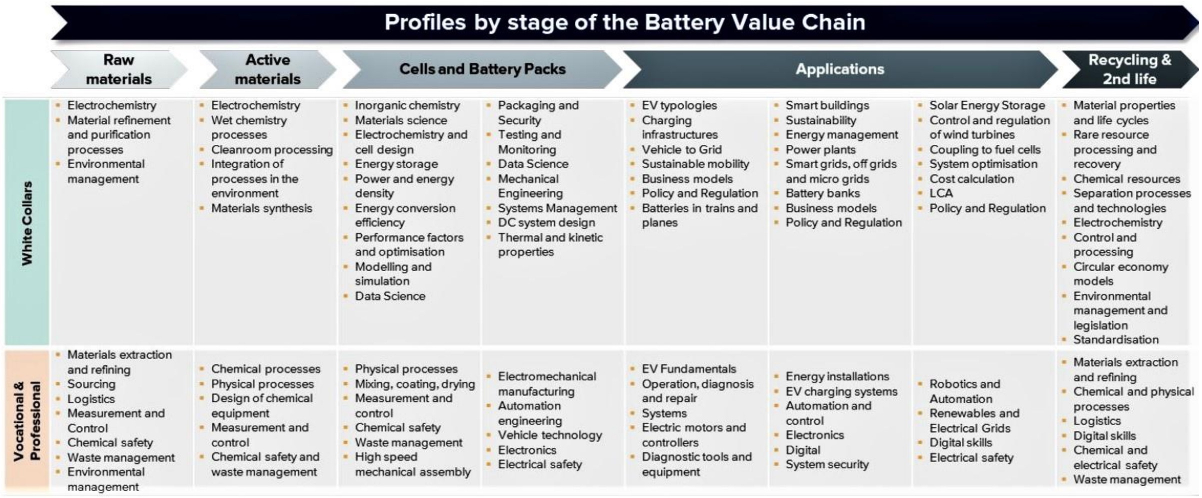

Figure 28: Profiles by stage of the battery value chain[87]

The US Bureau of Labour Statistics and Indeed job site provides interesting information about job roles and skills relevant to electric vans:

Source: US Bureau of Labour Statistics[88]

[87] *Battery Brunch - The Battery Report*. (2021). Battery Brunch. https://www.batterybrunch.org/battery-report (accessed on 15.04.2022)
[88] https://www.bls.gov/green/electric_vehicles/#hybrid

Scientific research

- Chemists
- Materials scientists

Design and development

- Chemical engineers
- Electrical engineers
- Electronics engineers
- Industrial engineers
- Materials engineers
- Mechanical engineers
- Mechanical drafters
- Software developers
- Commercial and industrial designers

Manufacturing

- Electrical and electronic equipment
- Electromechanical equipment assemblers
- Engine and other machine assemblers
- Team assemblers
- Computer-controlled machine tool operators
- Machinists
- Industrial production managers

Maintenance

- Automotive service technicians

Sales and support

- Retail salespersons
- Customer service representatives

Indeed jobs site[89]

Lightning eMotors[90] is an American company that designs and manufactures zero-emission all-electric medium and heavy-duty vehicles, including **passenger vans** and city transit buses. The Lightning products include commercial EVs based on platforms like the Ford Transit 350HD passenger and cargo vans, Ford E-450 shuttle bus and cutaway models, Ford F-59 step/food van, Ford F-550 cargo trucks and buses, Chevrolet 6500XD Low Cab Forward model, and 30-foot, 35-foot, and 40-foot transit buses.

Lightning e-Motors job advertisements:

- Lithium Maintenance Technician
- Battery Test Engineer
- Lithium - Material Handler
- Senior Battery Mechanical Engineer
- Application Engineer (Battery Storage)
- Battery Monitoring System Software Engineer
- Process Quality Engineer
- Platform Engineer
- Research & Development Engineer
- IT Systems Engineer
- Logistics Manager
- Functional Safety & Controls Engineer
- Quality Process Engineer
- CMM/Lab Technician
- Lead Platform Engineer (eChassis)
- Field Service Technician
- Regional Service Manager

[89] https://www.indeed.com/jobs?q=Lithium%20Battery&l=Glendale%2C%20CA&vjk=87e8d3b0c04cb29a
[90] https://lightningemotors.com/jobs/

4 Motorbikes

4.1 DRIVERS OF CHANGE

Two-wheeler manufacturers are increasingly producing **greener and more environmentally friendly** vehicles. Growing environmental concerns, limited fossil fuel reserves, and increasing government and municipal efforts to promote electric mobility drive motorcycle producers to bring **electric motorcycles** onto the market.

While the production of electric vehicles (EVs) is mainly driven by CO_2 emission regulation, one of the key drivers of electrification in the motorbikes sector is motivated by the expansion of the **product portfolio.** Electrified motorbikes are an exciting option for many users, including city-sharing companies, since there are much more **silent** and have good **acceleration** and relatively **low operating costs**. There seems to be no discussion about a possible ban on motorcycles with ICE technology.

Amended EU Regulation 168/2013[91,92,93,94] provides new emission standard EURO 5 in L-category, which entered into force on 1 January 2021. **Figure 29** shows the evolution of emissions standards of the L-category.

[91] *REGULATION (EU) No 168/2013 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL*. (2013). https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32013R0168&from=EN (accessed on 24.02.2022)
[92] *EU: Motorcycles: Emissions | Transport Policy.* (2020). TransportPolicy.Net. https://www.transportpolicy.net/standard/eu-motorcycles-emissions/
[93] Acem, I. (2019, December 16). *New Euro 5 environmental standard for motorcycles and mopeds to enter into force in 2020 - ACEM - The Motorcycle Industry in Europe*. ACEM. https://www.acem.eu/new-euro-5-environmental-standard-for-motorcycles-and-mopeds-to-enter-into-force-in-2020
[94] *Two- and three-wheel vehicles and quadricycles*. (2020). Internal Market, Industry, Entrepreneurship and SMEs. https://ec.europa.eu/growth/sectors/automotive-industry/legislation/two-and-three-wheel-vehicles-and-quadricycles_en

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	EURO 1	EURO 2	EURO 3	EURO 4	EURO 5
CO (g/km)	13.0	5.5	2.0	1.14	1.00
HC (g/km)	3.0	1.0	0.3	0.17	0.10
NOx (g/km)	0.3	0.3	0.15	0.09	0.06
PM (g/km)	–	–	–	–	0.0045
SHED* test	–	–	–	Yes	Yes
On-board diagnostics	–	–	–	Yes (OBD1)	Yes (OBD2)
Durability	–	–	–	20,000km	Lifetime

*Evaporative emission

Figure 29: Evolution of L-category emissions standards[95]

4.2 STAKEHOLDERS

Unlike China and other Asian countries, where electric bikes have been used for years, the EU market with electric motorbikes is still immature and relatively small. However, it has been growing yearly **(see Figure 30, Figure 31 and Figure 32)**.

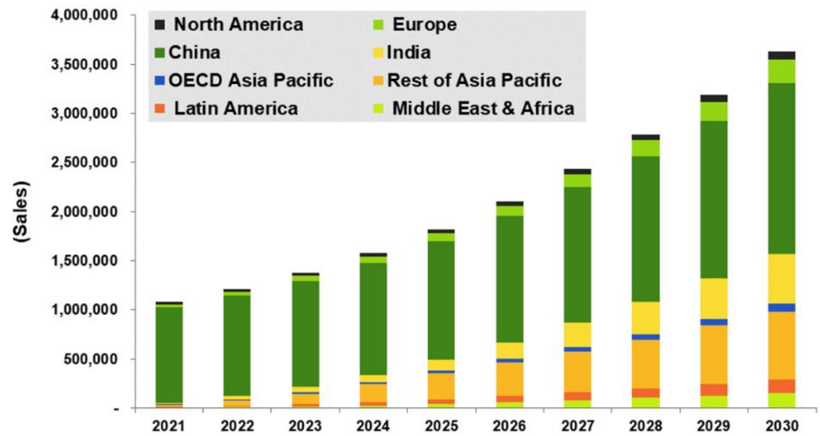

Figure 30: Prediction of sales of e-motorbikes[96]

[95] *Infineum Insight - Euro 5 motorcycles.* (2018, August 14). Infineum Insight. https://www.infineuminsight.com/en-gb/articles/small-engines/euro-5-motorcycles/ (accessed on 24.02.2022)

[96] *Major motorcycle companies will electrify, eventually | Greenbiz.* (2021, April 13). GreenBiz. https://www.greenbiz.com/article/major-motorcycle-companies-will-electrify-eventually (accessed on 24.02.2022)

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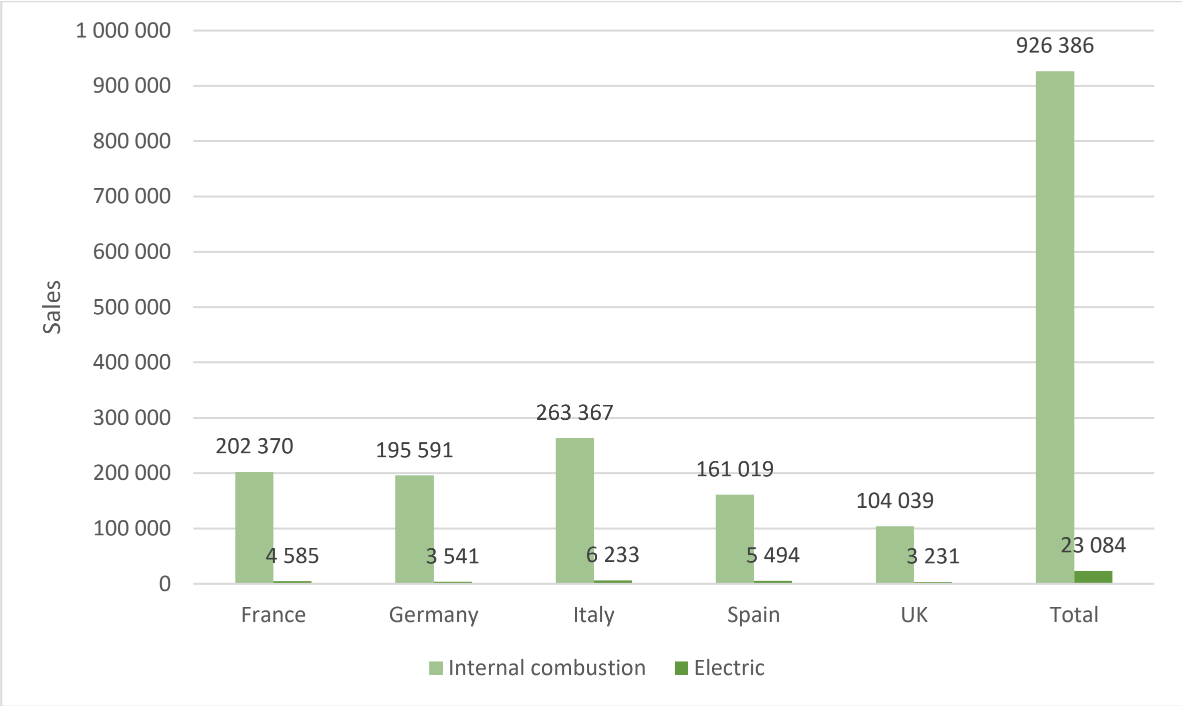

Figure 31: European sales of motorbikes in 2021[97]

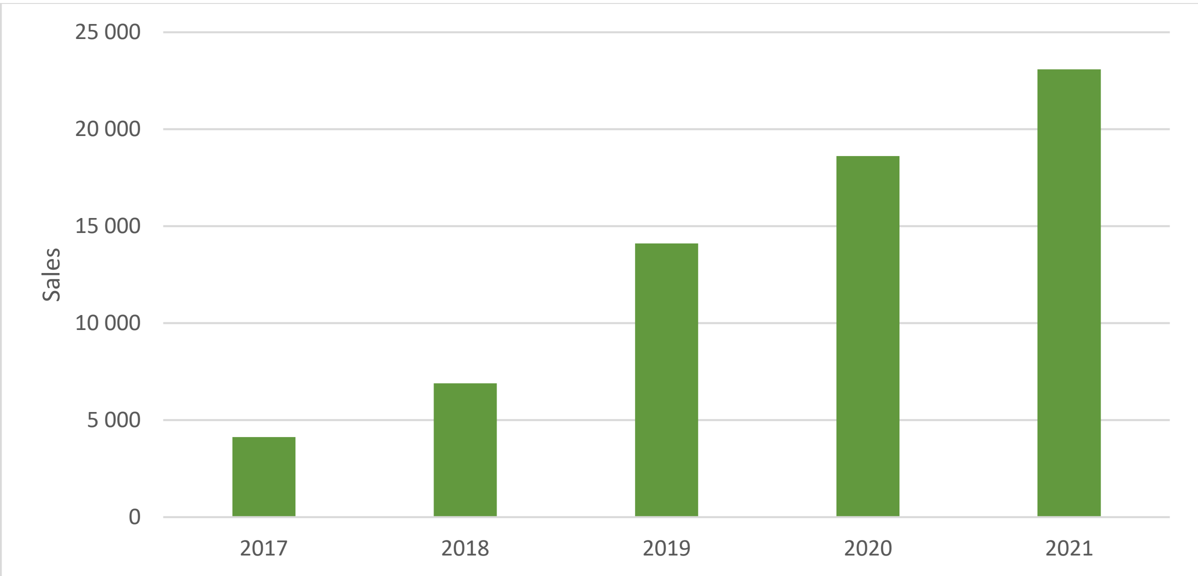

Figure 32: Evolution of EU sales of electric motorbikes[97]

Figure 33 shows maps with the locations of some E-motorbikes producers. Zero motorcycles, a pioneer of e-motorbikes or Gogoro, are among the most prominent producers.

[97] Dávila, P. (2022). *Market data - ACEM - The Motorcycle Industry in Europe*. ACEM. https://www.acem.eu/market-data

Figure 33: Electric motorcycle producers (selection)

4.3 TECHNOLOGY

Battery technology highly depends on the producer and type of motorbike. For example, Zero company uses battery packs with a voltage of about **100 V** with **pouch cells**, Honda in their e-scooter uses **cylindrical cells** 21700 with a voltage of about **50 V**. Example of an electric motorbike is shown in **Figure 34**.

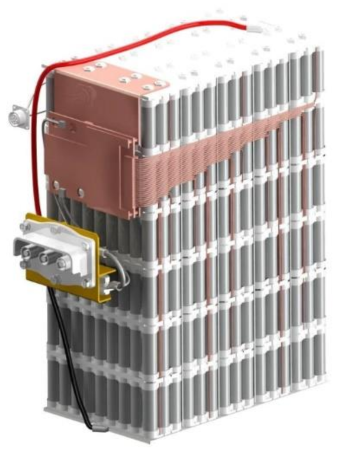

Figure 34: A 19 kWh battery pack from Evoke[98]

[98] *Evoke Electric Motorcycles adding reverse gear*. (2018). Green Car Congress. https://www.greencarcongress.com/2018/01/20180126-evoke.html

Most e-motorcycles use the same charging standards as electric vehicles. However, because they have smaller batteries, they can typically use Stage 1 and Stage 2 **AC charging** with an onboard charger. However, some models can handle Stage 3 **DC fast** charging[99,100]. In addition, some producers, Gogoro[101], for example, use **swappable batteries** that are charged outside the motorbike.

4.4 JOB, ROLES AND SKILLS

Job roles relevant to e-motorbikes and their batteries can include the following:

- **R&D** – developing and designing batteries and other electric systems for e-motorbikes
- **Manufacturing** – battery pack for e-motorbikes assembly
- **Servicing** – servicing or replacement of malfunctioning or end-of-life battery packs and refurbishing of the battery packs
- **Operation** - assistance at charging or battery swapping points. In the case of e-scooter sharing projects - the staff responsible for the monitoring of State of Charge (SoC), collecting and charging of e-scooters
- **Disassembly** - end-of-life e-motorbikes and battery packs

[99] Toll, M., & Toll, M. (2021, May 7). *Electric motorcycles that charge to 85% in 15 minutes? This e-moto company says it's close*. Electrek. https://electrek.co/2021/05/07/electric-motorcycles-that-charge-to-85-in-15-minutes-this-e-moto-company-says-its-close/ (accessed on 24.02.2022)
[100] **Stage 1** is charging from 230 V electric plug with the charger on cable, **Stage 2** is AC charging from the wall box and **Stage 3** is DC fast charging
[101] Laylin, T. (2016, January 6). *Gogoro unveils new home battery charger for electric scooters - sets sight on your city*. Inhabitat - Green Design, Innovation, Architecture, Green Building | Green Design & Innovation for a Better World. https://inhabitat.com/gogoro-unveils-new-home-battery-charger-for-electric-scooters-sets-sight-on-your-city/ (accessed on 24.02.2022)

5 Micromobility

5.1 DRIVERS OF CHANGE

Electric micromobility uses small & lightweight personal mobility devices such as **e-bicycles** (for details, see chapter eBikes), **e-scooters, e-mopeds, e-skateboards, e-hoverboards** or other kinds of **one or two-wheelers** by individuals to commute from one place to another, primarily within cities. Micromobility can be defined as shown in **Figure 35**.

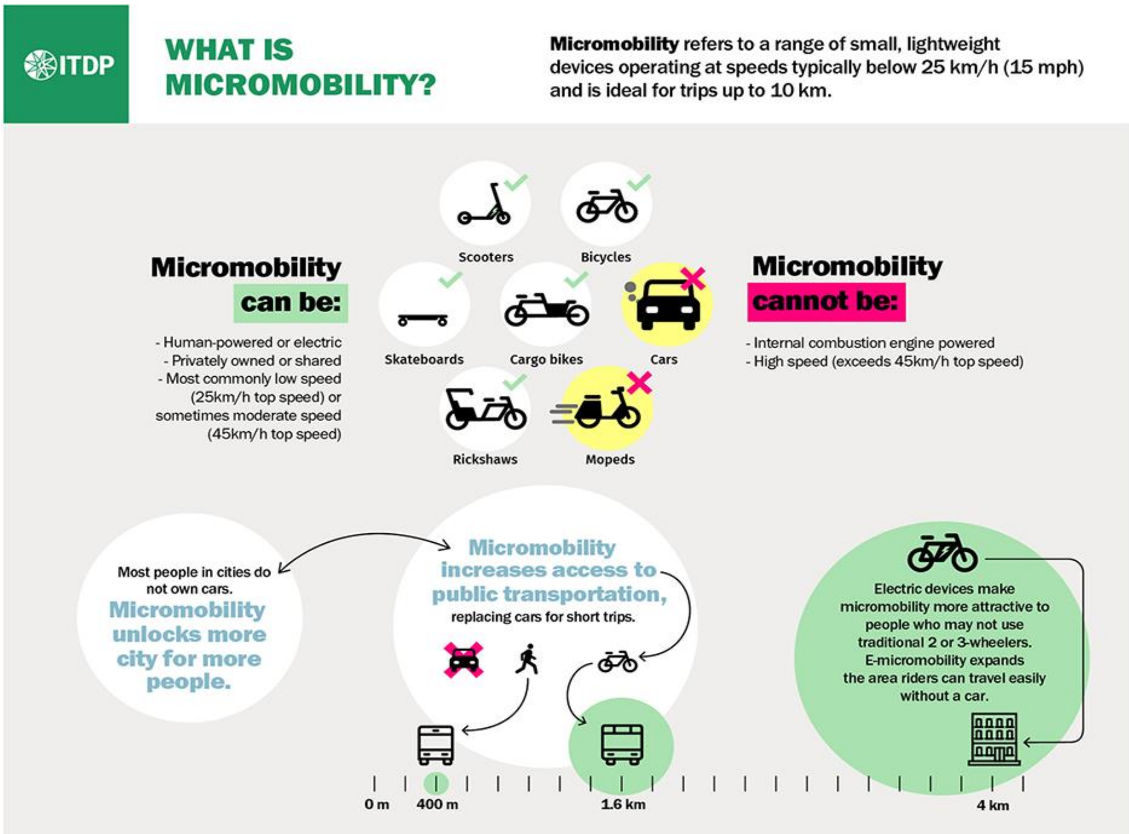

Figure 35: What is micromobility? [102]

[102] *Defining Micromobility*. (2021, September 1). Institute for Transportation and Development Policy. https://www.itdp.org/multimedia/defining-micromobility/# (accessed on 05.01.2022)

Personal motorised mobility devices can also include the vehicles shown in **Figure 36**

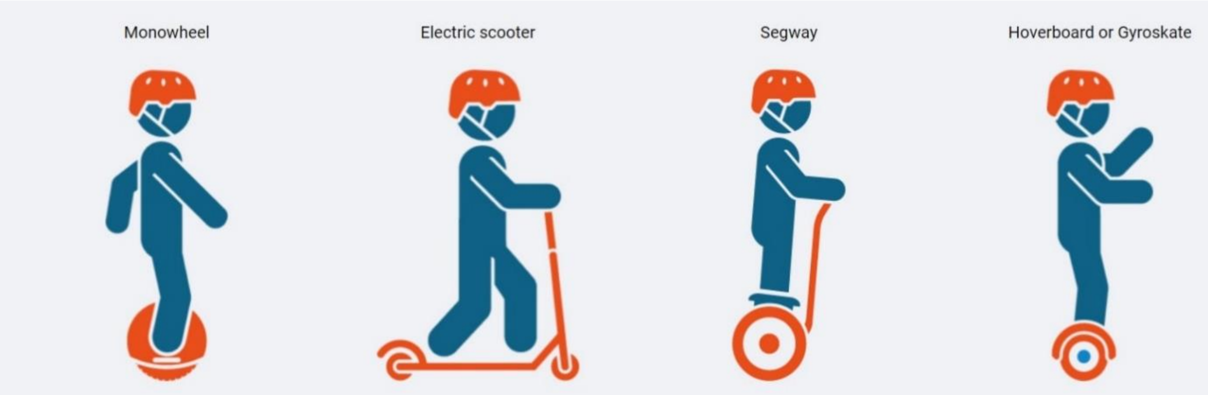

Figure 36: Personal motorised mobility devices[103]

The **benefits and challenges** of micromobility in cities have been identified in Ernst & Young's report "Micromobility: moving cities into a sustainable future":[104]

Benefits

- Environmental footprint — improve urban air quality and reduce climate change
- Getting people out of their cars
- Efficient mobility — provides convenient and flexible transportation for citizens and tourists

Challenges

- Unwanted modal shift —if e-scooters take passengers from bikes and walking instead of from cars
- Infrastructure — cities are not yet set up for the new micromobility options
- Visual pollution — some people do not take care of the scooters and throw them all over the city

The safety of the driver and the people in his surroundings has also become a topic of public discussion and regulation by local, national and EU authorities.

