Follow-up feasibility study on sustainable batteries under FWC ENER/C3/2015-619-Lot 1

Task 1 Report

Feasibility of Scope Extension to Electric Scooter, Bicycles, Mopeds and Motorcycles

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List of abbreviations and acronyms

Abbreviations	Descriptions
AS	Application service energy
BMS	Battery Management System
CBA	Cost-benefit-analysis
DC	Direct current
EOL	End-of-life
EPAC	Electrically power assisted bicycle
ESS	Elecrical energy storage system
EV	Electric vehicle
FU	Functional unit
GHG	Greenhouse gas
LEV	Light electric vehicles
LFP	Lithium-iron-phosphate
LIB	Lithium ion battery
NiMH	Nickel metal hydride
NMC	Lithium-manganese-nickel-cobalt
SLA	Sealed lead acid batteries
SOC	State of charge
SOH	State of health

1. Task 1: Feasibility of Scope Extension to Electric Scooter, Bicycles, Mopeds and Motorcycles

1.0. General introduction to Task 1

The original study defined a scope, which included electro-mobility applications for passenger electric vehicles and trucks, both hybrid and full electric. Batteries for lighter mobility applications (scooters, pedelecs, mopeds and motorcycles) were not in the original study scope. Though the batteries may have different design constraints, they still share many common characteristics, including battery chemistry.

The objective of this task is to consider to what extent, if any, requirements identified in the original study on performance, durability, carbon footprint, responsible sourcing, reuse/repurpose, recycle and so on, are applicable to lighter e-mobility applications (light electric vehicles - LEV) mentioned above.

This task should also analyse the implications of extending the scope of a possible regulation to LEV, including a cost/benefit analysis, as well as analysis of potential enforcement and verification issues.

Task 1 consists of the following subtasks:

- **Subtask 1.1 – Definition and specification of applications**

  This subtask gives definitions on LEVs considered within this study. The definitions are based on international standards, where possible. Furthermore, the batteries used in these applications will be specified (cell chemistries, technical parameters, battery system design etc.) and test standards will be outlined. Finally, typical use profiles of the LEV applications will be described.

- **Subtask 1.2 – Market**

  This subtask reviews historical market data on sales and stocks of light e-mobility applications. Based on historical data and further assumptions, forecasts on the potential future development of sales and stocks will be made.

- **Subtask 1.3 – Analysis of requirements**

  Based on the previous subtasks, this task analyses all requirements discussed in Task 7 "Policy Scenario Analysis" in the original study according to their applicability to light e-mobility applications. This includes analyses of requirements for battery lifetime, battery management systems, information provision about batteries, traceability of batteries, carbon footprint information and for battery design and construction.

- **Subtask 1.4 – Impact assessment and cost-benefit-analysis**

  This task analyses the implications of extending the scope and conducts a qualitative cost-benefit-analysis.

1.1. Subtask 1.1 – Definition and specification of applications

AIM OF SUBTASK 1.1:

The aim of this subtask is to give definitions on LEVs considered within this study. Furthermore, the batteries used in these applications will be specified (cell chemistries, battery system components, technical parameters) and test standards will be outlined. Finally, typical use profiles of the LEV applications will be described.

1.1.1. Definitions

As far as possible, the definitions follow the EU categorization of L-category vehicles (2- and 3-wheel vehicles and quadricycles).[1] Hence, in the following the categorization is described and it is explained which vehicle types are explicitly meant by which term within this study and which vehicle types are beyond the scope of this study. If the vehicle is considered within this study, a detailed definition is given on the following pages. If the vehicle category is not considered within this study, it is referred to the official categorization document which can be found within the regulation (EU) No 168/2013 of the European Parliament and of the Council as of 15.01.2013.