[103] *6 carmakers that are betting electric scooters and bikes — not cars — are the future of city transportation.* (2019, August 11). Business Insider Nederland. https://www.businessinsider.nl/ford-audi-bmw-vw-gm-make-mobility-products-2019-8?international=true&r=US#ford-super-cruiser-1 (accessed on 21.02.2022)

[104] *How micromobility is moving cities into a sustainable future*. (2020). How Micromobility Is Moving Cities into a Sustainable Future. https://www.ey.com/en_gl/automotive-transportation/how-micromobility-is-moving-cities-into-a-sustainable-future (accessed on 05.01.2022)

Micromobility can help to reduce **traffic congestion**. In the world's most populous cities, most trips are already taken by walking, cycling, and public transport. Many cities in India, for example, have less than 10 % of trips taken by car.

As a result, the global micromobility market was valued at **$44.12 billion** in 2020 and is projected to reach $214.57 billion by 2030, registering a CAGR of **17.4 %** from 2021 to 2030.[105] However, the low rate of internet penetration in developing regions and the rise in **vandalism & theft** are among the factors possibly hampering the growth of the global market. The European Union prioritises adopting electric motorcycles, e-scooters, and e-bikes[106] to help improve **air quality**.

Micromobility "Made in Europe" is well-positioned, especially considering the dynamic innovation ecosystem throughout the value chain, with companies such as ONO, Kumpan, Swobbee, DUCKT, GetHenry, and others. Furthermore, strong synergies could be reinforced with the automotive and battery supply chain. For instance, the demand from manufacturing in micromobility could require the production of about **2.5 battery Gigafactories**.[107]

5.2 STAKEHOLDERS

In 2019, the largest share of the micromobility deliveries was supplied by Ninebot and Xiaomi, two **Chinese** manufacturers. As of 2022, most of the micromobility devices still come from east Asia; the consequence is that a large proportion of the **economic value and job creation** is taking place outside the EU.[108]

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[105] *Micromobility Market Size, Share, Growth, Analysis, Report 2030*. (2021). Allied Market Research https://www.alliedmarketresearch.com/micro-mobility-market-A11372 (accessed on 10.12.2021)

[106] Maciej M. Sokolowski, 'Laws and Policies on Electric Scooters in the European Union: A Ride to the Micromobility Directive?', (2020), 29, European Energy and Environmental Law Review, Issue 4, pp. 127-140, https://kluwerlawonline.com/journalarticle/European+Energy+and+Environmental+Law+Review/29.4/EELR2020036

[107] Camara, C. (2021, December 12). Micromobility "Made in Europe" to Achieve our Climate Targets and Make our Cities More Sustainable. The European Files. https://www.europeanfiles.eu/climate/micromobility-made-in-europe-to-achieve-our-climate-targets-and-make-our-cities-more-sustainable (accessed on 05.01.2022)

[108] Dungs, J. (2021, September 1). *Electric Micromobility: how to cut emissions, create jobs and transform urban transport*. Energy Post. https://energypost.eu/electric-micromobility-how-to-cut-emissions-create-jobs-and-transform-urban-transport accessed on (12.03.2022)

Co-funded by the Erasmus+ Programme of the European Union

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China alone has more than 60,000 e-bike manufacturing companies. In the EU, we are currently "using" micromobility but are **not benefiting** from the associated value chain: the EU is missing out on a substantial economic opportunity with the potential to create up to **1 million jobs** by 2030.[109]

Stakeholders

Include manufacturers of personal micromobility devices (*for e-bikes, see chapter E-bikes*) and providers of e-mobility services, including sharing services:

1) Manufacturers (see Figure 37)

- **Niu Technologies** (China) is a global brand that designs and manufactures electric scooters. As the world's leading lithium-powered electric two-wheeler company, NIU created a new market category for smart electric two-wheeler vehicles. NIU's developed a 4th generation NIU Energy™ lithium battery technology with longer-lasting battery life, more extended range, and more lightweight that it claims is safer and more powerful.[110] The NIU Battery pack utilises e. g. Panasonic lithium-ion battery cells containing 29 Ah of energy. The battery weighs around 10 kg.
- **Govecs AG** (Germany) is the European leader in electric mobility solutions for free-floating sharing, rental and delivery services. Their e-scooters are designed with high-quality batteries, innovative motors and drivetrains, for example, made by BOSCH. In addition, they designed their own GOVECS Core drive train.[111]
- **Walberg Urban Electrics GmbH** (Germany) is a Hamburg-based manufacturer of small, foldable e-scooters. Quality, design and technology made their brand EGRET one of the most awarded brands in the e-scooter market.[112]
- **myStromer A.G.** (Switzerland) - established in 2010. It has been developing powerful Speed Pedelecs (high-speed e-bikes).[113]

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[109] *Micromobility Report.* (2019). InnoEnergy. https://www.innoenergy.com/discover-innovative-solutions/reports/micromobility-report/ accessed on 05.01.2022

[110] NIU - The World's #1 Smart Electric Scooter. (n.d.). NIU. https://www.niu.com/en/n-series/battery/ (accessed on 13.04.2022

[111] About GOVECS. (n.d.). GOVECS. https://www.govecsgroup.com/en/company/about-govecs (accessed on 12.04.2022)

[112] *Egret*. LinkedIn. https://www.linkedin.com/company/my-egret/about/ (accessed on 13.04.2022)

[113] *myStromer AG*. LinkedIn. https://www.linkedin.com/company/mystromer/ (accessed on 13.04.2022)

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- **emco electroroller GmbH** (Germany) has been producing electric scooters since 2011, and they specialise in e-scooter sharing, fleet management with e-business scooters and delivery of scooters for delivery services. They claim to offer the most extensive range of electric scooters in Germany - with models from 1000 to 3000 watts, top speeds from 25 to 45 km/h and ranges of up to 130 kilometres.[114]
- **Kumpan Electric Scooter**[115] - manufactured by E-bility GmbH that was founded in 2010 in Remagen. Their battery pack is a **plug-and-play** solution controlled by AI software, which can simply be detached from the scooter and recharged in standard sockets, bearing the potential to be applied in **several different products**, from power tools to lawnmowers.[116]
- **Scotsman -** is a scooter brand based in Silicon Valley and uses a state-of-the-art 3D-printing process which allows for an unprecedented level of customisation. Each frame is made to fit the owner's unique body size and riding style.[117] The special production process offers several advantages: the basic construction, manufactured in one pass, should be light and shockproof, with no joints or adhesive parts. The two-part battery integrated with the base plate can also be used as a power bank thanks to USB slots.[118]

[114] emco. (n.d.). About us. https://www.emco-e-scooter.com/en/about-us/ (accessed on 13.04.2022)
[115] *Home*. Kumpan Electric. https://www.kumpan-electric.com/en/ (accessed on 05.01.2022)
[116] *EIT InnoEnergy and maker of Kumpan Electric e-scooters partner to transform European mobility market.* (2020). Kumpan Electric. https://cdn.ebility.de/app/uploads/2020/08/EIT-innoenergy-invests-in-Kumpan-electric_March2020.pdf (accessed on 20.04.2022)
[117] Scotsman - About us. (n.d.). Scotsman. https://scotsman.me/about-us (accessed on 20.04.2022)
[118] Schmitt, T. (2021, June 9). Scotsman: Der Roller aus dem 3-D-Drucker. next-mobility. https://www.next-mobility.de/scotsman-der-roller-aus-dem-3-d-drucker-a-1027137/ (accessed on 18.12.2021)

Figure 37: Micromobility – manufacturers (selection)

2) Micro (e-)mobility providers (see Figure 38)

A European coalition of shared micro-mobility providers was established in 2021. **Micro-Mobility for Europe**[119](MMfE), comprising Bird, Bolt, Dott, FreeNow, Lime, TIER, Voi and Wind declares it wants to contribute to the development of a "coherent policy framework" in Europe to ensure the growth of micromobility solutions in cities and support the rapid transition to zero-emission urban mobility.

- **Bird** - electric bikes and scooters provide eco-friendly transportation for riders in over 350 cities worldwide. Easy to remove for charging or charge while on the e-bike, the 36 V/12.8 Ah removable battery safety-tested battery is built to last and is certified to meet standards for electric bicycles.[120] This company is present in more than 350 communities – Europe included.
- **ElectricFeel AG** - a Swiss company, acts as a shared micromobility platform that puts everything in one place, from operations to customer info to a connected data warehouse.[121]

[119] Micro-mobility for Europe. (2021, December 17). Home. http://micromobilityforeurope.eu (accessed on 05.01.2022)
[120] Bird Bike. (n.d.). BIRD. https://bike.bird.co (accessed on 15.02.2022)
[121] ElectricFeel | The All-in-One Solution for Shared Mobility. (n.d.). ElectricFeel. https://www.electricfeel.com/ (accessed on 15.02.2022)

- **Dott** - is a micromobility company based in Amsterdam founded in 2019. Dott operates over 30,000 shared electric scooters and electric bikes in 17 cities in Europe.[122]
- **Lime** is an electric scooter and bike-sharing company, one of the global leaders in micromobility. It offers its services in over 100 countries around the world.[123]
- **Tier** provides micromobility services using electric devices such as e-scooters, e-bikes and e-mopeds for rent and operates battery charging stations. TIER Mobility is one of Europe's leading shared micro-mobility providers, with a mission to "Change mobility for good". By providing people with a range of shared, light electric vehicles, from e-scooters to e-bikes and e-mopeds, powered by a proprietary Energy Network, TIER helps cities reduce their dependence on cars.[124] They work together with a Battery-as-a-Service (BaaS) provider, Swobbee, on a pilot project concerning exchangeable batteries for e-scooters.[125]
- **Swobbee's Battery Swapping System** (BSS) is the world's first manufacturer offering its independent battery-sharing system with an intermodal approach for small electric vehicles such as e-scooters, e-cargo bikes or e-scooters.[126]

[122] Dott | Unlock your city | Sustainable rides for all. (n.d.). DOTT. https://ridedott.com (accessed on 15.02.2022)
[123] Electric Scooter and Bike Rentals. (2022, April 26). Lime Micromobility. https://www.li.me/ (accessed on 15.02.2022)
[124] *TIER Mobility*. LinkedIn. https://www.linkedin.com/company/tiermobility/ (accessed on 10.02.2022)
[125] Sattler, L. (2021, July 5). Düsseldorf wird Testfeld für E-Scooter-Wechselakkus. next-mobility. https://www.next-mobility.de/duesseldorf-wird-testfeld-fuer-e-scooter-wechselakkus-a-1035484/ (accessed on 15.12.2021)
[126] Wunder Mobility. (n.d.). Swobbee. https://www.wundermobility.com/marketplace/swobee/ (accessed on 11.02.2022)

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Figure 38: Micromobility - providers (selection)

5.3 TECHNOLOGY

Many companies, including global automobile brands and auto parts manufacturers, produce various types of products, such as single-wheel and two-wheel Segway vehicles and electric bicycles[127]. Personal Mobility Devices have common features such as being **eco-friendly**, **portable,** and **easy to move** within short to medium distances using **electricity** as a power source. **Table 3** summarises various types of PMDs currently on the market.[128]

[127] For details see a separate chapter E-Bikes

[128] Lim, Sang-Kil & Lee, Hae-Sol & Cha, Hyun-Rok & Park, Sung-Jun. (2020). *Multi-Level DC/DC Converter for E-Mobility Charging Stations*. IEEE Access. PP. 1-1. 10.1109/ACCESS.2020.2977663. (accessed on 18.04.2022)

Table 3: Examples of Personal Mobility Devices[128]

Manufacturer	Device	Battery	Voltage [V]	Charging Type
Cross	E-bike[129]	Li-ion	36	OFBC
Unibike	E-bike	Li-ion	36	OFBC
Ecobike	E-bike	$LiFePO_4$	36	OFBC
Hyundai	E-scooter	Li-ion	36	OFBC
Coclever	E-scooter	Li-ion	36	OFBC
Yuneec	E-board	Li-ion	24	OFBC
Segway	One wheel Segway	Li-ion	63	OFBC
Segway	E-wheel	Li-ion	24	OFBC
Razor	E-heel wheel	Li-ion	12	OFBC
*OFBC: Off-Board Charger				

Electric bikes - *see separate chapter **E-Bikes***

Electric scooters

The battery's capacity can range between approx. **0.15 – 4 kWh** and has a voltage of **24 V, 36 V, or 48 V**, although they can be as high as 96 V or even 120 V.[130]

The European electric scooter market is segmented into **sealed lead-acid batteries, lithium-ion,** and **lithium-polymer (LiPo)** batteries. **Lithium-ion** battery technology dominates due to its energy density and other parameters. Some e-scooters use **lead-acid** batteries - scooters for kids and other cheaper models, for example.[131]

The **LiPo** battery segment is expected to grow as it is preferred by most electric bike manufacturers and is widely equipped on e-bikes. The LiPo battery is less expensive than other lithium batteries and maintains its performance. LiPo batteries use solid, colloidal polymers or organic electrolytes. LiPo batteries also have advantages, such as large capacity and fast charging capabilities[132] **(see Figure 39, Figure 40, Figure 41 and Figure 42)**.

[129] For details see a separate chapter E-Bikes
[130] M. (2021, September 9). *Comprehensive Guide to Electric Scooter Batteries (Must-Know Bits, Tips, Hacks)*. EScooterNerds. https://escooternerds.com/electric-scooter-batteries/ (accessed on 13.04.2022)
[131] J. (2021, August 10). *Technical Guide: Electric Scooter Batteries* ». Electric Scooter Guide. https://electric-scooter.guide/guides/electric-scooter-batteries/ (accessed on 13.04.2022)
[132] *Europe Electric Scooter Market by Size, Share, Forecasts, & Trends Analysis*. (n.d.). Meticulous Research. https://www.meticulousresearch.com/product/europe-electric-scooter-market-5239 (accessed on 13.04.2022)

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Figure 39: Electric scooter[133]

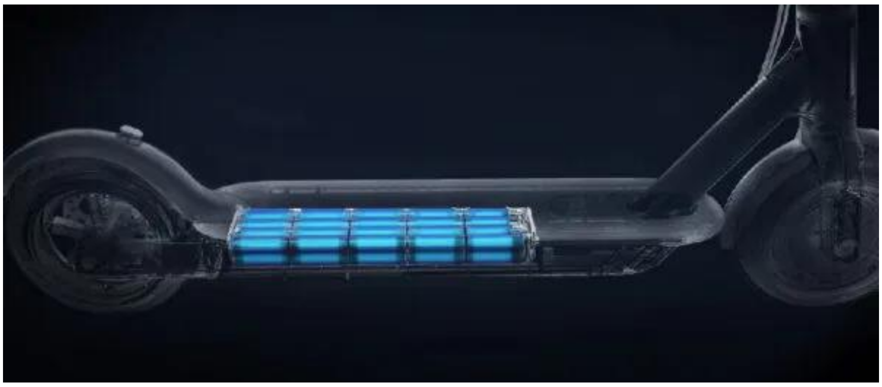

Figure 40:Example of storage of a battery pack in scooter[130]

The production of batteries is one of the most carbon-intensive parts of e-scooter manufacturing, contributing the most to e-scooters overall lifetime emissions.

133 *Sencor SCOOTER ONE*. (2022). Alza.Cz. https://www.alza.cz/sport/sencor-scooter-one-d6103039.htm (accessed on 13.04.2022)

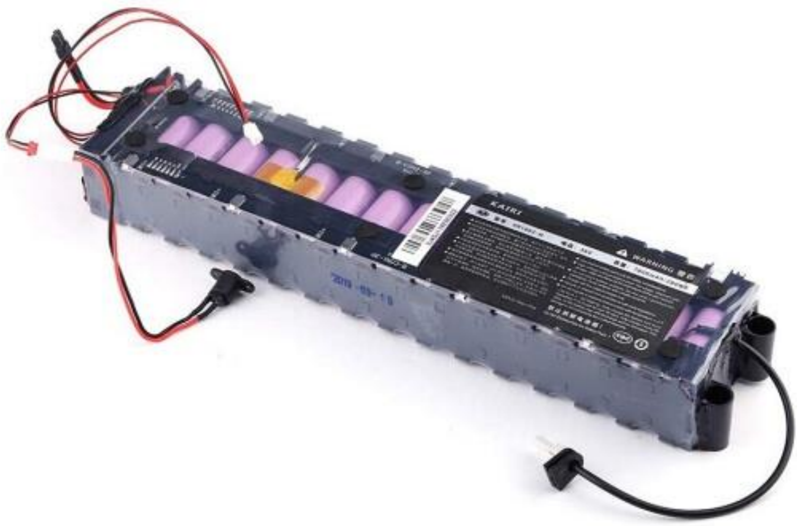

Figure 41: Example of an electric scooter battery pack[131]

Figure 42: Example of battery cells used in a scooter battery pack[131]

The standard lifespan is **at least 400-700 charging cycles**, which roughly equals a minimum of **14,000-25,000 km** driven. Shared e-scooter batteries can achieve 22,500+ km of expected battery life.[134] Batteries' minimum lifespan can be between 2 and 3 years, depending on the

[134] B. (n.d.). *Micro-Mobility position on EU Battery Regulation*. Micro-Mobility for Europe. https://micromobilityforeurope.eu/micro-mobility-position-on-eu-battery-regulation (accessed on 05.01.2022)

intensity of their use. Charging the battery can take approx. 2–5 hours. Details of the electricity flow are shown in **Figure 43**[135].

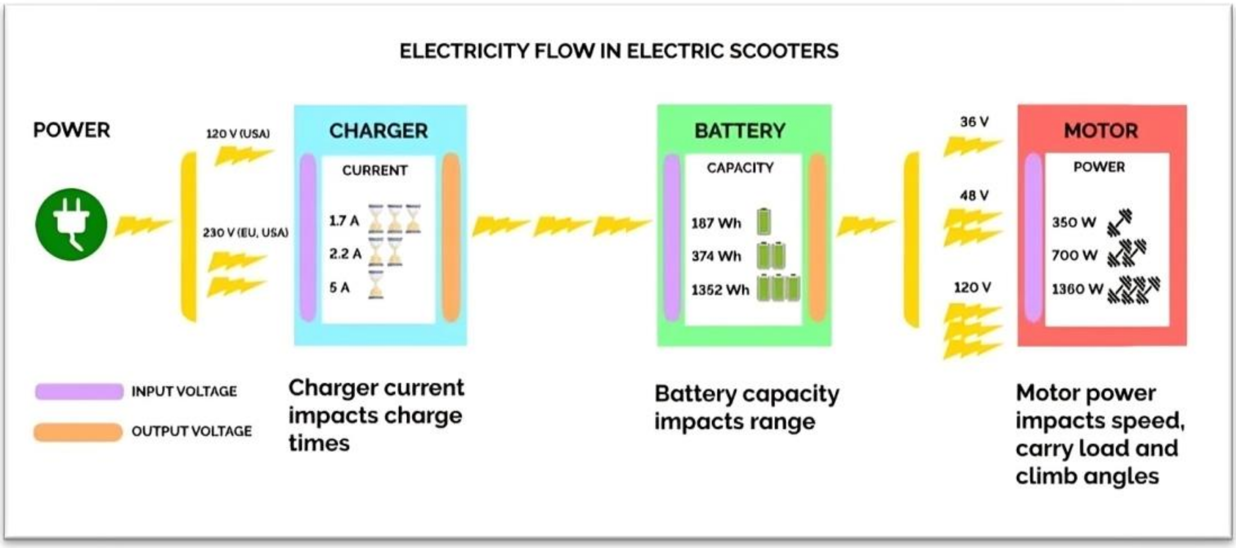

Figure 43: Electricity flow in e-scooters[136]

A selection of the s-scooter products shows their varying technical parameters (**Table 4**).

Table 4: Example of batteries used for e-scooters

Yamaha Motor Co[137]	**Multi-Location Battery**
Type	PASB6 (Lithium-ion battery)
Watt-Hour Rating	500 Wh
Battery Capacity	13.4 Ah
Voltage	36 V
Charging time	approx. 4.0 hrs
Weight	3.0 kg
Niu Technologies110	**MQiGT Standard Range**
Battery Technology	4th GEN NIU ENERGY SMART POWER TECH

[135] M. (n.d.-b). *Comprehensive Guide to Electric Scooter Batteries (Must-Know Bits, Tips, Hacks)*. EScooterNerds. https://escooternerds.com/electric-scooter-batteries (accessed on 18.04.2022)
[136] Usa, E. M. (2021, September 29). *Technology inside the Energica electric motorcycles*. Energica. https://www.energicamotorusa.com/technology/ (accessed on 12.04.2022)
[137] *FAQ*. (n.d.). YAMAHA MOTOR CO., LTD. https://global.yamaha-motor.com/business/e-bike-systems/faq/ (accessed on 13.04.2022)

Voltage	48 V
Battery capacity	31 Ah × 2
Battery Cell Type	18650 Lithium Ion
Charging Current	9 A (Single) / 16 A (Dual)
Riese & Müller GmbH[138]	**Bosch DualBattery 1000**
Battery capacity	2 x 500 Wh
Series	Load 60, Load 75
Voltage	36 V
Capacity	2 × 13.4 Ah (26.8 Ah)
Charging time	6 h
Walberg Urban Electrics GmbH112	**Egret Pro**
Range	Up to 80 km
Battery capacity	840 Wh
Voltage	48 V
Capacity	17.5 Ah
Charging time	5 h

Trade statistics

According to Trade Map[139] , **Germany** was the biggest importer of HS 871160[140] - motorcycles, including mopeds and electric bikes **(see Figure 44)**. On the other hand, **China** was the biggest exporter **(see Figure 45)**.

[138] DualBattery | Technology. (n.d.). Riese & Müller. https://www.r-m.de/en-us/technology/dualbattery/ (accessed on 14.04.2022)
[139] *Trade map*. (2022). ITC. https://www.trademap.org/Index.aspx (accessed on 18.03.2022)
[140] "Motorcycles, incl. mopeds, and cycles fitted with an auxiliary motor, with electric motor for propulsion" https://www.tariffnumber.com/2022/871160 (accessed on 18.03.2022)

Importer country	Imported value in 2020 EUR thousand	Market share %
Germany	1.430.082	20%
Netherlands	987.937	14%
USA	970.257	14%
France	485.134	7%
Switzerland	352.537	5%
Belgium	311.893	4%
Austria	224.720	3%
UK	221.795	3%
Spain	215.081	3%
Italy	207.143	3%
Rest of the world	1.699.357	24%
Total	**7.105.936**	

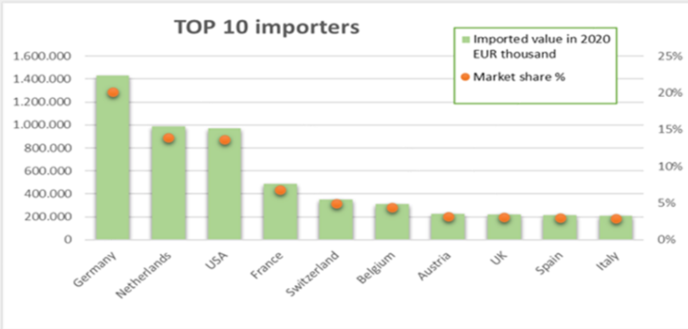

Figure 44: TOP 10 Importers[141;142]

Exporter country	Exported value in 2020 EUR thousand	Market share %
China	3.071.270	35%
Germany	1.179.494	13%
Netherlands	1.026.830	12%
Taiwan	872.295	10%
Austria	334.834	4%
Hungary	327.610	4%
Bulgaria	269.099	3%
Belgium	244.075	3%
Czech Republic	192.326	2%
Hong Kong (China)	159.436	2%
Rest of the world	1.089.016	12%
Total	**8.766.285**	

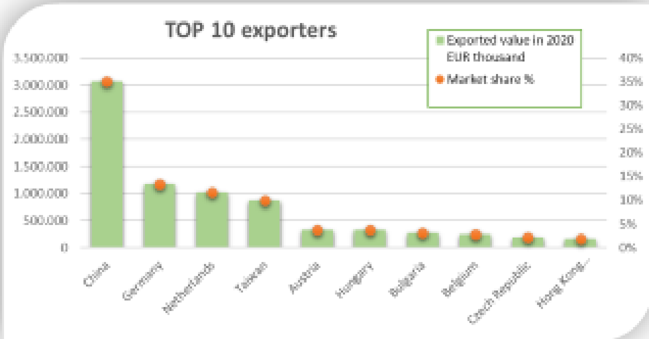

Figure 45: TOP 10 exporters[141;142]

Carmakers are increasingly looking toward new ways to move people around, including tapping into the rising trends of e-bikes and e-scooters:

- The **Ford** Supercruiser - a chopper-style electric bike with a 600-watt motor running off a 48 V and 10 Ah Lithium-ion battery pack using Samsung cells.[143]

[141] *Micromobility: a major asset for intermodality*. (2021, December 15). Mobiprox. https://mobiprox.fr/micromobility-a-major-asset-for-intermodality/ (accessed on 21.02.2022)
[142] *La micro-mobilité en questions*. (2020, November 23). Mobiprox. https://mobiprox.fr/la-micro-mobilite-en-questions/ (accessed on 21.02.2022)
[143] Ford Supercruiser Review. (2019, November 4). ElectricBikeReview.Com. https://electricbikereview.com/ford/supercruiser/ (accessed on 20.03.2022)

- French carmaker **Peugeot** - produced bicycles long before making cars - as far back as the 19th century. After going through periods of licensing out the brand to other manufacturers, the company brought it back in-house in 2010, according to the brand's website. Since then, the company has developed a whole line of e-bikes, such as the electrically-assisted eLC01.[144]
- **Audi** has developed its own electric scooter. Despite its name, the e-tron scooter is more of a cross between a skateboard and a scooter than a traditional electric scooter.[145] To be transported in a car, bus or train, the twelve-kilogram e-scooter can be folded up and stored in the back of the car or, if preferred, pulled like a trolley.[146]
- **Volkswagen** has been developing the compact Cityskater for quite some time. In the meantime, the electrically driven last-mile surfer is about to be ready for series production. Unlike typical electric scooters, the Cityskater has a rear wheel and two front wheels - each leg has its own running board. A steering rod provides the necessary support, while the intuitive weight shift from one leg to the other steers the vehicle - similar to skiing.[147]

[144] eLC01. (n.d.). Peugeot Cycles. https://cycles.peugeot.com/elc01 (accessed on 21.02.2022)
[145] 6 carmakers that are betting electric scooters and bikes — not cars — are the future of city transportation. (2019, August 11). Business Insider Nederland. https://www.businessinsider.nl/ford-audi-bmw-vw-gm-make-mobility-products-2019-8?international=true&r=US#ford-super-cruiser-1 (accessed on 21.02.2022)
[146] Audi combines e-scooter with skateboard. (n.d.). Audi MediaCenter. https://www.audi-mediacenter.com/en/press-releases/audi-combines-e-scooter-with-skateboard-11957 accessed on 21.02.2022
[147] Micromobility: With Volkswagen innovations through the city. (n.d.). Volkswagen AG. https://www.volkswagenag.com/en/news/stories/2019/07/urban-innovative-sustainable.html (accessed on 21.02.2022)

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5.4 JOB, ROLES AND SKILLS

Identified skills and competencies in this sector:

- **Systems Engineer for Battery Management Systems (BMS)** – one of the most desired job roles in the sector, requires studies in the field of electrical engineering and good knowledge of battery systems and lithium-ion cells, with strong programming skills[148]
- **Product Design Manager** – another job very desired in the shared micromobility - with the focus on a solid experience in building and shipping applications or software and different design tools Sketch, Flinto, InVision, Framer[149]

In general, many job roles rely on **strong IT skills** and/or **electronics/electrical engineering** and experience in **software engineering**. Additional competencies include strong communication skills, business intelligence, measurement and test technology handling, and others.

[148] Anforderungs- und Systemingenieur (m/w/d) für Batterie-Management-Systeme (BMS) wird eingestellt! (n.d.). bmz-group. https://bmz-group.csod.com/ats/careersite/JobDetails.aspx?site=4&id=255 (accessed on 18.04.2022)
[149] https://careers.bolt.eu/positions/6024247002, (accessed on 18.04.2022)

6 E-Bikes

6.1 DRIVERS OF CHANGE

The growth of sales of electric bikes (e-bikes) since the beginning of the 21st century in Europe has been driven by numerous factors, such as decarbonisation and activities related to improving health quality in city centres, ageing of the population, the popularity of shared mobility, but most of all with the advancements in **lithium-ion battery technology**. "A decade ago, the battery technology simply did not exist to supply batteries which were light and compact enough, with adequate energy density and affordable pricing."[150]

E-bikes are used for recreational activities, tourism and commuting, and by delivery and postal services. They are increasingly popular among the elderly, who no longer have to worry about rugged terrain. In addition, growing environmental awareness, bike-sharing projects' popularity in some cities, and the Covid-19 pandemic have helped increase the spread of e-bikes.

Limiting factors to even more considerable market uptake in some regions might include high battery prices and customers' worries concerning the limited lifespan of lithium-ion batteries.

6.2 STAKEHOLDERS

E-bikes have been standard for many years in countries such as **China,** trying to tackle heavy air pollution and dense traffic. China has been dominating the battery pack production for e-bikes, investing heavily in **production and R&D** capabilities. Some major producers, such as CATL, have been adding extra production lines for **LFP** (lithium iron phosphate) batteries to meet the increased demand for batteries for e-bikes.[151]

[150] Branquinho, L. (2021, June 14). *How do electric bikes work?* Cyclingnews.Com. https://www.cyclingnews.com/features/how-do-electric-bikes-work/ (accessed on 24.02.2022)
[151] *E-Bike Battery Pack Market | 2022 - 27 | Industry Share, Size, Growth - Mordor Intelligence*. (2022). ww.Mordorintelligence.Com. Retrieved May 5, 2022, from https://www.mordorintelligence.com/industry-reports/e-bike-battery-pack-market (accessed on 24.02.2022)

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In 2018, the European e-bike market was valued at 9 Billion USD. It is expected to continue to grow **(see Figure 46)**, and its value is expected to reach **18 Billion USD** in 2027. [151] More than **130 million** electric bicycles (using all battery technologies) are expected to be sold worldwide between 2020 and 2023.[152]

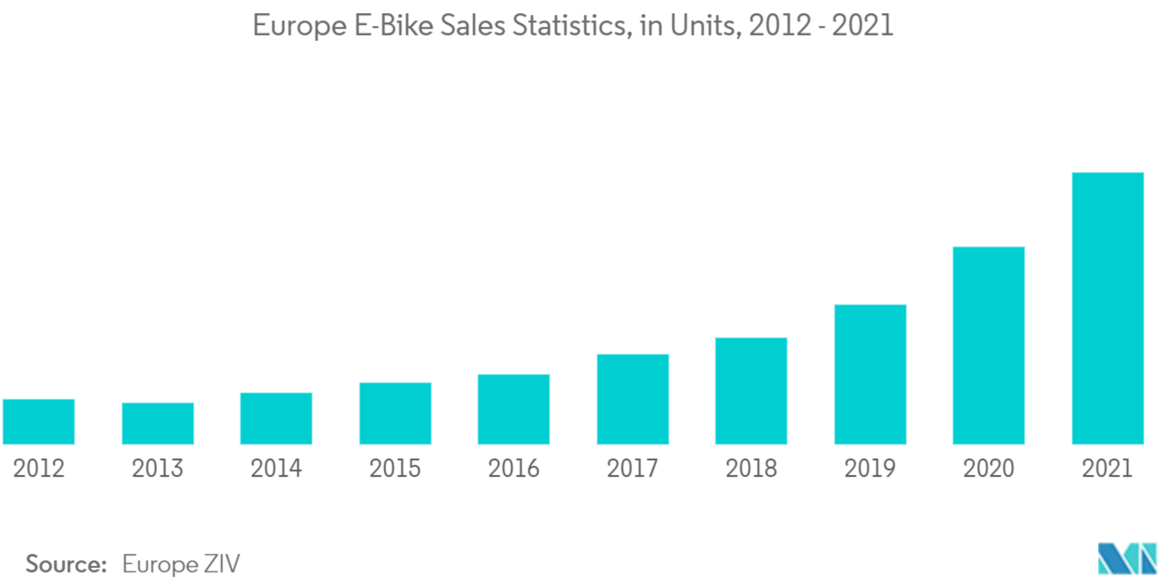

Figure 46: European E-bike sales 2012-2021[153]

In Germany, for example, the sales of e-bikes have **outpaced** sales of conventional bikes already in 2019 **(see Figure 47)**.

[152] *Facts & Statistics of Electric Bicycles [2022] + Infographic.* (2022, April 27). eBicycles. https://www.ebicycles.com/ebike-facts-statistics/ (accessed on 24.02.2022)

[153] *E-Bike Market Analysis & Trends | Industry Growth 2021 to 2026 - Mordor Intelligence*. Mordor Intelligence. https://www.mordorintelligence.com/industry-reports/e-bike-market#faqs (accessed on 24.02.2022)

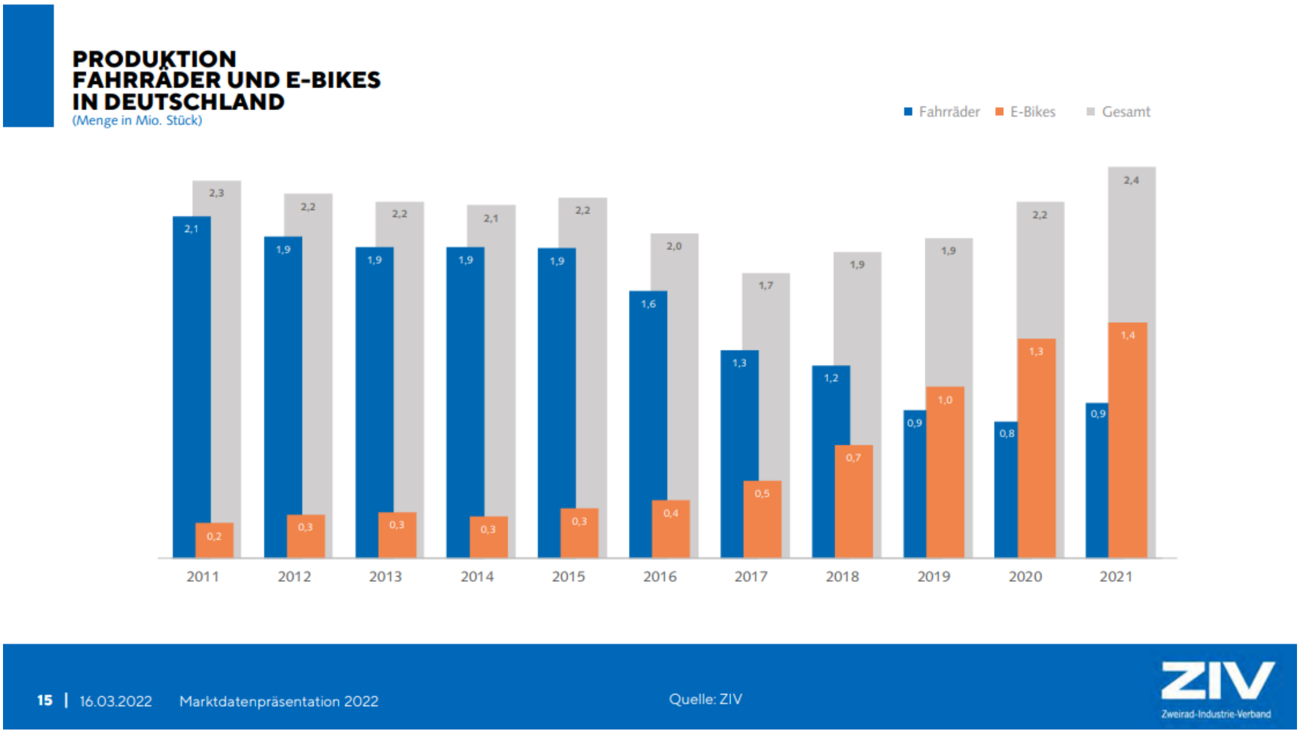

Figure 47: Germany e-bike sales 2011-2021[154]

The European e-bike market is dominated by **Germany, France, Netherlands** and **Italy**. However, it is somewhat scattered, with many producers holding smaller market shares, while on the other hand, the e-bike **battery pack market** is relatively consolidated.

The most significant **e-bike manufacturers (see Figure 48)**[151]

1) **Giant Bicycles Co. Ltd** – a Taiwanese bicycle manufacturer with manufacturing facilities in Taiwan, China, the Netherlands, and Hungary, established in 1972. The world's largest bicycle manufacturer and designer.

2) **Merida Industry Co. Ltd** - a Taiwan-based company, manufacturing in Taiwan, China, and Germany, where it also has its R&D headquarters.

3) **Riese & Muller** – German bicycle manufacturer, based in Darmstadt, founded in 1993. All its bicycles are assembled by hand in Germany. One of the first e-bike

[154] *Marktdaten Fahrräder und E-Bikes 2021.* (2022). https://www.ziv-zweirad.de/fileadmin/redakteure/Downloads/Marktdaten/ZIV_Marktdatenpraesentation_2022_fuer_Geschaeftsjahr_2021.pdf (accessed on 24.02.2022)

manufacturers to introduce Bosch DualBattery technology and has been equipping many series with it ever since. The battery capacity of the E-Bikes is up to 1.25 kWh. The DualBattery technology enables the parallel use of two batteries.[155]

4) **Fritzmeier Systems GmbH & Co. K.G. (M1 Sporttechnik)** – German machinery and transport systems group based in southeast Germany, founded in 1926.

5) **Yamaha Bicycles** – a Japanese company founded in 1887. Its branch Yamaha Bicycles has been manufacturing e-bikes since 1993.

6) **Trek Bicycle Corporation** – a US (Wisconsin) based company founded in 1975 with manufacturing sites in the US, the Netherlands, Germany, Taiwan and China.

7) **Cannondale Bicycle Corporation** – founded in 1971 with headquarters in the U.S. (Connecticut). Assembles bikes in Taiwan, the US and the Netherlands.

8) **ONO Motion**[156] - ONOMOTION is a Berlin-based e-mobility company introducing the ONO E-Cargo Bike, combining a bicycle's flexibility with a van's capacity and durability. The 1.4 kWh battery can be replaced within seconds and allows a range of up to 30 km.

Figure 48: Example of e-bike manufacturers

[155] DualBattery | Technology. (n.d.). Riese & Müller. https://www.r-m.de/en-us/technology/dualbattery/ (accessed on 13.04.2022)

[156] Neue Mobilitätskonzepte und -fahrzeuge aus Berlin. (2022, April 4). ONOMOTION GmbH. https://onomotion.com (accessed on 05.01.2022)

The most significant **e-bike battery pack** manufacturers **(see Figure 49)**[151]

1) **Samsung SDI Co. Ltd** – headquarters in South Korea, established in 1970, manufacturing batteries in S. Korea, China, and Hungary.
2) **Yamaha Corporation** – a Japanese company, founded in 1887
3) **Yoku Energy (Zhangzhou) Co. Ltd** - a Chinese company founded in 2004, producing Lithium-ion polymer batteries, Lithium-ion cylindrical batteries (including LiFePO4 batteries) and Li-ion battery packs[157]
4) **Kingbo Power Technology Co. Limited** – a Chinese company developing and producing high-tech lithium-ion batteries, Li-polymer batteries, LiFePO4 batteries, Li-ion battery systems[158]
5) **Liv Cycling** – specialising in bicycles and components for women. Part of the Giant group (Taiwan)
6) **Shimano Inc**. – producing bicycles and components. Established in 1921 in Japan, having main production sites in China, Malaysia, and Singapore
7) **Panasonic Industry Europe GmbH** - part of the Panasonic Industrial Solutions company, which belongs to the global Panasonic Group with headquarters in Japan. Panasonic was founded in 1955.
8) **BMZ GmbH** - involved in the entire product life cycle of cross-industry lithium-ion battery systems. The group is headquartered in Karlstein, Frankfurt am Main, Germany, with additional manufacturing facilities in China, Poland, and the U.S.
9) **Mahle GmbH -** is an automotive parts manufacturer based in Stuttgart, Germany, having production plants and research and development centres in Germany, the U.K., the U.S., Brazil, Japan, China, India, Poland, Spain, Slovenia and Luxembourg
10) **Varta AG** – a German battery manufacturer with headquarters in Ellwangen, founded in 1887, has several manufacturing sites in many countries in Europe and beyond

[157] *Zhangzhou Yoku Energy Technolog Co.,Ltd. (n.d.). Www.Youkuenergy.Com*. Retrieved May 10, 2022, from http://www.yokuenergy.com/index.php?m=content&c=index&a=show&catid=7&id=3 (accessed on 24.02.2022)
[158] *Top Lithium Ion Battery in Germany | German Lithium Ion Battery |* Germany, UK, Russia. (n.d.). Lithium Ion Battery Manufactures Germany. Retrieved May 10, 2022, from https://kingbopower.com/about.php (accessed on 24.02.2022)

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11) **Johnson Matthey -** a British company headquartered in London, England, established in 1817 with many manufacturing sites in Europe and beyond

Figure 49: E-bike battery pack manufacturers (selection)

6.3 TECHNOLOGY

E-bikes usually carry a battery pack with a capacity ranging from approx. **0.3–1.0 kWh** (sometimes with extensions) stored inside or outside the frame or attached to the rack. Some long-range models can carry a bigger battery with a capacity of 3.3 kWh, for example.[159] The battery pack is often replaceable. The batteries are the costliest component. For example, a 0.5 kWh e-bike battery pack can cost around EUR 500.

The lithium-ion batteries used in e-bikes often have a **cylindrical** shape, and their chemistry variants include Nickel Manganese Cobalt (NMC), Lithium Cobalt Oxide (LCO), and Lithium Iron Phosphate (LFP).[160] Lithium-ion battery technology has been dominating over lead acid battery technology **(see Figure 50)**.

[159] *Optibike. (n.d.). The Best Long-Range E-Bike. Retrieved August 20, 2022, from https://optibike.com/long-range-touring/*

[160] George, N. (2020, June 22). *E-bike battery advice from a battery engineer*. SomEV. Retrieved May 10, 2022, from https://www.som-ev.com/blog/everything-about-e-bike-batteries-from-a-battery-engineer (accessed on 24.02.2022)

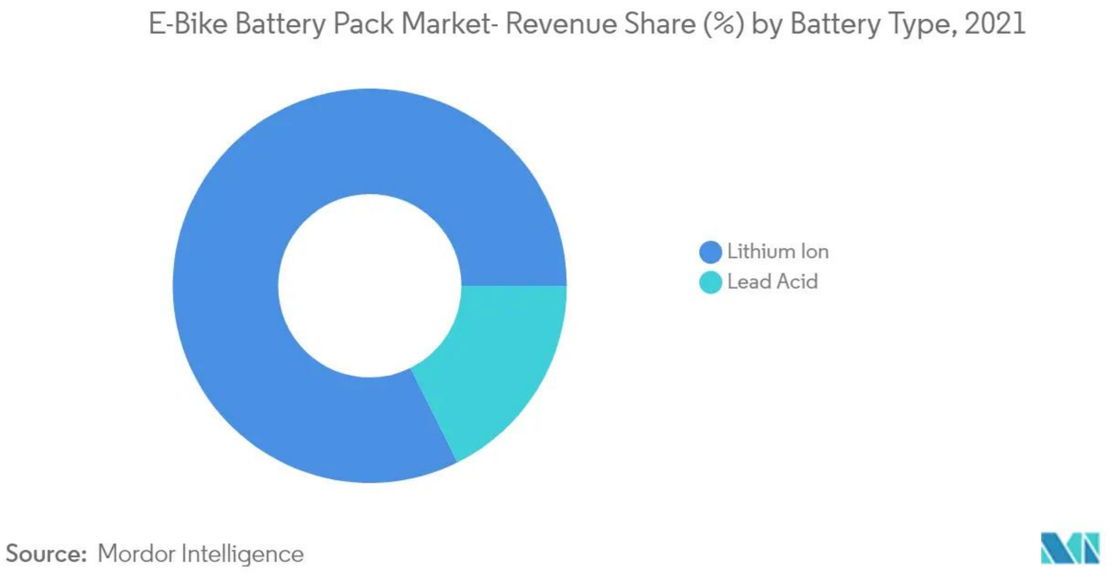

Figure 50: Used battery types in 2021[151]

Regarding the range on a single charge, city e-bikes can reach approx. 50-60 km, standard e-bikes with 0.4–0.5 kWh battery 100–120 km and longest range e-bikes approx. 350-400 km.[161] Unlike electric cars, the battery capacity of e-bikes and their range is considered **sufficient**, although there is always room for improvement regarding the lifespan of the battery, its performance, charging speed, weight and costs. The voltage of the e-bike batteries differs based on the required performance, mainly ranging from 36 V up to 72 V, with 36 V and 48 V variants being the most common **(see Figure 51)**.[151]

Compared to a conventional bike, an e-bike has an electric motor, speed and torque sensors, battery management system, charger, controllers and other **components**. E-bike **types** include city bikes, mountain bikes and cargo bikes. Some companies offer advanced systems and services, such as navigation, anti-theft, remote diagnostics or ABS[162].

[161] Karni, I. (2021, November 16). *What is E-bike Range on Single Charge? How Far Can E-Bikes Go? Easy E-Biking. Retrieved* May 10, 2022, from https://easyebiking.com/how-far-can-electric-bikes-go/ (accessed on 24.02.2022)
[162] Tottoc, J. K. M. (2021, July 6). *Top 10 Electric Bike Companies. Yahoo Finance*. Retrieved May 10, 2022, from https://finance.yahoo.com/news/top-10-electric-bike-companies-102206305.html?guccounter=1&guce_referrer=aHR0cHM6Ly93d3cuZ29vZ2xlLmNvbS8&guce_referrer_sig=AQAAANKRG-3XhGONHhjuJR8RvQSXVDdYkvCK_burJepDVV7bPL4EkpZ0kF45SlYyYyxfS_Pww5LCWF65zrZW6GYpemxLoDi-0vNif626V5Gq5b8GhGv5Fhc4hsFM9stXvvy1a3aqQVYv1_LlznNrgKhuvdaKp0SchaFUE7gqH9tlQ7p1 (accessed on 24.02.2022)

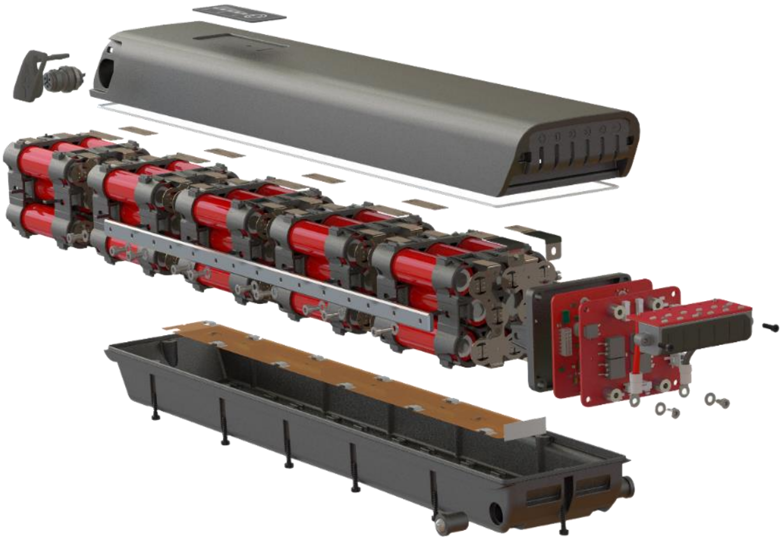

Figure 51: Structure of a battery pack[163]

6.4 JOB, ROLES AND SKILLS

Job roles relevant to batteries in e-bikes can include the following:

- **R&D** – developing and designing batteries and other electric systems for e-bikes
- **Manufacturing** – battery pack/e-bike assembly
- **Servicing** – servicing or replacement of malfunctioning or end-of-life battery packs and cells, refurbishing of the battery packs
- **Operation** - assistance at charging or battery swapping points. In the case of e-bike sharing projects - the staff responsible for the monitoring of State of Charge (SoC), collecting and charging of e-bikes
- **Disassembly** - of end-of-life e-bikes and battery packs

163 *DRIVE SYSTEMS*. BMZ GROUP -Batteriehersteller und Batteriesysteme. https://bmz-group.com/index.php/en/battery-systems-en/drive-systems (accessed on 24.02.2022)

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7 Aerospace

7.1 DRIVERS OF CHANGE

This chapter analyses battery devices that can move in the atmosphere - aeroplanes and drones. Nevertheless, there are also some exciting developments concerning devices capable of operating in the orbit and outer space – satellites and spaceships.

In the last ten years, there have been 250 **satellite** explosions in orbit, and ten of them occurred due to batteries with the old nickel-hydrogen battery technology. Nowadays, satellites are using modern lithium-ion batteries with no issues yet. Currently, lithium-ion technology is extensively tested. One of the critical activities when the satellite is at the end of its life, is to drain the batteries to have almost no energy to eliminate possible ignite while out of service.[164]

The **International Space Station** (ISS) is the most complex space object. In 2021 the astronauts had a mission to change batteries from old nickel-hydrogen to modern lithium-ion. According to NASA, the task required 13 different astronauts and 14 spacewalks. Boeing provided new space-grade lithium-ion cells. The technology consists of standard 18650 cells used in many applications on Earth. The following task for astronauts is to change six solar arrays to enable enough power for the new battery system.[165]

Aeroplanes

The limitations for air travel using **battery-powered aeroplanes** are relatively high, and due to limited operational range, it has so far been mostly limited to pilot projects in regional air transport **(see Table 5)**. Nevertheless, for example, it is increasingly used within large agglomerations or for specific short trips as an "**air-taxi**" as a convenient and fast way of (future) travelling.[166]

[164] *Testing space batteries to destruction for cleaner skies*. (2019). The European Space Agency. https://www.esa.int/Safety_Security/Clean_Space/Testing_space_batteries_to_destruction_for_cleaner_skies (accessed on 24.05.2022)
[165] Garcia, M. (2021, February 2). *Spacewalkers Complete Multi-Year Station Battery Upgrades.* NASA. https://www.nasa.gov/feature/spacewalkers-complete-multi-year-effort-to-upgrade-space-station-batteries/ (accessed on 24.05.2022)
[166] National Renewable Energy Laboratory. (n.d.). *Electrification of Aircraft: Challenges, Barriers, and Potential Impacts*. https://www.nrel.gov/docs/fy22osti/80220.pdf (accessed on 24.05.2022)

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Table 5: Electrification of aircraft: Main factors behind the global change (selection)

Reduced costs	Fuel costs can be reduced by up to **90 %** and maintenance costs by up to **50 %**. The revitalisation of some routes due to lower operational costs
Regional travel market	Increased use of smaller airports that are **closer to the passengers**
Noise reduction	**Noise reduction** by 85 %
Economic development	Potential economic boom at **small airports** that are currently less used

Around **45 %** of flights globally are within reach of electric aircraft (under 500 miles), currently projected to reach the market by 2030. This could help to decarbonise the aeroplane industry significantly.[167]

Drones

Technology advancements in lithium-ion batteries, their decreasing costs, and at the same time, good energy density and reasonable weight have helped the **global widespread** of remote-controlled crewless aerial vehicles - drones - in recent years **(see Figure 53)**. Other drivers include the availability of cheap microprocessors and the possibility of carrying cameras enabled by merging radio-controlled aircraft and smartphone technology.[168]

[167] National Renewable Energy Laboratory. (n.d.). *Electrification of Aircraft: Challenges, Barriers, and Potential Impacts*. https://www.nrel.gov/docs/fy22osti/80220.pdf (accessed on 24.05.2022)
[168] https://interestingengineering.com/a-brief-history-of-drones-the-remote-controlled-unmanned-aerial-vehicles-uavs (accessed on 24.05.2022)

Drones have been in **military use** for decades. However, in recent years have become popular among hobbyists and in **commercial** or other **professional use** such as e. g. delivery, surveillance, law enforcement, cinematography, agriculture, protecting animals, health care, construction or mining.[169] Amazon's pilot delivery project Prime Air **(see Figure 52),** tested in California, is one of the examples that attracted considerable media attention.

Figure 52: Pilot delivery project by Amazon[170]

[169] Alkobi, J. (2022, February 22). *The Evolution of Drones: From Military to Hobby & Commercial*. Percepto. https://percepto.co/the-evolution-of-drones-from-military-to-hobby-commercial/(accessed on 24.05.2022)

[170] Staff, A. (2022, June 13). *Amazon Prime Air prepares for drone deliveries*. US About Amazon. https://www.aboutamazon.com/news/transportation/amazon-prime-air-prepares-for-drone-deliveries (accessed on 24.05.2022)

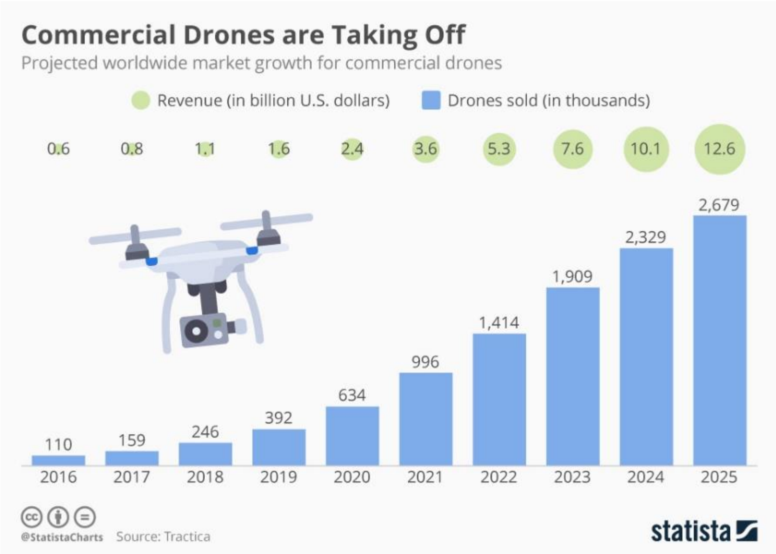

Figure 53: Drones market grow [171]

In addition, the recent Russia – Ukraine military conflict has amplified the significance of using drones that can provide real-time military intelligence or even carry bombs, missiles, and other weapons. As a result, the **drone battery market** is projected to grow from USD 4.0 billion in 2021 to **USD 9.6 billion by 2026**, at a CAGR of 19.0 % from 2021 to 2026.

7.2 STAKEHOLDERS

Aeroplanes

Many of the announced futuristic aviation projects are just sketches on paper or pure visions. Nevertheless, some exceptions exist - companies already listed on the stock market or signed contracts with major corporations worldwide:

- **Lilium Jet** is based in Munich, Germany. The company bets on developing first of its kind electric vertical take-off and landing jet **(see Figure 54)**. It is now undergoing a certification process under the European Union Aviation Safety Agency (EASA).[172]

[171] Buchholz, K. (2019, February 28). *Commercial Drones are Taking Off. Statista Infographics*. https://www.statista.com/chart/17201/commecial-drones-projected-growth/ (accessed on 24.05.2022)
[172] Borrás, J. (2022, April 14). *Lilium Jet eVTOL Project Inches Towards EASA Certification*. CleanTechnica. https://cleantechnica.com/2022/04/14/lilium-jet-evtol-project-inches-towards-easa-certification/ (accessed on 24.05.2022)

Figure 54: Electric vertical take-off and landing jet[173]

- **Eviation** is an Israel-based company developing an all-electric passenger aeroplane named Alice **(see Figure 55)**. It shall accommodate nine passengers and two crew members. The plane is in the process of testing under the US Federal Aviation Agency (FAA) rules.[174]

Figure 55: Alice – a battery aeroplane by Eviation[176]

[173] *Lilium Jet - The First Electric VTOL (eVTOL) Jet - Lilium*. (2022). Evtol.Com. https://lilium.com/jet (accessed on 24.05.2022) (accessed on 24.05.2022)
[174] Head, J. O. A. E. (2022, April 6). *Approaching first flight, Eviation's Alice readies to test FAA*. The Air Current. https://theaircurrent.com/aircraft-development/eviation-alice-readies-first-flight-faa/ (accessed on 24.05.2022)

Drones

Major players include the following companies **(see Figure 56)**[175]:

- EaglePicher Technologies (US)
- Plug Power (US) – military drones
- Shenzhen Grepow Battery Co. Ltd (China)
- RRC Power Solutions (Germany)
- HES Energy Systems (Singapore) – military drones
- Inventus Power (US) – military drones
- Oxis Energy Ltd. (UK) – military drones

Figure 56: Aeroplanes and drones manufacturers (selection)

7.3 TECHNOLOGY

Aeroplanes

Eviation announced a range of up to 815 km (440 nautical miles) for its battery aeroplane on one charge.[176] The central power unit of the electric jet consists of two powerful electric engines from a US-based company MagniX with joined power of up to 650 kW, and the jet

[175] *Drone Battery Market*. (2021). Markets and Markets. https://www.marketsandmarkets.com/Market-Reports/drone-battery-market-131005766.html (accessed on 21.05.2022)
[176] *Eviation – Eviation Alice*. (2022). Eviation. https://www.eviation.co/ (accessed on 24.05.2022))

powers a large battery pack of **820 kWh** up to **980 kWh** (currently in the prototype stage, final battery capacity not published yet).[177]

Eviation has not provided details about its battery technology but aims to have on board **72 interchangeable battery modules** distributed across 12 packs to provide power across the whole electric jet equally. [178]

Drones

Compared to other battery applications mentioned in this report, the capacity of batteries used in drones is **relatively tiny**. It commonly ranges between 150–25,000 mAh and has a voltage of 3.7–22.2 V, depending on the drone's size and purpose. For example, common hobby drones can have a battery with 3.7 V or 7.4 V and **1,000–2,500 mAh**.

There are drones designed to remain in the air as long as possible or, on the other hand, high-performance sports drones requiring quick bursts of energy. There are also very special drones being developed, such as drones designed to carry heavy payloads or micro-drones for special purposes.

The drone battery market can be segmented into lithium-based, nickel-based, and fuel cell-based. The lithium-based has been dominating and is expected to lead the market in the future.[175] Particularly, the **lithium-polymer** (LiPo) technology is trendy. The advantages of LiPo include high energy density relative to their size and weight, higher voltage per cell and a slower rate of discharge. However, they are sensitive to properer charging to avoid overheating and ignition.[179] Future battery technologies such as lithium-metal and lithium-sulphur with high energy density and other advantages are promising for the drones segment.[175]

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177 Randall, C. (2021, August 4). *Eviation Aircraft presents technical details for “Alice.”* Electrive.Com. https://www.electrive.com/2021/07/04/eviation-aircraft-presents-technical-details-for-alice/ (accessed on 24.05.2022)
178 Posts, V. M. (2021, May 12). *What we know about Lilium’s eVTOL batteries so far*. Evtol.Com. https://evtol.com/features/lilium-evtol-batteries-what-we-know/ (accessed on 21.05.2022)
179 Editorial Staff. (2020, June 1). *The need for battery safety systems for drones*. Power Electronics News. https://www.powerelectronicsnews.com/the-need-for-battery-safety-systems-for-drones/ (accessed on 21.05.2022)

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7.4 JOB ROLES AND SKILLS

Job roles and skills relevant to electric aeroplanes and electric drones can include the following

- Aeroacoustic Engineer
- Aerodynamicist
- Compliance Verification Engineer – Flight & Human Factors
- Electrical propulsion engineer
- Flight Control Laws Engineer
- Lead Material & Processes Engineer - Energy Storage Systems
- Power Electronics Design Engineer
- Stress Engineer - Energy Storage System
- Test Engineer – Battery Abuse

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8 Trains

The application of batteries in trains is in a relatively **early stage**, which is why this chapter is rather brief and also has a simplified structure. Modern trains are either primarily electric, using a pantograph taking electricity from the grid or primarily diesel with a small electric engine or diesel-electric combining both technologies. On average, 56 % of European railways were electrified in 2019, with some countries reaching up to 91 % electrification.

The first fully **battery-powered trains** have been launched and tested in real conditions. For example, the company Union Pacific Railroad ordered 20 battery-powered freight locomotives from **Wabtec and Progress Rail**. The goal is to test them in California and Nebraska heavy-traffic areas.[180]

Apart from the US, European companies are somehow progressing too. For example, in the Netherlands, **Stadler** company successfully tested its battery trains with Arriva Netherlands that are intended to be used on non-electrified lines. Another main factor was to use the **regenerative braking** power, which is not commonly used in regular trains.[181]

A German company **Alstom** successfully tested a battery train in Bavaria in December 2021 **(see Figure 57)**. In partnership with the Technical University in Berlin, the company demonstrated the economic benefits of using batteries in trains in either non-electrified or partially-electrified train lines.[182]

In parallel with battery-powered testing trains, Alstom company also works on **hydrogen technology** to compare the long-term testing results of both technologies in real-world conditions. Besides testing in Germany, the company tested its hydrogen trains

[180] Johnson, K. (2022, February 4). *Battery-Powered Trains Are Picking Up Speed*. Wired. https://www.wired.com/story/battery-powered-trains-gather-speed/ (accessed on 24.05.2022)
[181] Sapién, J. C. (2022, February 28). *Trial of Battery-Powered Trains in the Netherlands a Success.* Railway-News. https://railway-news.com/trial-of-battery-powered-trains-in-the-netherlands-a-success/ (accessed on 24.05.2022)

in Usti and Labem and other cities in the Czech Republic. The goal is to test it in **non-electrified routes** in the country and calculate the actual savings. [182]

Figure 57: Battery train by Alstom[183]

8.1 JOB ROLES AND SKILLS

Job roles and skills relevant to electric trains can include the following

Job roles:

- Rail Operations Manager
- Electrical & Mechanical Engineer
- Logistics Engineer
- Dispatch Worker
- Rail maintenance technician
- Train maintenance technician
- Rail logistic coordinator
- The train driver and train operator

[182] *Společnost ALSTOM představila Ústeckému kraji vodíkový vlak budoucnosti: Ústecký kraj*. (2022). Ústecký kraj. https://www.kr-ustecky.cz/spolecnost-alstom-predstavila-usteckemu-kraji-vodikovy-vlak-budoucnosti/d-1767533 (accessed on 24.05.2022)

[183] *Alstom presents its battery-powered multiple unit train in Saxony.* (2021). Alstom. https://www.alstom.com/press-releases-news/2021/9/alstom-presents-its-battery-powered-multiple-unit-train-saxony (accessed on 24.05.2022)

Skills:

- Digitalisation
- Data collection, monitoring
- Cyber security
- Sensing technologies
- Smart metering
- Connectivity and terminal technologies – programming
- Smart power supply

9 Inland Waterways Vessels

9.1 DRIVERS OF CHANGE

Inland waterway vessels are both tourism/passenger and cargo vessels. **Customer demand** for green solutions and **technological developments** of lithium-ion batteries are among the key factors driving the segment towards electrification. Another key driver is reducing the total cost of investing in electrical solutions for ship owners over many years. Total cost is reduced both because **prices for battery packs are falling** towards 2030 **(see Figure 58)** and because the cost of technology for propulsion and electrical installations onboard vessels are expected to fall due to industry maturity and market size.

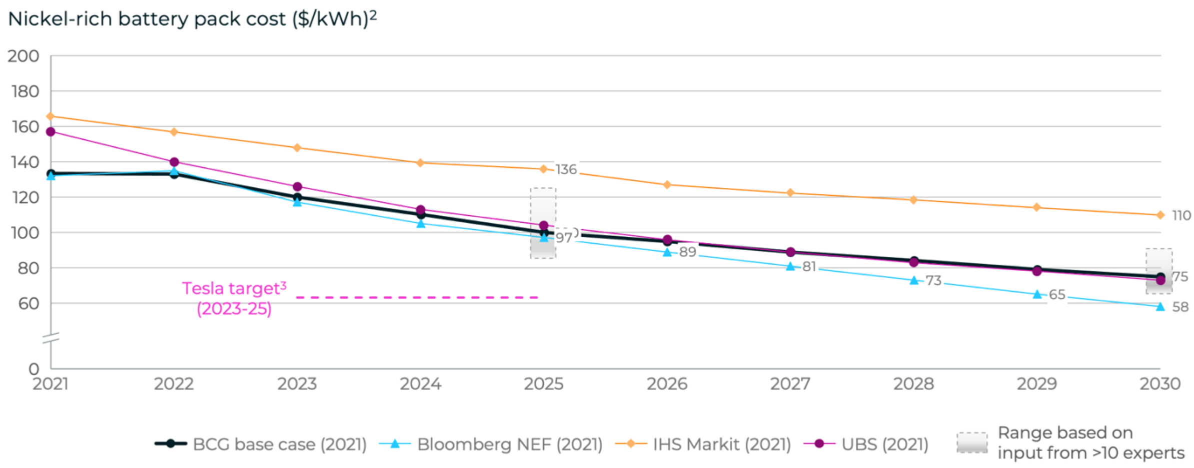

Figure 58: Battery price outlook[184]

The reduced investment cost will enable more shipowners to "go green" for new builds and retrofit existing vessel fleets over time. It can be expected that the **tourist/passenger fleet** to take the lead because customer demand is more mature in this segment than cargo.

Today, EU emission regulations are not the key driver for electrification in the inland waterways segment. However, we expect this to change rapidly as the **EU emissions trading scheme (ETS)** puts a price on maritime emissions. In 2023, companies chartering large vessels

[184] Bostin Consulting Group 2021: Predicted reduction of battery packs towards 2030 (Corvus internal study)

will be required to purchase allowances for **20 %** of their emissions from ships that call at EU ports, rising to **100 %** by 2026. [185]

There is a high **market potential** for the electrification of Inland Waterways in Europe – both in terms of retrofit and for new builds:

- >15,000 inland vessels in Europe, with ~6,000 applicable for electrification. ~2,000 vessels are expected to be hybrid or fully electric by 2030.
- Mostly retrofit (~75 %), but also potential for new builds
- Growth is expected to happen after 2025. Several EU-funded projects were initiated to boost the adoption.
- European river cruise fleet has steady growth and a young fleet – indicating high potential for both new builds and retrofits
- A fragmented customer landscape requires standardised solutions
- Inland waterways fleet is **ideal for electrification**: a large volume of smaller vessels, near shore (less costly to build charging infrastructure connected to the grid), and vessels are "within public sight. "(Visible emissions are a vital driver for electrification).

Regulatory & incentive programs

Under the European Green Deal program and the Sustainable & Smart Mobility Strategy, the following incentive programs and national ambitions can be identified (selection)[186;187]:

- NAIADES III Action Plan entitled "Boosting future-proof European inland waterway transport" focuses on the shift of freight transport to inland waterways and the sector's irreversible path to zero-emission. The objectives of this action plan are aimed at stimulating or promoting zero-emission and digital waterborne transport.
- Co-Programmed Partnership on Zero-Emission Waterborne Transport as well as the inclusion of waterborne transport applications in the EU Innovation Fund.

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[185] *Historic extension of EU's carbon market gets green light from Parliament.* (2022, June 22). Transport & Environment. https://www.transportenvironment.org/discover/historic-extension-of-eus-carbon-market-gets-green-light-from-parliament/ (accessed on 10.05.2022)

[186] *Towards future-proof inland waterway transport in Europe*. (2021). Waterborne. https://www.waterborne.eu/images/210919_Towards_future-proof_inland_waterway_transport_in_Europe.pdf (accessed on 10.05.2022)

[187] Corvus Energy market outlook report 2022. (Corvus internal study)

Co-funded by the Erasmus+ Programme of the European Union

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- Germany (2021): The European Commission approved a $156 M German scheme to sustainably modernise the inland waterway fleet.
- Netherlands (2021): Zero-emissions vessels can get grants from DKTI.
- Netherlands (2019): The government will examine the electrical and hydrogen charging infrastructure required for inland shipping.
- Netherlands (2019): Ambition of 150 zero-emissions inland vessels by 2030.
- Netherlands (2019): Ambition for additional efforts for growth and integration of zero-emissions inland vessels.

Customer demand & preferences

- Visible emissions - customers in tourism & passenger segments **prefer green solutions** to non-green solutions when given a choice. This will speed up the shift towards green solutions as soon as the market offerings become differentiated.
- Green cargo transport chains - more and more cargo owners, mainly within consumer goods, are asking for greener transport choices to reduce their aggregated **emissions footprint**. This trend should move goods from roads to inland waterways as soon as a green alternative is in place.
- **Renewable energy** growth - Europe is at the forefront of introducing wind and sun to the energy mix. Inland waterways need a network of charging stations and related grid-based infrastructure to speed the transition. This combination is a perfect match.
- **Standardised** infrastructure and technology solutions - small companies typically operate inland waterways segments with only a few vessels in their fleet. This indicates that most vessels will need to use the same shore-based infrastructure. Therefore, a set of standardised technology solutions would be very beneficial to keeping costs and investments low.

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The Netherlands is among the leaders in the electrification of the segment. In this regard, the following flagship initiatives are worth mentioning:

- **Alphenaar Cargo vessel**[188]

  Sustainable inland shipping company Zero Emission Services (ZES) BV has started operations with the Alphenaar, the first Dutch inland vessel to use interchangeable energy containers for propulsion **(see Figure 59)**. The Alphenaar sails between Alphen aan den Rijn and Moerdijk transporting beer for Heineken, ZES's first end customer.

- **Port of Rotterdam**[189]

  The Port of Rotterdam has announced that free shore-based power is available at Maaskade in Rotterdam for large inland vessels that participate in a trial with shore-based power from a battery system. Dutch green energy supplier Skoon Energy has installed a battery system there on behalf of the Port of Rotterdam Authority to strengthen the local shore-based power supply for inland shipping.

- **The Nationaal Groeifonds**[190]

  The Nationaal Groeifonds, an initiative of the Dutch Ministries of Economic Affairs & Climate Change and Finance, is investing in Zero Emission Services (ZES) to speed up the implementation of ZES' system solution for inland shipping. According to ZES, the company will receive the €50 million (around $54.9 million) investment for the entire value chain in which it operates. It will be used to develop 75 battery containers for maritime applications (ZES packs), 14 docking stations where the ZES packs are charged and 45 electrified inland vessels.

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[188] Prevljak, N. H. (2021, September 7). *First Dutch zero-emission inland vessel starts op*. Offshore Energy. https://www.offshore-energy.biz/first-dutch-zero-emission-inland-vessel-starts-op/ (accessed on 15.05.2022)
[189] Prevljak, N. H. (2022, March 15). *Port of Rotterdam: Free shore power from battery for inland vessels*. Offshore Energy. https://www.offshore-energy.biz/port-of-rotterdam-free-shore-power-from-battery-for-inland-vessels/ (accessed on 15.05.2022)
[190] Habibic, A. (2022, April 18). *Dutch govt accelerating sustainable inland shipping*. Offshore Energy. https://www.offshore-energy.biz/dutch-govt-accelerating-sustainable-inland-shipping/ (accessed on 15.05.2022)

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Figure 59: First Dutch zero-emission inland vessel[188]

Market situation:

Table 6: Data on inland waterway freight transport[191;192]

Segment	# Of vessels	# Of companies	# Of employees
Cargo / Freight	16,000	5,662	22,902
Tourism / Passenger	8,000	4,028	23,187
Total	24,000	9,690	46,089
Data from	2020 (estimate)	2018	2018

Market facts

Observations from market facts **(see Table 6)**:

1. Small-scale companies (primarily family-owned): Average 4.8 employees per company
2. Small-scale companies: average 2.5 vessels per company
3. Small-scale vessels: average two employees per vessel (less for Cargo, more for Tourism)

Germany and **the Netherlands** were the main contributors to the EU inland waterway transport, accounting for 70 % of the total in 2020. The Netherlands led on two fronts. First, the country recorded the highest volume of freight transported per inhabitant with 20 tonnes and almost half (49 %) of the registered freight transport vessels on EU inland waterways.

[191] Zelichowska, K. (2021, November 30). *Eurostat data on inland waterway freight transport*. Inlandwaterwaytransport. https://www.inlandwaterwaytransport.eu/eurostat-data-on-inland-waterway-freight-transport/ (accessed on 15.05.2022)
[192] *Statistics Explained*. (2021). Eurostat. https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Inland_waterways_freight_transport_-_quarterly_and_annual_data (accessed on 24.05.2022)

The fleet of cargo inland vessels in Europe consists of almost **10,000 vessels** registered in Rhine countries, **3,500 vessels** registered in Danube countries and **2,300 vessels** registered in other European countries. Total approximately 16,000 vessels. Fleet size has declined by approx. 10% over the last five years, whilst the total load capacity has been stable.

The Netherlands, Germany and France have the highest number of companies and employment in inland waterway freight transport. For passenger transport, the leading positions are held by the Netherlands, Germany, Italy, and Sweden.

Passenger companies in Europe are active in the following segments: **river cruises, day-trip navigation on rivers, canals, and lakes**. In addition, the **ferry transport** of passengers is also part of the sector. Germany is leading regarding employment in passenger transport with more than **6,000** persons employed. The Netherlands follows with more than **3,000** persons.

9.2 STAKEHOLDERS

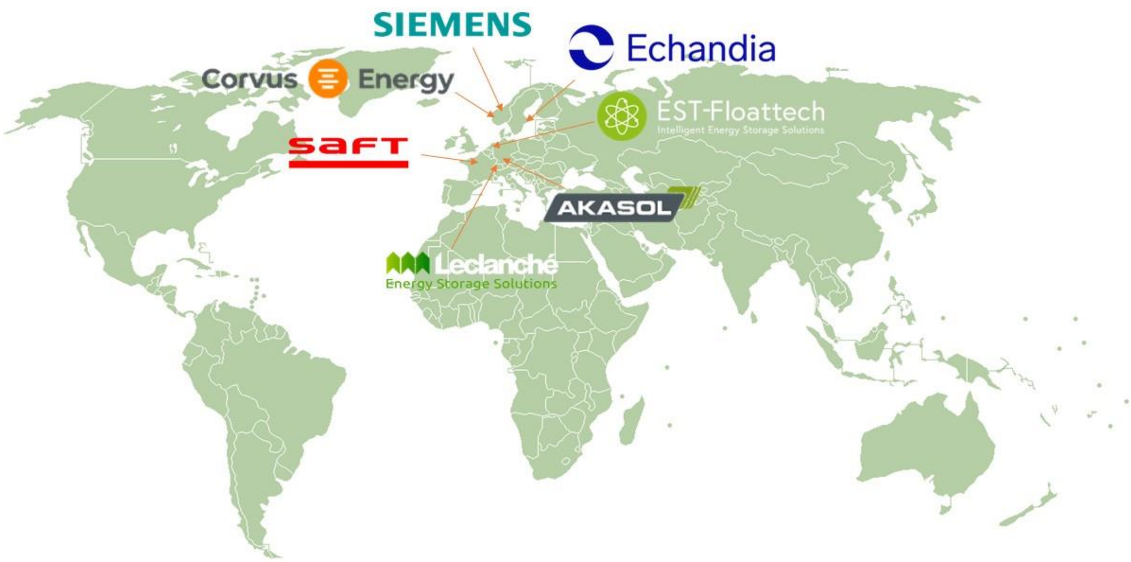

Figure 60: Vessels manufacturers (selection)

9.3 TECHNOLOGY

The current technological maturity for **Maritime Energy Storage Systems (BESS)** is high. Battery manufacturers in Europe can, together with European shipbuilders, deliver integrated solutions for tourism, passenger vessels, and cargo vessels. BESS is a viable option to power both fully electric and hybrid vessels.

From a technological point of view, inland waterway vessels are somewhat **similar to maritime vessels**, described in detail in the first ALBATTS project WP5 desk research report.[193] Vessels use the same batteries as BEVs but on a larger scale. One of the differences is in **battery pack architecture**, where vessels use more battery packs connected together as a system of modules.

Challenges relevant to the full electrification of the inland waterways fleet:

- **Charging infrastructure** for inland waterways is not widely accessible today. We should not expect fast growth in building charging infrastructure for a segment dominated by small companies with limited investment funds. Incentives programs and public funds, together with adequate regulation, could speed up the development of the charging infrastructure. Without accessible charging, shipowners will postpone their decision to convert their vessel fleet to electric. Charging infrastructure is the crucial **enabler** for the electrification of inland waterways.
- **Standardisation** of charging plugs and AC/DC supply (charging power). Inland waterways would benefit from a similar regulation as is in place for BEVs/BETs; standardisation of **charging plugs for AC/DC** energy supply. Standardising plugs and AC/DC supply can ensure economies of scale for the segment with many small companies. Maritime organisations like "The European Inland Waterway Transport Platform" (IWT) and others could lead joint efforts for this segment to unite charging standardisation.
- **Grid capacity** for electrical power is challenging across industries and European countries, including the inland waterways segment.

[193] Chapter 3.5.2 Vessels in ALBATTS D5.1 report, available at https://www.project-albatts.eu/Media/Publications/4/Publications_4_20200930_12811.pdf

9.4 JOB ROLES AND SKILLS

Job roles and skills relevant to batteries for inland waterways include the following:

- **R&D -** developing and designing batteries and other electrical systems for maritime operations, requiring high safety and robustness to fit Class society regulations to secure the highest standard of passenger and crew safety.
- **Manufacturing** - battery pack/modules assembly into complete Marine Battery Energy Storage Systems (BESS).
- **Servicing -** commissioning and servicing vessels in operation, at the dock, on board or, if possible, remotely.
- **Operation** - education and training of crew in maritime safety, operations, charging, and manoeuvring of vessels with Battery Energy Storage Systems (BESS)
- **Disassembly** - end-of-life BESS and battery packs ready for reuse or recycling.

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10 Job Roles and Skills for Mobile Battery Applications

This section provides an overview of the job roles and skills needed for **heavy-duty electric vehicles, vans** and other mobile battery applications: **motorcycles, e-bikes, e-scooters, drones, satellites, trains** and inland waterway **vessels**. They are based on the number of job advertisements analysed by the project members - data set: **160 job advertisements**.

Needs are categorised by the following structure for mobile battery applications with general descriptions in respective chapters below:

- Design and Development
- Manufacturing
- Maintenance
- Sales, Services, and Support
- Technical Project Management

Higher importance is given to the **sector-specific** and **transversal** technical skills/knowledge seen per individual category. On the other hand, academic, soft, and transversal basic skills are summarised for the whole data set.

10.1 DESIGN AND DEVELOPMENT

Job roles included in this chapter include engineers, engineering technicians, drafters, software developers/engineers, or industrial designers. **Engineers** generally develop economical solutions to technical problems according to the requirements or specifications by applying various principles of science and engineering techniques. Engineers link research, development, and theory into practice by developing commercial and industrial solutions via **engineering design process**, as seen in **Figure 61** below.

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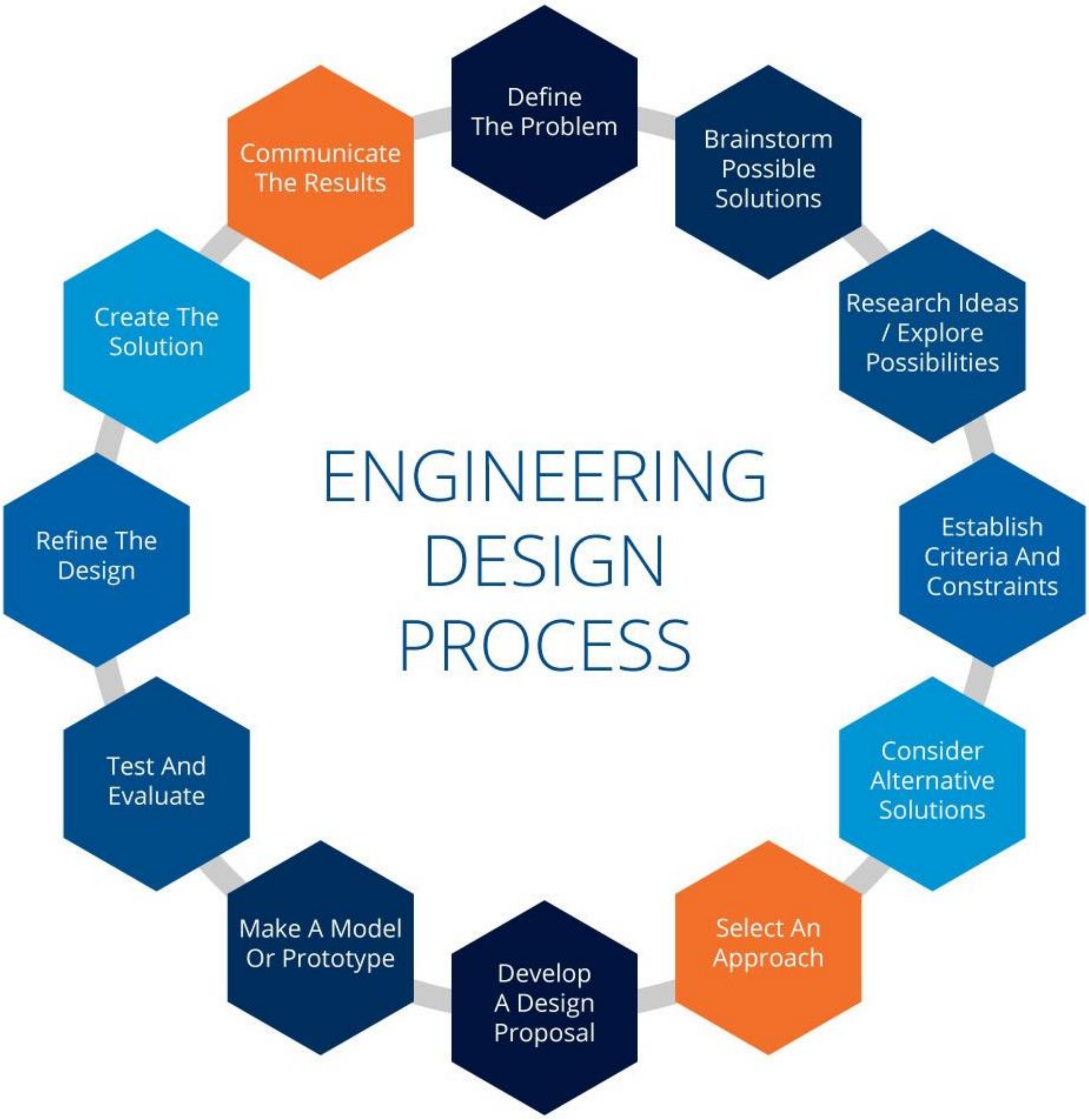

Figure 61: Engineering Design Process[194]

Engineers use computers and software tools to produce and analyse designs and simulate or test the systems. Computers are also necessary to monitor quality control processes.

[194] *What is the Engineering Design Process? A Complete Guide*. (2022). TWI. https://www.twi-global.com/technical-knowledge/faqs/engineering-design-process (accessed on 30.07.2022)

10.1.1 Work Environment

Engineers can work in offices, laboratories, or industrial plants/factories and are employed by companies that manufacture electric vehicles and other mobile battery applications**.** Engineering positions are **highly demanded** globally in the manufacturing sector, particularly in the automotive sector.

Engineers work with other **engineering teams**, scientists, and managers, such as industrial managers, to design new processes for manufacturing electric vehicles and other mobile battery applications and optimise them. In addition to the engineers (white-collars), blue-collar positions are also needed, such as engineering technicians or mechanical drafters who assist engineers.

10.1.2 Job Roles and Skills Needs

Electrical engineers can design, develop, test, and supervise the manufacturing of electrical components and design the electrical circuits and other electrical systems (electricity distribution, heating systems, air-conditioning, lighting, visual displays and others).

Electronics engineers focus on electronic components and systems, such as control systems. They do not focus on the distribution and generation of electricity.

Industrial engineers work on the effectiveness of the production – people, machines, materials, information, or energy to manufacture. They innovate manufacturing processes.

Materials engineers develop, process, and test materials to be used in the vehicle or another mobile battery application. Importance is given to innovative sustainable, lightweight, and durable materials.

Mechanical engineers design, develop, and test tools, machines, and other mechanical devices inside the vehicle or other mobile applications themselves or the ones used to manufacture/repair/maintain the vehicle and other mobile battery applications. Other fields of interest include steering systems, transmissions or drivetrains.

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Software developers or **System Engineers (embedded, Battery Management Systems - BMS)** design and create software or systems where they apply computer science concepts and mathematical analysis to create and evaluate SW/system applications that make the computer run within the vehicle. EVs are heavily computer-controlled. For example, onboard computers are used to produce and distribute the proper amount of electricity to power the vehicle in given conditions or to control the charging and various other systems such as the BMS.

SKILLS AND COMPETENCE NEEDS

Results of the job advertisements analysis and the desk research **(see Figure 62, Figure 63 and Figure 64)**

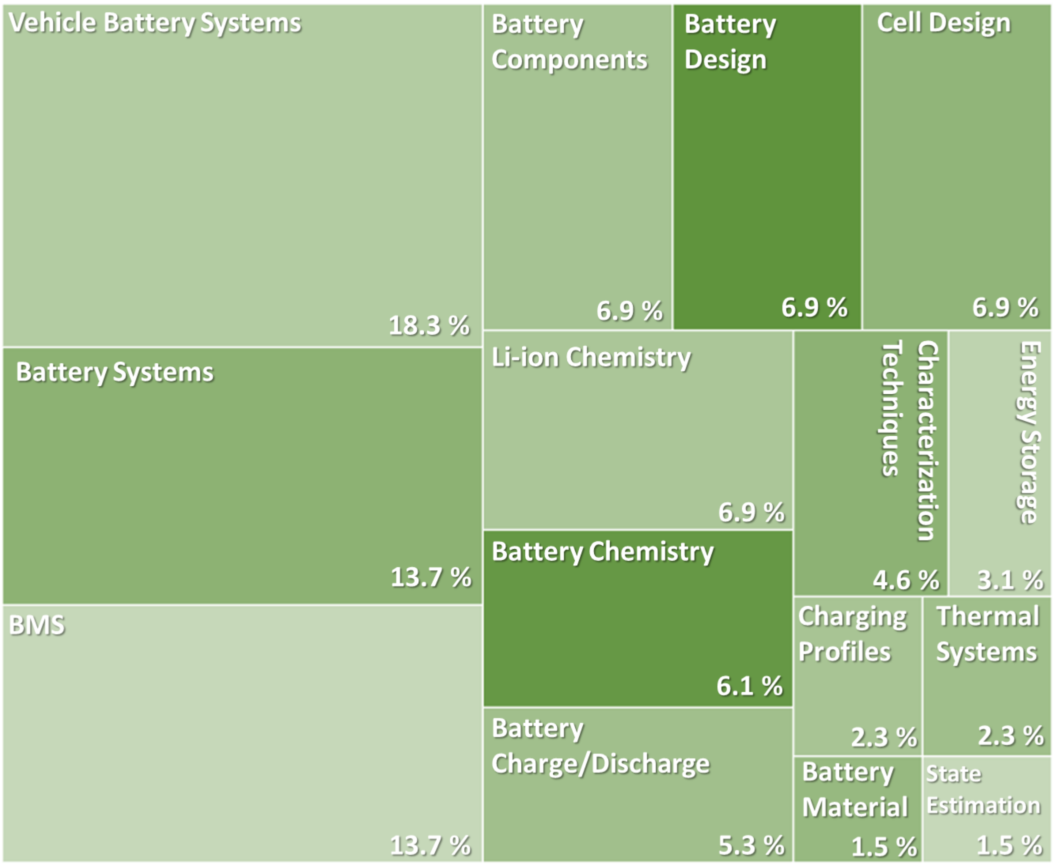

Figure 62: Design and Development – Sector-Specific Competence Needs

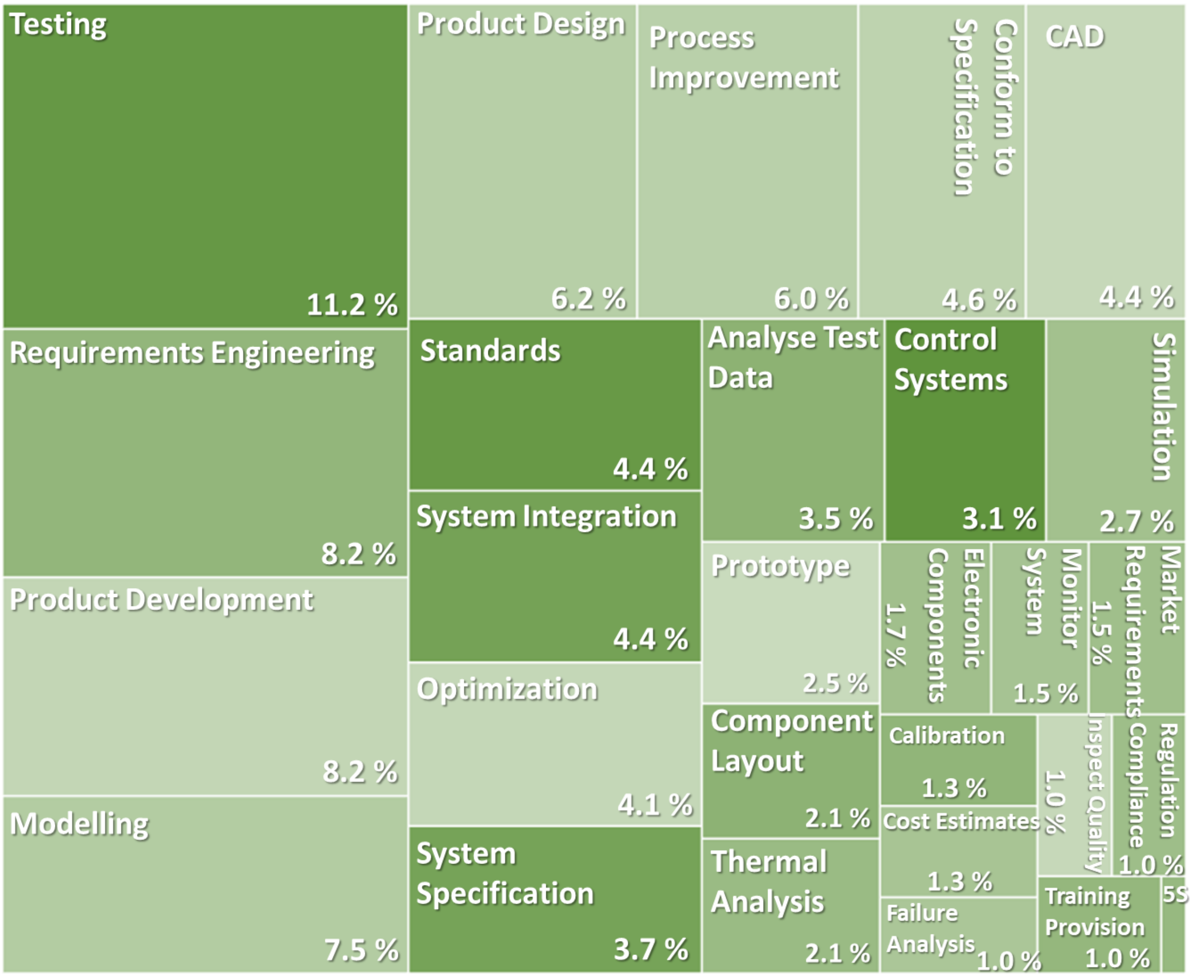

Figure 63: Design and Development - Cross Sectoral Specific Skills Needs

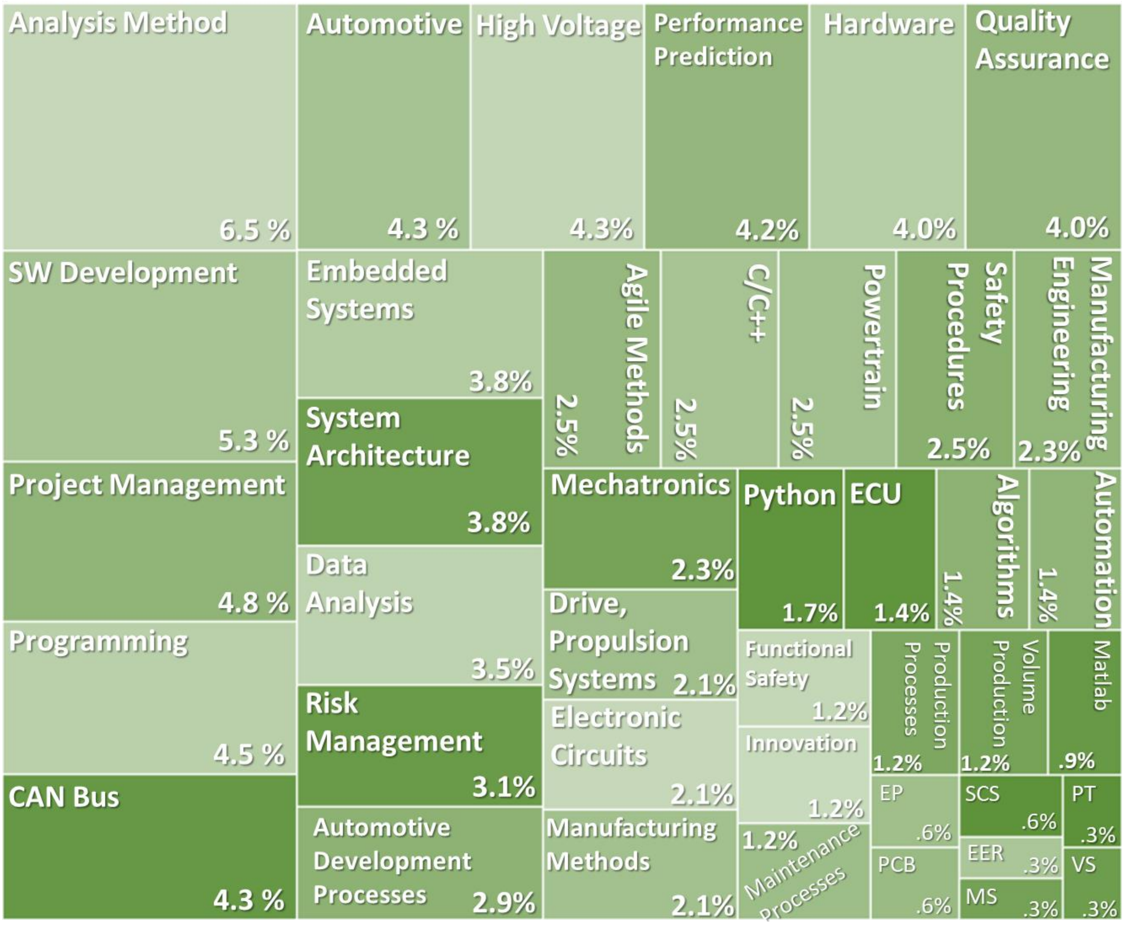

Figure 64: Design and Development – Cross-Sectoral Specific Knowledge Needs

* EP … Electronics packaging; SCS … Safety Critical Systems; PT … Production Technology; EER … Electrical Equipment Regulation; MS … Mechanical Structures; VS … Vision Systems; PCB … Printed Circuit Boards

10.2 MANUFACTURING

Manufacturing of electric vehicles and other mobile battery applications requires a skilled and large workforce **(see Figure 65, Figure 66 and Figure 67)**. Relevant systems are often **more complex** than in traditional vehicles and applications, thus requiring more complex and **innovative manufacturing** processes and methods. Many workers might have experience in ICE vehicle manufacturing or other related sectors.

10.2.1 Job Roles and Skills Needs

Electrical and electronic equipment assemblers build devices such as electric motors, electronic control devices or sensors with the help of automated systems and machines/equipment – they fit together parts of larger components or control the production lines used for this purpose.

Electromechanical equipment assemblers use tools to build and assemble electromechanical or mechatronic components, for example, engines, electric motors, or generators. Compared to the previous, the scope of the work is mainly focused on more mechanical components than electronics.

Engine and other machine assemblers can construct and assemble engines either fully electrical or hybrid.

Team assemblers – operators work on a variable set of tasks on a traditional production line or in a "lean" manufacturing system where they may rotate between several different types of assembly work. These workers, usually in teams, complete the vehicle's final assembly or the other mobile battery applications.

Computer-controlled machine tool operators use machines to create metal and plastic components. They program or use programs available for the production machines together with the appropriate machine set-up or supplementary tools. They are also often responsible for the machine and production line maintenance and troubleshooting.

Machinists use tools and equipment to produce precision parts. They monitor the quality of the output and operation of the machines. They also produce small-scale prototypes of the parts for future volume production.

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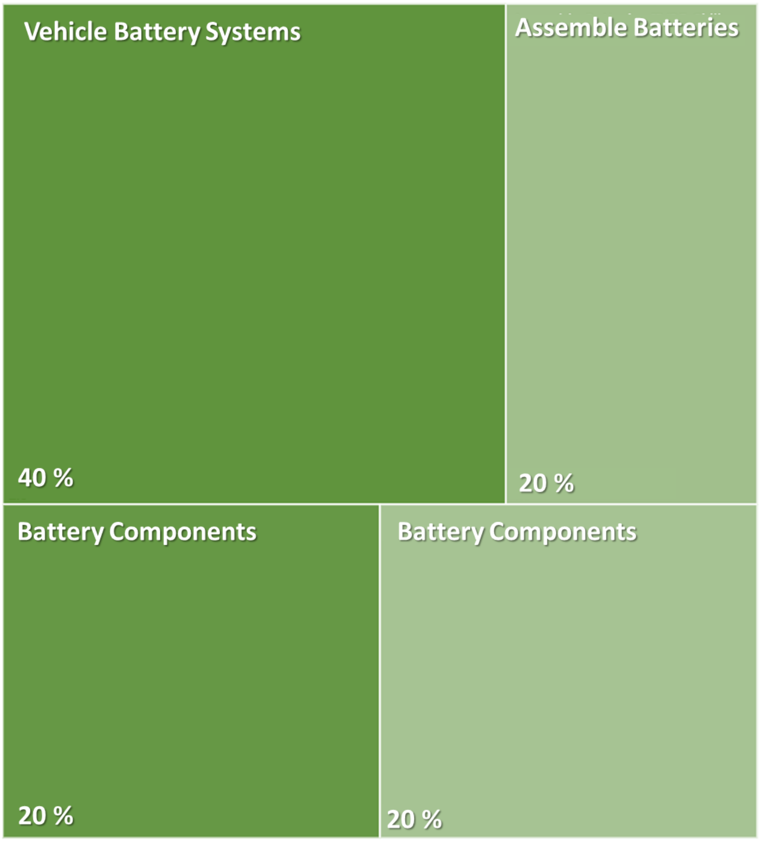

Figure 65: Manufacturing – Sector-Specific Competence Needs

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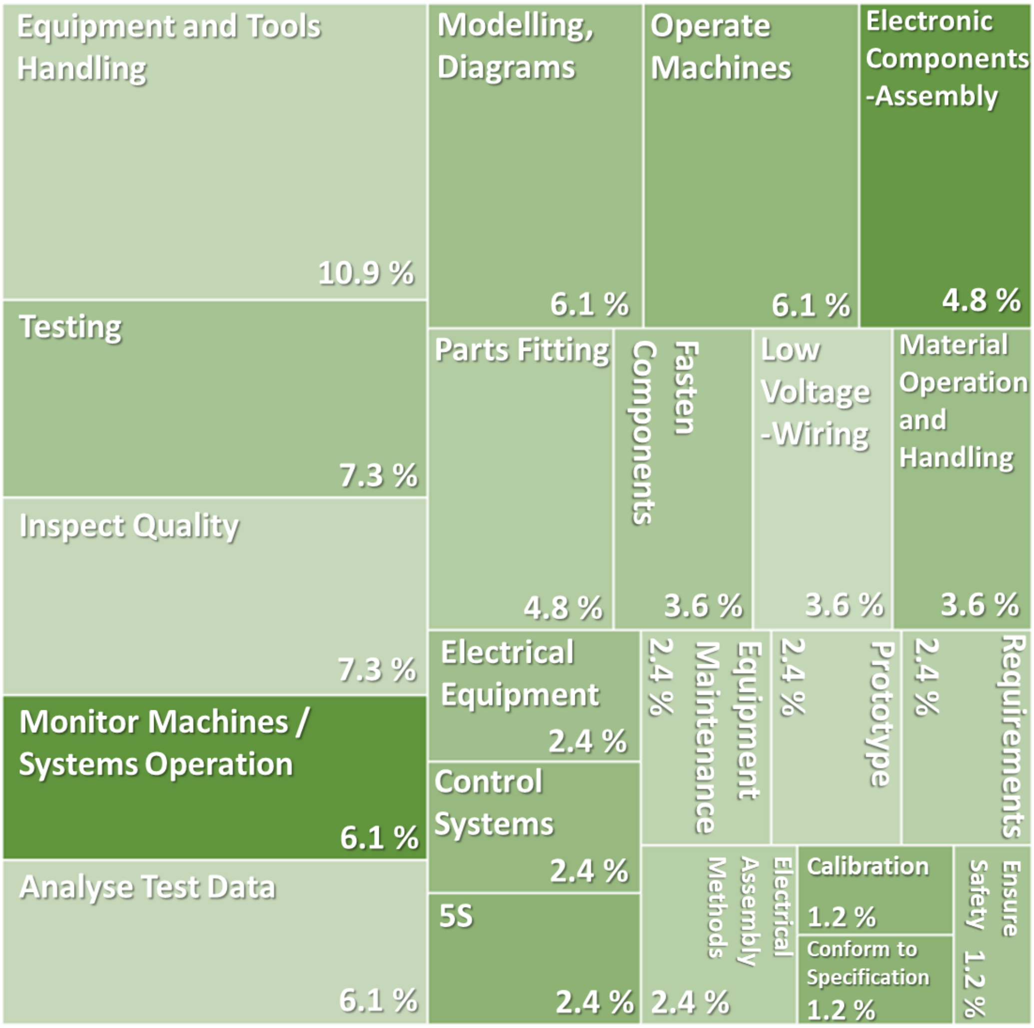

Figure 66: Manufacturing – Cross Sectoral Specific Skills Needs

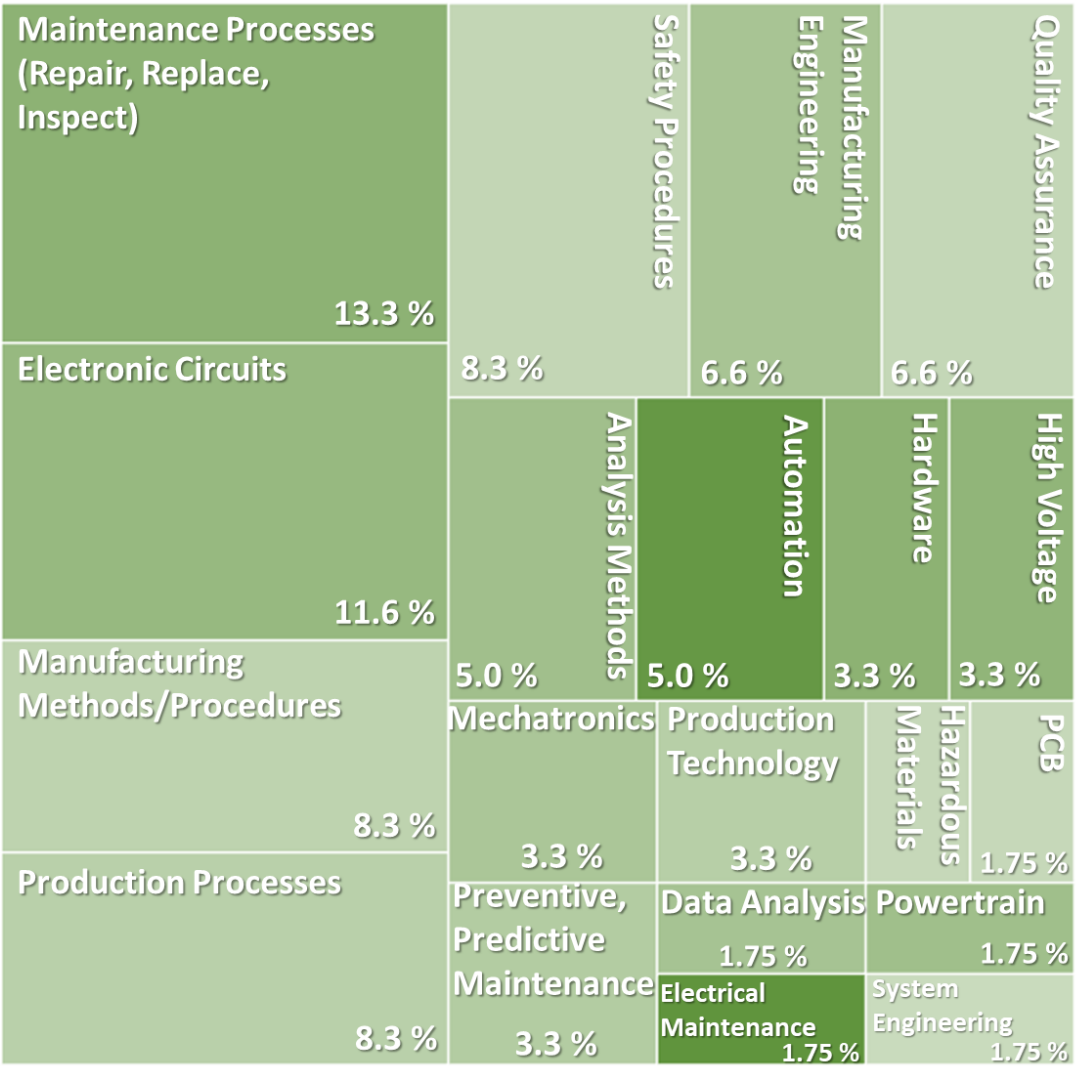

Figure 67: Manufacturing – Cross Sectoral Specific Knowledge Needs

10.3 MAINTENANCE

Electric vehicles and other mobile battery applications must occasionally be maintained and repaired. Ordinary repair workers can do routine maintenance and repair, but the batteries, electrical systems and drivetrain often need a **specially trained** workforce **(see Figure 68, Figure 69 and Figure 70)**.

10.3.1 Job Roles and Skills Needs

Service technicians, mechanics and **electricians** inspect, maintain, and repair vehicles that run on batteries or are hybrid. The service technician and mechanic works have evolved from dealing with simple mechanical parts to more digital and technology-related work –

electromechanical parts, high voltage systems and others. Vehicles and other mobile battery applications and their performance are regulated by computers and electronic systems, which requires the workers to use the computerized repair shop equipment and work with electronic components as well as traditional hand tools.

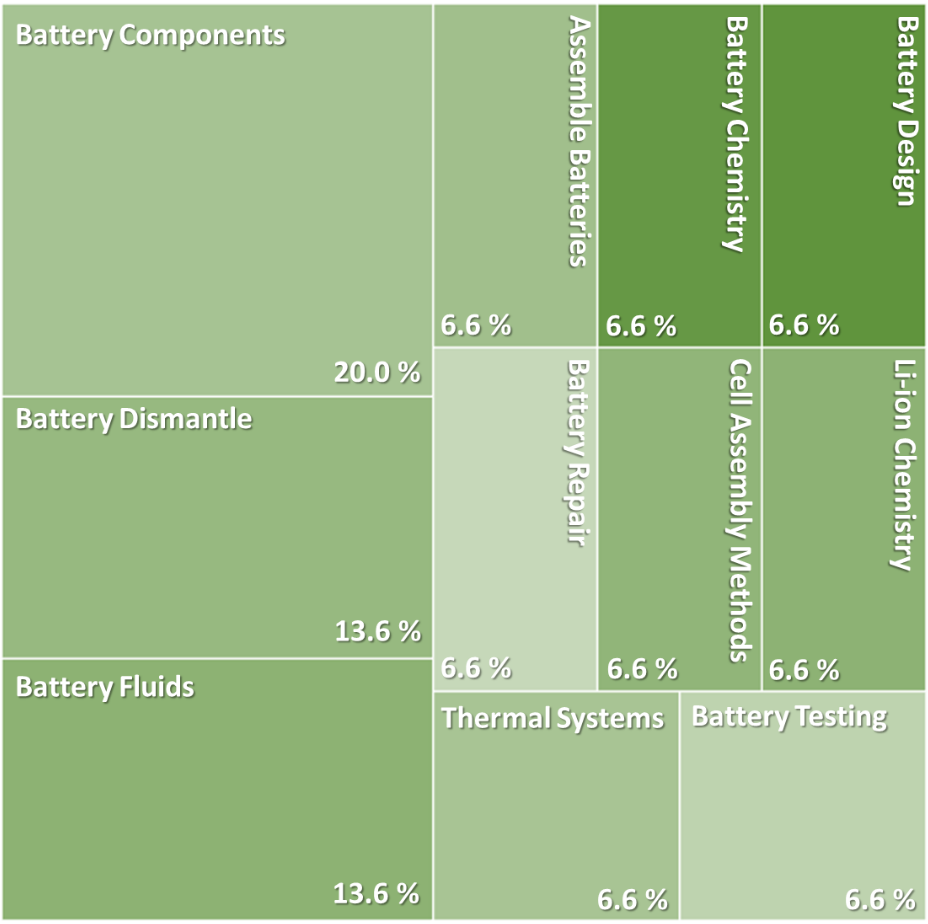

Figure 68: Maintenance – Sector-Specific Competence Needs

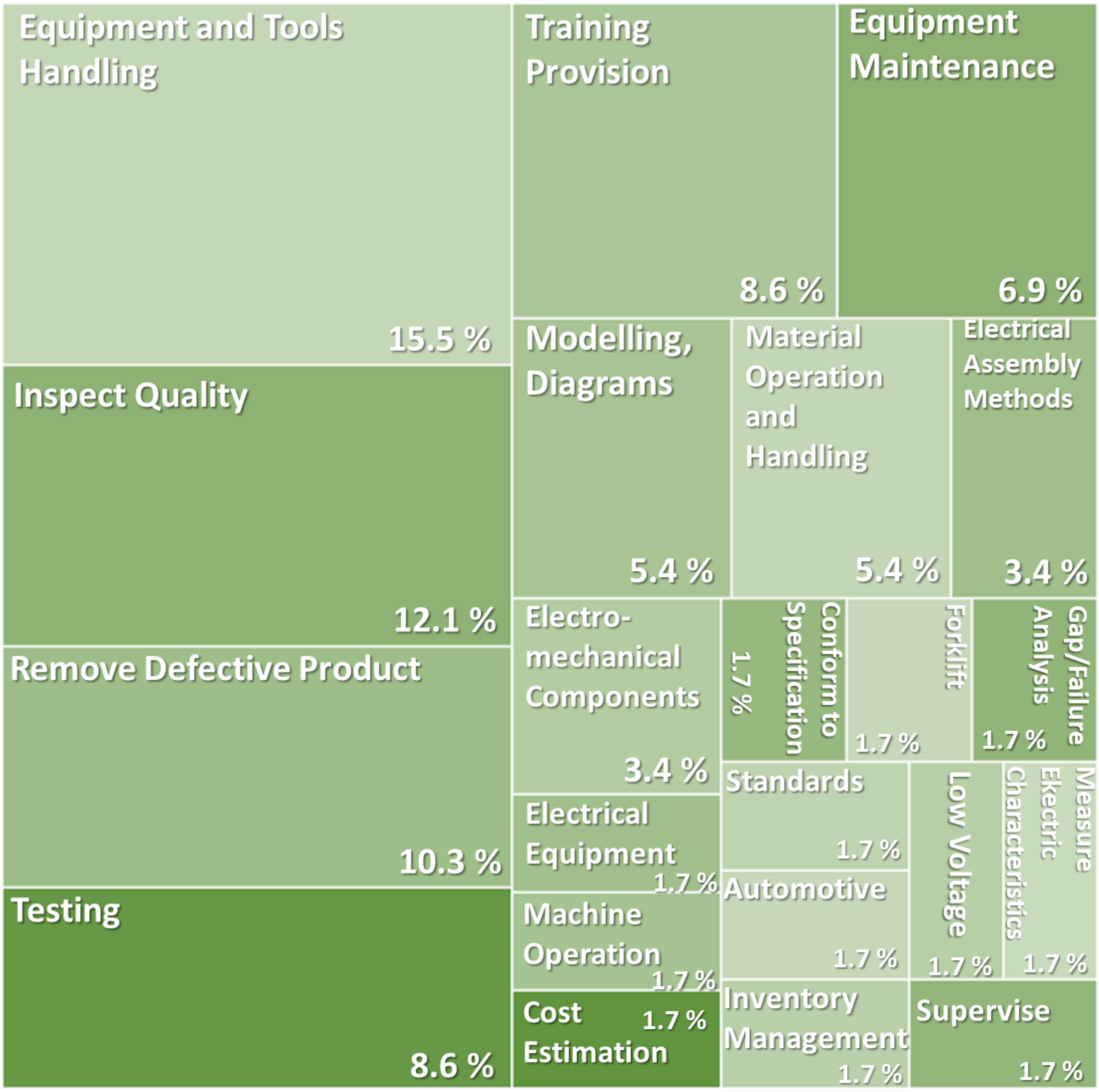

Figure 69: Maintenance – Cross Sectoral Specific Skills Needs

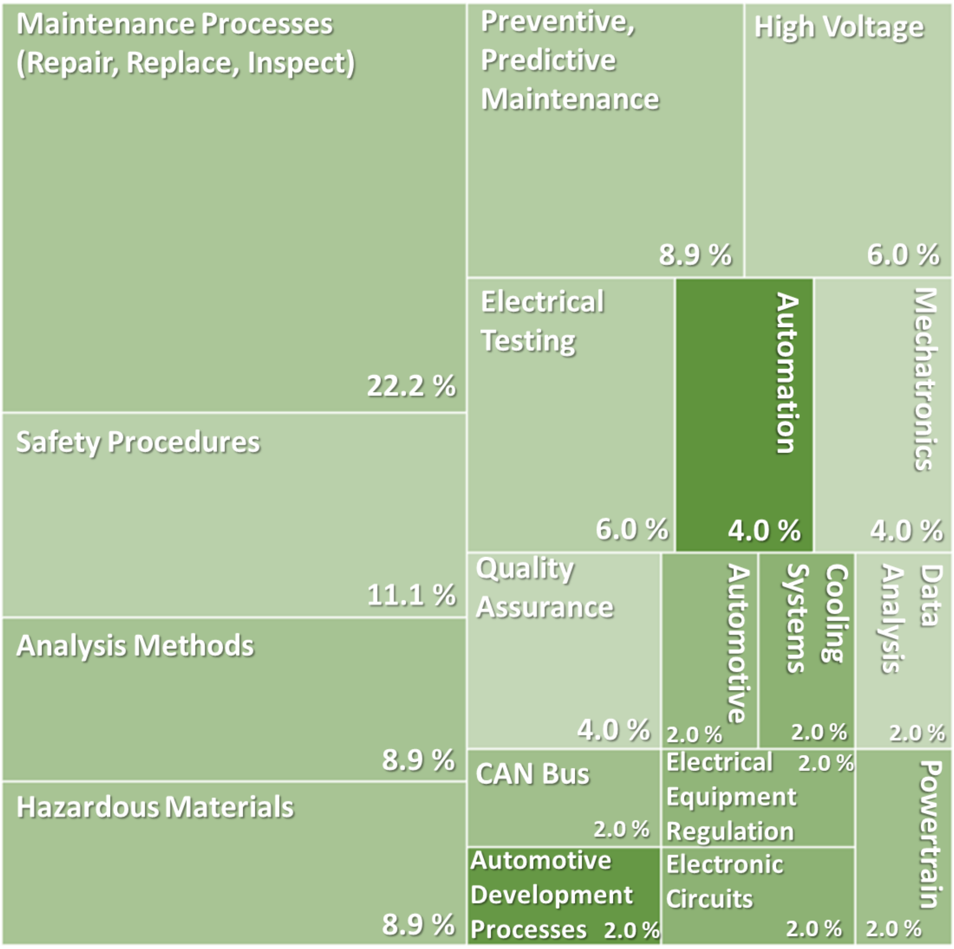

Figure 70: Maintenance – Cross Sectoral Specific Knowledge Needs

10.4 SALES, SERVICES, SUPPORT AND TECHNICAL MANAGEMENT

The following text refers to occupations related to the processes around customer care, services, and meeting customer needs/requirements relevant to the purchase of an electric vehicle or other mobile battery application.

Technical management runs technical projects and manages engineering teams and departments, thus requiring more technical background and soft skills **(see Figure 71 and Figure 72)**.

10.4.1 Job Roles and Skills Needs – Sales, Services and Support

A retail salesperson sells a product to a customer and conducts financial transactions to complete the sale while helping meet the customer's needs. Salespeople know various models, parameters, specifications and financing options.

Customer service representatives can provide a valuable link between the customer and the companies that produce products or services related to electric vehicles and other mobile battery applications. They address customer inquiries or problems.

Other roles within this category are various **product managers**, **training provision roles**, **strategic development** or **supply chain management roles** that manage products from a high-level perspective and from the strategical point of view of the company - to develop sustainable and innovative plans, to meet market requirements and to increase the income of the company.

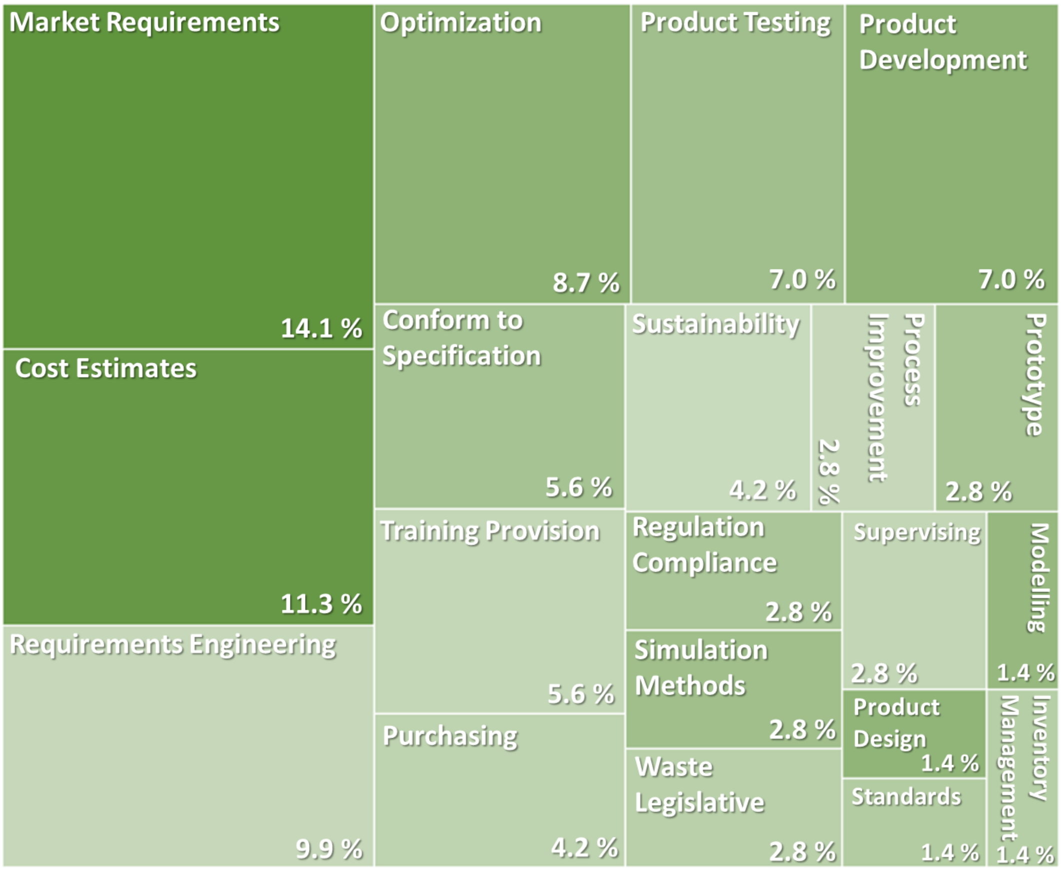

Figure 71: Sales, Services, and Support – Cross-Sectoral Specific Skills Needs

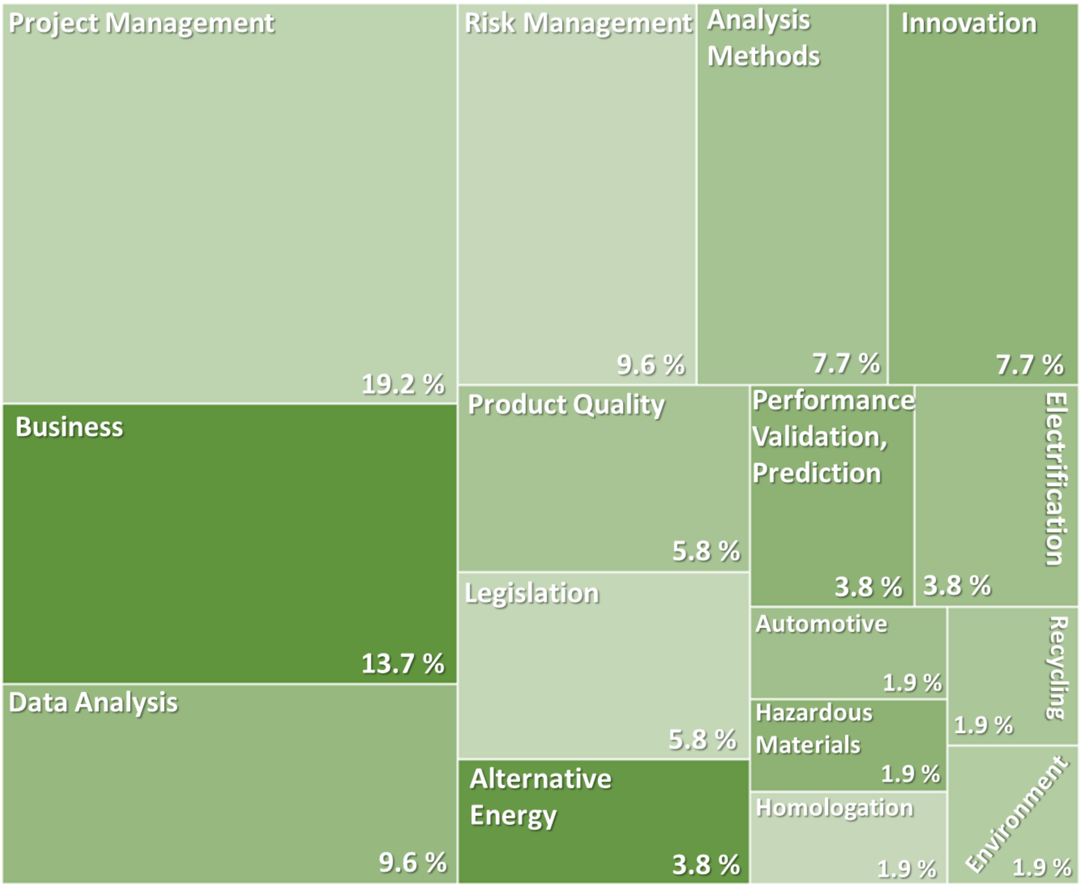

Figure 72: Sales, Services, and Support – Cross-Sectoral Specific Knowledge Needs

10.4.2 Job Roles and Skills Needs – Technical Management

Industrial production managers help plan, direct, and coordinate the production activities required to manufacture a vehicle or other mobile battery applications and components. The same applies to managers in other departments mirroring the engineering positions, for example, **systems managers, test managers,** and **electrical/mechanical engineering managers** who do the same for specific components and aspects of the production **(see Figure 73, Figure 74 and Figure 75)**.

All management roles ensure that specific requirements and goals are met within the defined timeframe, budget and in desirable quality. In addition, they are responsible for monitoring the activities.

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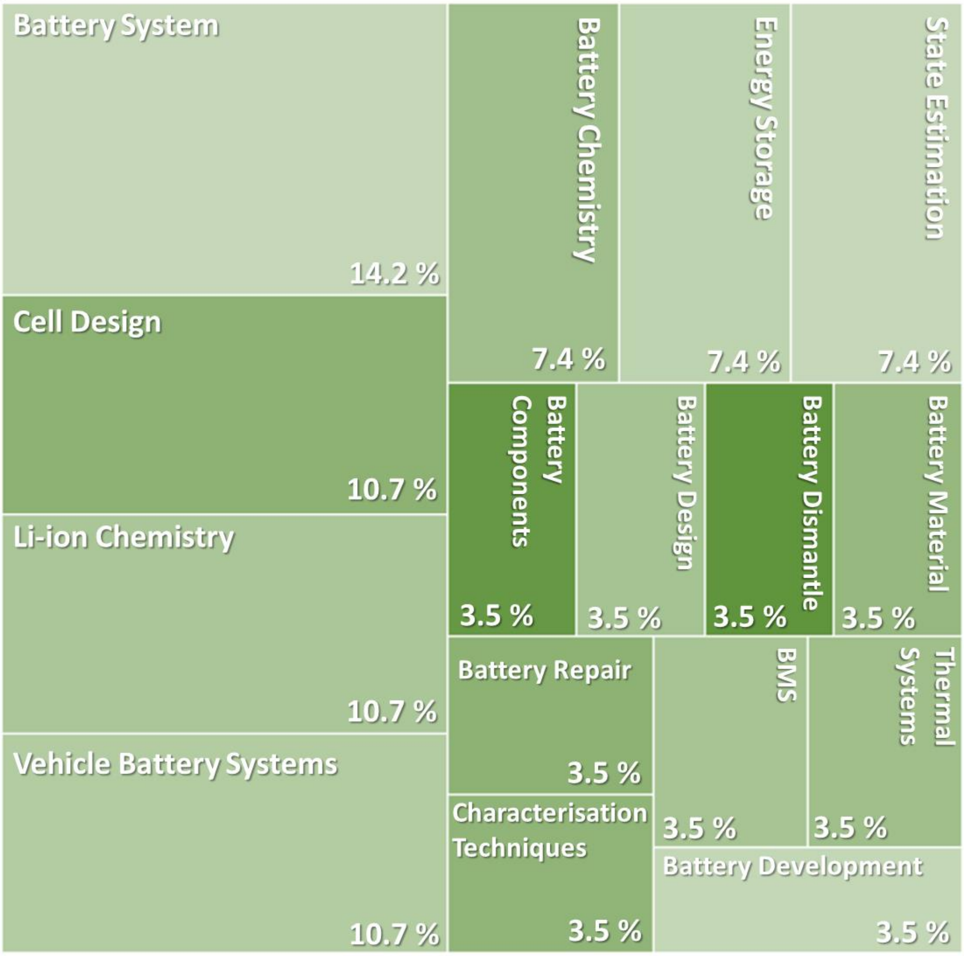

Figure 73: Technical Management – Sector-Specific Competence Needs

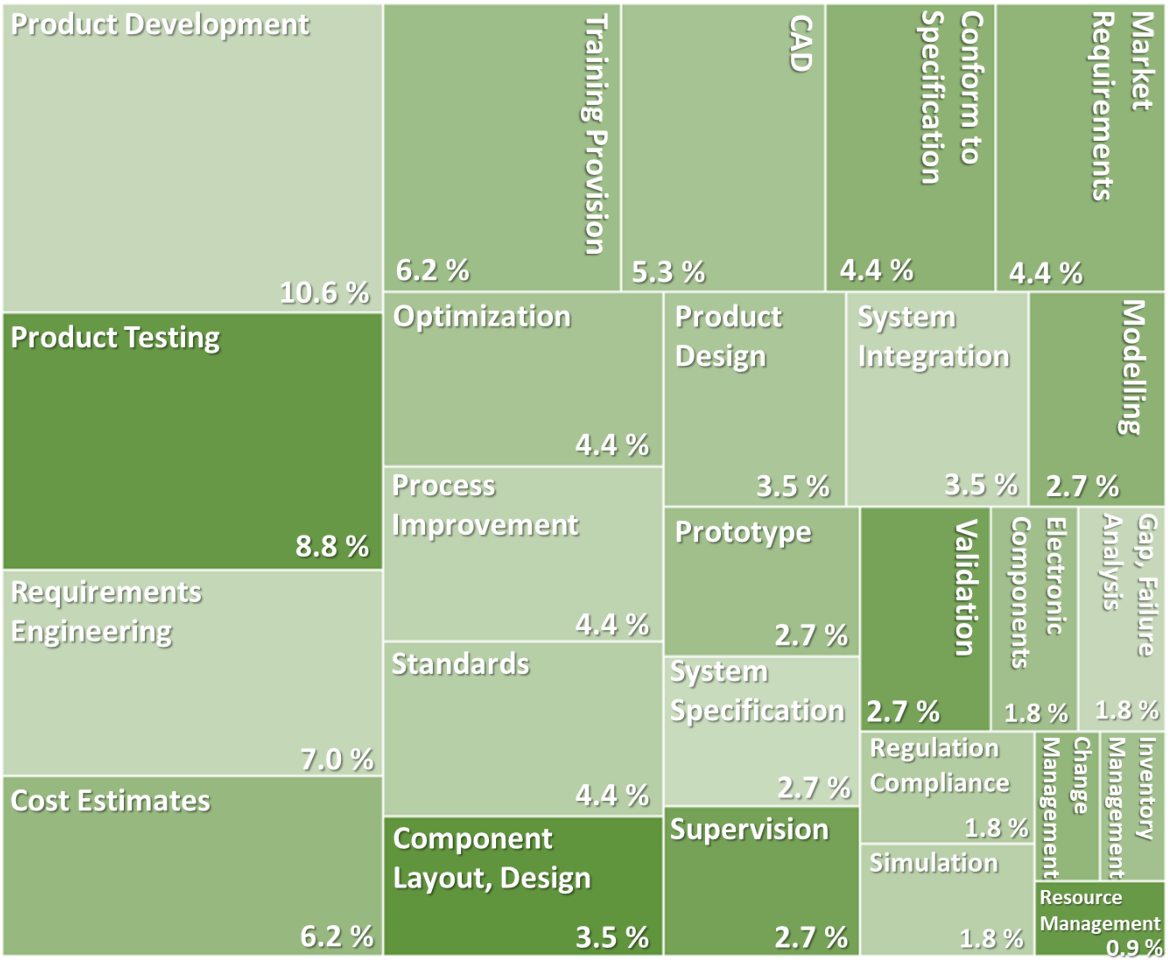

Figure 74: Technical Management – Cross Sectoral Specific Skills Needs

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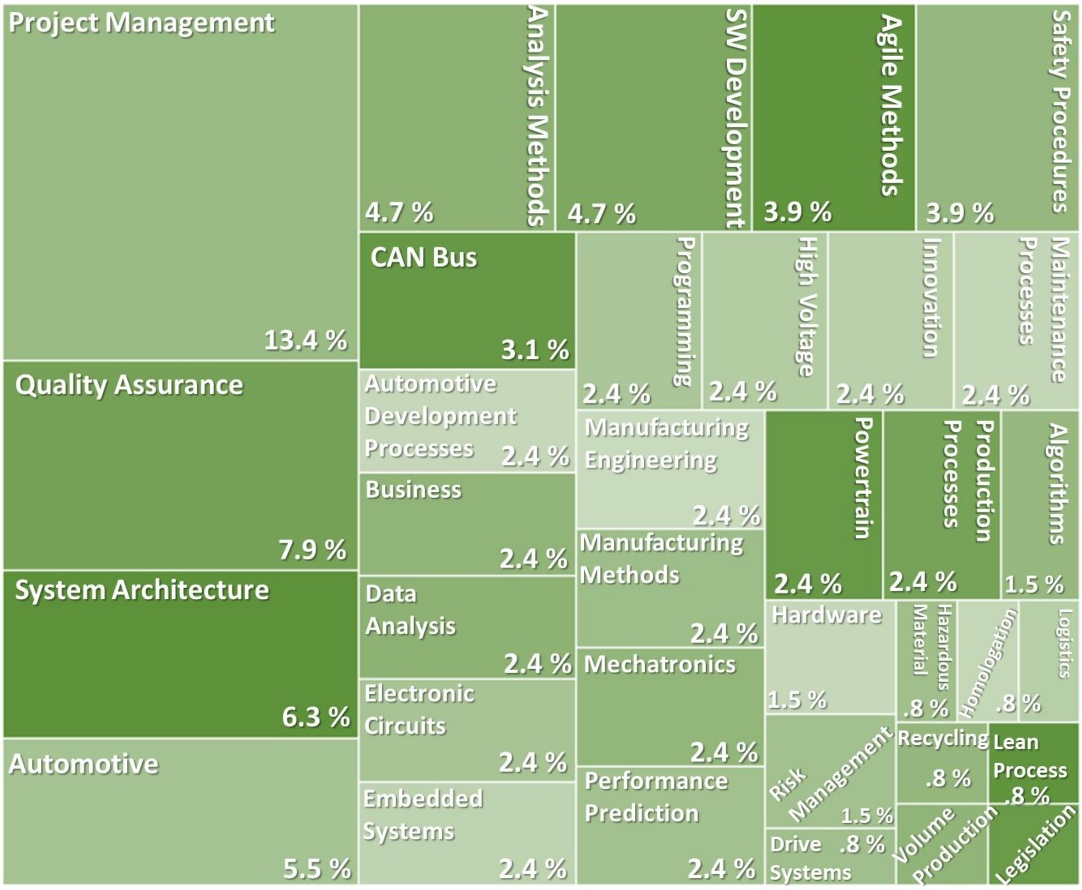

Figure 75: Technical Management – Cross-Sectoral Specific Knowledge Needs

11 Annex A: Analysed Job Advertisements

DOMAIN	JOB ADVERT
Trains	Project Engineer - Control Electronics for E-mobility
Trains	Electronic Motor Bench Test Technician
Trains	Resident in Charge of Products
Trains	Electrical Technician
Trains	Automation Engineer
eBikes	Requirements and System Engineer for BMS
eBikes	Electronics Technician for Devices and Systems / Prototypes in Battery Systems
eBikes	Development Engineer / Technician - Battery System Testing
eBikes	Embedded SW Developer for BMS
eBikes	HW Developer for BMS
eBikes	Product Designer
eBikes	Mechanical Engineering Manager
eBikes	SW Developer - Applications
eBikes	Electrical Engineer - Batteries and Chargers
MicroMobility	Software Engineering Manager
MicroMobility	SW Engineer Tech Lead
MicroMobility	Mobility Strategist
MicroMobility	Field Technician
MicroMobility	SW QA Engineer
MicroMobility	Production Manager - Micromobility
MicroMobility	Business Intelligence Analyst
MicroMobility	City Manager
MicroMobility	Learning and Development Strategist
MicroMobility	Expansion Project Manager - Charging Solutions
Aviation	Maintenance Planner - Aircraft
Aviation	Battery Mechanical Engineer - Aviation
Aviation	Battery System Engineer - Aviation
Aviation	Experimental Test Pilot
Aviation	Propulsion Integration Engineer
Aviation	Senior Aerodynamics Engineer
Aviation	Director of Supply Chain
Aviation	Senior Power Electronics Designer
Motorbikes	Electrical Engineer - Firmware Manager
Motorbikes	Lithium-ion Cell Battery System Engineer
Motorbikes	Battery Systems Manager
Motorbikes	Battery Production Technician
Motorbikes	Electrical Engineer - Motorbikes
Motorbikes	Electrical Design Engineer
Motorbikes	Powertrain Manufacturing Engineer
Motorbikes	Powertrain Mechanical Systems Design Engineer
Motorbikes	Electrification Engineer - Electric and Hybrid Powertrain

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Motorbikes	Powertrain Calibration Engineer
Motorbikes	Battery System Engineer
Motorbikes	Powertrain Calibration Development Tech
Motorbikes	Electrical System Engineer
Motorbikes	Powertrain Calibration Engineer
Motorbikes	Dealer Tools and Training Manager
Motorbikes	Rework Mechanic
Vans	Lithium Maintenance Technician
Vans	Battery Test Engineer
Vans	Material Handler
Vans	Battery Mechanical Engineer
Vans	Application Engineer - Battery Storage
Vans	Battery Monitoring System SW Engineer
Vans	Process Quality Engineer
Vans	Platform Engineer
Vans	RnD Engineer
Vans	IT Systems Engineer
Vans	Logistics Manager
Vans	Functional Safety and Controls Engineer
Vans	Quality Process Engineer
Vans	CMM Lab Technician
Vans	Lead Platform Engineer
Vans	EV General - Chemists
Vans	EV General - Material Science
Vans	EV General - Chemical Engineer
Vans	EV General - Electrical Engineer
Vans	EV General - Electronics Engineer
Vans	EV General - Industrial Engineer
Vans	EV General - Materials Engineer
Vans	EV General - Mechanical Engineer
Vans	EV General - Mechanical Engineering Technician
Vans	EV General - Mechanical Drafters
Vans	EV General - Software Developers
Vans	EV General - Commercial and Industrial Designers
Vans	EV General - Electrical and Electronic Equipment Assemblers
Vans	EV General - Electromechanical Equipment Assemblers
Vans	EV General - Engine and Other Machine Assemblers
Vans	EV General - Team Assemblers
Vans	EV General - Computer-controlled Machine Tool Operators
Vans	EV General - Machinists
Vans	EV General - Industrial Production Managers
Vans	EV General - Automotive Service Technicians
Vans	EV General - Retail Sales Person
Vans	EV General - Customer Service Representatives

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Trucks	Product Analyst
Trucks	Electric Vehicle Engineer - Charging
Trucks	Field Service Technician
Trucks	Vehicle Safety Engineer
Trucks	High Voltage Battery DRE
Trucks	Battery Technical Lead
Trucks	Electrical Engineer
Trucks	Product Validation Engineer
Trucks	Senior Battery Controls Engineer
Trucks	Electrochemistry Lead - Battery Materials
Trucks	System Engineer
Trucks	Vehicle Technician
Trucks	Battery Cell Simulation Engineer
Trucks	Diagnostic Engineer - BMS
Trucks	SW Component Owner
Trucks	Mechanical Design Engineer
Trucks	Machine Learning Engineer in Simulation within Autonomous Systems
Trucks	Technical Project Manager
Trucks	Design Engineer - Thermal Management System
Trucks	Development Engineer - Battery Cell Chemistry and Energy Storage
Buses	Electromobility Project Leader
Buses	EV Project Manager
Buses	Electronics Technician
Buses	Automotive Mechatronics Technician
Buses	Development Engineer - Traction Batteries
Buses	Test Engineer - Charging Functions
Buses	Development Engineer
Buses	Test Engineer - Charging
Buses	Development Engineer - Powertrain
Buses	Industrial Project/Product Manager
Buses	Electronics Expert
Buses	Mechatronics Technician - High Voltage
Buses	Application Engineer - Electromobility
Buses	Group Manager - BMS
Buses	Function System Design Engineer - BMS
Buses	Diagnostics System Engineer
Buses	Supply Chain Business Specialist - Battery Cells
Buses	Senior Buyer - BMS
Buses	Senior Buyer - Battery Cells
Buses	Production Technician - Transmission
Buses	Maintenance Specialist
Buses	Maintenance Technician
Buses	Release Engineer - Charging and Power Distribution
Buses	Transmission System Lead

Buses	Battery Cell Simulation Engineer
Buses	Vehicle Validation Head
Buses	Thermal Design Engineer
Buses	eDRIVE SiL Integrator
Buses	Battery Charging Simulation Expert
Buses	Battery Charging Functional Engineer
Utility Vehicles	Battery Pack Production Employee
Utility Vehicles	Technical Assembly Worker
Utility Vehicles	EV Conversion Engineer
Utility Vehicles	Service Mechanic - EVs
Utility Vehicles	Mechatronics Engineer
Utility Vehicles	Certification and Homologation Manager
Utility Vehicles	Advanced Field Service Technician
Utility Vehicles	Application Engineer
Utility Vehicles	Automotive Technical Trainer
Utility Vehicles	Industrial Engineer
Utility Vehicles	Service Technician - EV
Utility Vehicles	Manufacturing Engineer
Utility Vehicles	Electrical Engineering Technician
Utility Vehicles	Automotive Mechatronics Technician
Utility Vehicles	Development Engineer - HW and Power Electronics
Utility Vehicles	Mechanical Designer

12 Annex B: Information About Zero Emissions Busses

Table 7: Overview of current battery and fuel cell manufacturers and bus models - selection

Manufacturer	Battery system /Fuel cell	Charging system	Operational range
BYD/ADL EV	BYD lithium iron phosphate battery technology, 348 kWh	Choice of dual plug 2×40 kW AC charging and single plug 102 kW DC charging	Up to 160 miles on a single charge, depending on the duty cycle and operating conditions
BYD/ADL Double Decker EV	BYD lithium iron phosphate battery technology, 339 kWh or 382 kWh	Choice of dual plug 2×40 kW AC charging, 112 kW DC charging and roof-mounted charging rails	Up to 160 miles on a single charge, depending on the duty cycle and operating conditions
ADL Double Decker hybrid	32 kWh lithium nickel manganese cobalt battery, an option of external socket for DC plug charging	Plug-in battery charging is optionally available.	Up to three miles in electric mode.
ADL Double Decker FCEV	Fuel cell system: Ballard FCmove-HD, Battery system: Lithium-ion battery, Hydrogen tanks: NPROXX composite pressure vessels	-	up to 300 miles
Arrival EV	Max. battery capacity of 310.8 kWh	*information not found*	200-408 km range depending on the payload (up to 8,000 kg)
Arthur BUS FCEV	the traction battery 15 kWh, fuel cell from 60-125 kW, hydrogen tanks 350 bar TYPE 4	-	more than 450 km
bluebus EV	LMP (Lithium Metal Polymer), entirely solid-state cell without any liquid components, no nickel or cobalt, and a lithium metal electrode, a technology produced by Blue Solutions, a Bolloré Group subsidiary; On-board energy up to 126 kWh, 400 V (6 m bus) / On-board energy up to 441 kWh, 600 V (12 m bus)	charge time: 6.5 hours, max. power: 140 kW, 22 kW on-board charger, T2 plug on the rear panel (6 m bus) / charge time 5 hours, max. power: 160 kW, DC/standard Combo CCS (12 m bus)	up to 200 km (for 6 m bus) / up to 320 km (12 m bus)

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Bozankaya trambus - with a trolley	up to 650 kWh	Auxiliary Inverter 33 kW (40 kW peak), Charger 6-8 kW	up to 400 km
Bozankaya EV	Lithium Iron Phosphate ($LiFePO_4$), Lithium Titanate (LTO); 200-230 kWh (10.7 m bus) / 250 kWh (12 m bus) / 390/450 kWh (18 m bus) / 520/600 kWh (25 m bus)	charge time 3-8 hours, input voltage: 400 V; charging power 45/90 kW (10,7 m bus) / charging power: 60/150 kW (12 m, 18 m and 25 m bus)	Up to 300 km (10.7 m bus) / Up to 340 km (12 m bus) / up to 400 km (18 m and 25 m bus)
BYD EV	Lithium Iron Phosphate	DC Combo-2 / 80 kW AC (3 hours charging time) / pantograph charging	ca 200 km (for coach, city conditions)
Caetano Bus EV	Lithium Titanate (LTO), 36-120 kWh (airport bus - e.COBUS) / NMC - 385 kWh, LTO – 100 kWh (pantograph) (e.City Gold)	Onboard charger 7 or 14 kW, input 400 V AC, output 700 V DC; external DC fast chargers, 30-150 kW available, input 400 V AC, output 700V DC, charging time: 30 min-3 hours (e.COBUS) / CCS Type 2 - up to 150 kW, Onboard charger - up to 22 kW, Pantograph, GB/T (e.CityBus)	up to 100 km (e.COBUS) / up to 300 km (e.City Gold)
Caetano Bus FCEV	H2 Tanks - type 4 composite tanks; 5x 312 l (max. 37.5 kg: 350 bars), FC Stack Nominal Power – 60 kW (Toyota FC Stack), LTO battery 29-44 kWh	H2 Refuel time <9 min, optional: charging CCS Type 2 - AC/DC	up to 400 km
Chariot Motors EV	Lithium iron phosphate 172 kW (8.5 m bus) /345 kWh (12 m bus) / 518 kWh (18 m bus)	CCS2 - charging time 2 hours (8.5 m bus) / 3 hours (12 m and 18 m bus)	up to 400 km
Chariot Motors UC bus	40 kWh Aowei Ultra-capacitor 720 V 1000 F (12 m bus) / AOWEI UC battery 108 kWh (18 m bus)	Aowei pantograph (650 V, 200 A) + EU standards gun charging (12 m bus) / CCS2	5 to 10-minute single charge allowing up to 90 km range on a single charge (SORT 2)
CRRC EV	CATL Lithium Iron Phosphate 338.4 kWh (12 m bus)	90 kW DC plug-in charger (CCS Type 2 connector)	*information not found*
Ebusco EV	Lithium iron phosphate, >250 kWh / >350 kWh, >400 kWh or >500 kWh (12 m, 1.5m and 13 m bus) / >350 kWh, >500 kWh (18 m bus)	CCS Combo2	350-450 km (2.2 version) / 575 km (3.0 version)
Carrosserie Hess lighTRam EV	353 kWh / 471 kWh (10 m and 12 m bus) / 589 kWh (18 m bus) / 707 kWh (19 m bus)	CCS2 -150 kW, 200 A DC / CCS2 – 350 kW, 500 A DC / pantograph 450 kW	*information not found*

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Heuliez Bus EV (CNH Industrial)	73 or 88 kWh / 102 or 117 kWh / 245-350 kWh / 280-385 kWh	CCS Combo2 /pantograph OppCharge	*information not found*
Hybricon EV	CATL Lithium iron phosphate, up to 422 kWh (suitable for arctic conditions)	Ultrafast Charging allows buses to run for up to 1 hour after only 180 s of charging	*information not found*
Hyundai Bus EV	128 kWh, 256 kWh	*information not found*	for 256 kWh battery up to 290 km
Hyundai Bus FCEV	180-kW high-capacity hydrogen fuel cell system, which consists of two 90 kW hydrogen fuel cells, 5 hydrogen tanks storing a total of 34 kg of hydrogen	-	Up to 500 km
Iveco BUS EV (CNH Industrial)	NMC 293 kWh (9.5 m bus) / 293 kWh or 334 kWh or 376 kWh or 418 kWh (10.7 m bus) /376 kWh or 334 kWh or 418 kWh or 460 kW (12 m bus); Lithium Titanate 73 kWh or 88 kWh in case of pantograph charging buses	CCS Combo2 /Opportunity fast charging via off-board pantograph (4 poles pantograph – up to 450 kW)	*information not found*
Irizar Bus/Tram Bus EV	Li-Ion up to 437 kWh (for slow charging option) / 395 kWh (for fast charging option) / 90 kWh (for ultra-fast charging option)	slow charging: 100 kW, 3-4 hours / 395 kWh (fast charging) / fast charging: 450 kW, 5 min (pantograph) or 150 kW (Combo2), ultra-fast charging: 2 hours / 450 kW, 5 min (pantograph)	up to 350 km
MAN Bus EV	NMC 480 kWh (rigid bus) / 640 kWh (articulated bus), plan to include also LFP	charging capacity 150 kW	over 350 km
Mercedes Benz Bus EV (Daimler)	Li-Ion NMC 292 kWh - 396 kWh (rigid and articulated bus), 441 kWh solid-state batteries	NMC - by a plug (CCS Type2), pantograph or charging rails	NMC ca 200 km; with solid-state batteries up to 320 km (rigid bus) and up to 220 km (articulated bus)
Mercedes Benz Bus FCEV (range extender) planned as of 2023	fuel cell, in addition to a large traction battery	-	300 km

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Proterra EV	up to 675 kWh	operating with DC fast chargers ranging in power from 60 kW to 450 kW; plug-in (J1772-CCS Type 1) or pantograph (SAE J3105)	up to 329 miles
OTOKAR OTOMOTIV	Li-Ion NMC 110 kWh (6.6 m bus) / 210 kWh, 280 kWh, 350 kWh / 350 kWh, 490 kWh, 560 kWh (18.75 m articulated bus)	charging time from 1.5 hours (6.6 m bus) / charging time ca 4 hours (12 m bus)	ca 200 km (6.6 m bus) / 300 km (12 m bus)
Rampini EV	electrical traction system based on ferrite lithium cells, designed and produced by Rampini; 210 kWh (6 m bus) / 358 kWh (12 m bus)	*information not found*	ca 250 km (6 m bus) / ca 200 km (8 m and 12 m bus)
Scania	NMC 264 kWh or 330 kWh; in future supplies from Northvolt	plug-in (CCS type 2, up to 150 kW) or pantograph (up to 300 kW)	up to 250 km
Safra Bus FCEV	NMC 130 kWh, Fuel cell 45 kW (30 kW useful), 6 hydrogen tanks 350 bar	-	over 350 km
Škoda Electric EV	Li-Pol 222 kWh (12 m High Energy Bus) / Lithium Titanate 78 kWh (12 m High Power Bus)	CCS 2 or 150 kW via pantograph 600/750 V DC (12 m bus) / slow charging - charging time 6-8 hours or fast charging 70 min (High Energy Bus) / Fast-charging from the console: 6-8 minutes, slow plug-in charging with balancing: 6-8 hours	150-200 km (High Energy Bus) / 30 km (High Power Bus)
Solaris EV	Li-Ion up to 553 kWh (18m bus) / 58 kWh (trolley bus); use of CATL LFP announced in 2022	plug-in / pantograph (trolley bus)	more than 300 km (18 m electric bus)
Solaris FCEV	fuel cell 70 kW (12 m bus), 5 hydrogen tanks x 312 l, Li-Ion battery	-	up to 350 km
SOR EV	Winston Battery / Lithium-ion 172 kWh (8 m, 9,8 m and 11.1 m bus) / NMC 242 kWh (362 Ah) or 388 kWh (582 Ah) (12 m bus)	slow depot charging, fast charging 120 kW, 200 A	up to 180 km (12 m bus)
Switch EV	NMC 389kWh (12 m bus)	only plug-in charging (CCS), full charge in less than 3hrs, overnight charging in 7 hours	about 390 km
Temsa EV	240 kWh / 300 kWh / 360 kWh	CCS Combo2, charging time 2-3 hours (150 kWh DC)	more than 250 km

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Ursus Bus EV	Li-Ion	plug-in / pantograph / range extender	*information not found*
Ursus Bus FCEV	Li-Ion NMC 74 kWh, hydrogen tanks with capacity approx. 33 kg (H35 - 350 bar) - in total 1,200 l, fuel cell with 60 kW (2 x 30 kW)	hydrogen refuelling connector ECH TC 6	450 km
Van Hool EV	NMC 490 kWh (12 m bus) - 686 kWh (24 m articulated bus) / trolleybuses NMC up to 72 kWh or Lithium Titanate 4x15 kWh	*information not found*	*information not found*
Van Hool FCEV	24 KWh - 132 kWh, fuel cell FCmove HD	-	*information not found*
VDL EV	215 kWh - 420 kWh	Combo2 charging plug for a charging power of 50 kW / pantograph - a capacity of up to 450 kW can be generated	*up to 600 km*
VDL FCEV	tow range extender trailer (Bosch)	-	350 km
Volvo Bus EV	Li-Ion up to 470 kWh (12m bus) / up to 470 kWh (18m bus) / up to 565 kWh (18,7m bus)	CCS 150 kW / Roof charging - OppCharge and roof-mounted pantograph, max charge power 300 kW (12m bus), 400 kW (18m bus) or 450 kW (18,7m bus)	up to 470 km (12 m bus) / up to 470 km (18 m bus) / up to 565 km (18,7 m bus)
Wrightbus EV	340 kWh or 454 kWh (double decker) / NMC 340 kWh, 454 kWh or 567 kWh	fast charge time of 2.5-3 hours (double decker) / fast charge time 2.5-3.5 hours, CCS2 Combo2 Socket with up to 150 kW plug-in charge or up to 360 kW opportunity charging	up to 200 miles (double-decker) / up to 250 miles (single-deck bus)
Wrightbus FCEV	hydrogen tanks 27 kg with a total of 1120 Litres (350 Bar) (doubler decker) / Ballard Fcmove 70 kW Fuel Cell Module, up to Hydrogen tanks 7 Cylinder configuration – 50 kg, battery 30 kWh / 45 kWh (single deck bus)	refuelling time 8 minutes (double decker) /	up to 280 miles (double-decker) / up to 640 miles (single-deck bus)
Yutong	CATL LFP 375 kWh (12 m bus), up to 563.83 kWh	Charged via 90k W DC plug-in charger (CCS Type 2 connector)	up to 300 km (12 m bus)

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