Table 1: Categorization of studied vehicles based on the EU L-categorization

Category	Sub-category	Category name	This study
L1e Light two-wheel powered vehicle	L1e-A	Powered cycle	Pedelec
	L1e-B	Two-wheel moped	E-moped (and Pedelec)
L2e Three-wheel moped	L2e-P	Three-wheel moped for passenger transport	E-moped
	L2e-U	Three-wheel moped for utility purposes	
L3e Two-wheel motorcycle	L3e-A1	Low-performance motorcycle	E-motorcycle
	L3e-A2	Medium-performance motorcycle	
	L3e-A3	High-performance motorcycle	

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[1] Based on regulation (EU) No 168/2013 of the European Parliament and of the Council as of 15.01.2013

	L3e-AxE	Enduro motorcycles	
	L3e-AxT	Trial motorcycles	
L4e Two-wheel motorcycle with side-car			E-motorcycle
L5e Powered tricycle	L5e-A	Tricycle	E-motorcycle
	L5e-B	Commercial tricycle	
L6e Light quadricycle			Not considered due to low market volumes
L7e Heavy quadricycle			Not considered due to low market volumes

In order to determine use profiles, battery-specific characteristics or market forecasts, it is necessary for this study to aggregate the vehicle (sub-) categories to clusters, which can be explored further with regards to the aim of this study. Therefore, categories L6e and L7e are excluded since they currently do not show market-relevant sales figures, which makes defining use profiles and calculate market forecasts too uncertain.

E-scooter

As can be seen from Table 1, e-scooters are not directly within the scope of the L-vehicle categorization. However, they are electrically driven two-wheelers. Furthermore, the process of defining a standardization for these types of vehicles is still ongoing at the time of this study (IEC 2019). Moreover, several EU member states are currently dealing with regulating e-scooters but have not defined a law or regulation yet. There are also countries such as the United Kingdom or Ireland banning e-scooters. This is why we draw on recent national laws, within the EU, regulating this vehicle type (Austria, Belgium, Czech Republic, Denmark, France, Germany, Netherlands, Norway, Spain, and Sweden). As the national laws sometimes even differentiate from city to city within a certain country and laws differentiate between countries, the definition aims to bring the main regulation factors together, which are of relevance for this study (AHK 2019, BBC 2019, Bicle 2019, BMJV 2019, El País 2019, ePilot 2019, ETSC 2019, Euronews 2019, Grayling 2019).

The maximum speed allowed ranges from 20 to 25 km/h. Regarding the lanes where e-scooters are allowed to drive, there is a clear trend to cycling lanes if available. If these are not available, pavements are mostly forbidden and roads are recommended for e-scooters. In some countries such as Sweden or Norway, the regulations have been adapted to those of bicycles. This also holds for the Czech Republic and Austria with the addition that e-scooters qualify as (e-) bikes as long as they do not exceed a maximum speed of 25 km/h and an electrical power of 600 W or 1 kW. Moreover, taking passengers on e-scooters is usually forbidden such that e-scooters are single-occupancy vehicles. In countries like Germany or the Netherlands, the e-scooters have to be insured.

There are further vehicles that might fall into the category of e-scooters such as monowheels, segways or other self-balancing[2] vehicle types. However, e-scooters have been showing tremendous growth rates in sales and usage (via shared services), which has not been the case for other vehicle types, potentially being part of this category. Moreover, current sales figures for other vehicle types, related to e-scooters (vehicles with seating, self-balancing vehicles), are relatively small and it is assumed that these vehicles do not show very different technical characteristics, with regards to their batteries, and usage or user profile than e-scooters. This is why we focused on e-scooters within this category in order to calculate use profiles and market forecasts.

A tentative definition can be given as follows:

- electrically power driven two-wheelers with a maximum speed between 20 and 25 km/h (depending on country-specific regulation)
- without seat, but with handlebars
- max. continuous power of 500 to 1,400 W

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[2] Self-balancing if equipped with integrated electronic balance-, engine-, steering- and deceleration technology, which enables the vehicle to balance itself.

Pedelec (Electrically power assisted bicycle: EPAC)

The pedelec or electrically power-assisted bicycle is a powered cycle as defined in the L1e-A sub-category. For the definition, this classification as well as the European Standard EN 15194:2017 is applied.

- Cycle[3], equipped with pedals and an auxiliary electric motor, which cannot be propelled exclusively by means of this auxiliary electric motor, except in the start-up assistance mode
- Maximum continuous rated power of 250 kW
- Output progressively reduced and finally cut off as EPAC reaches speed of 25 km/h or sooner if the cyclist stops pedalling
- Cut off speed is the speed reached at the moment the current has dropped to zero or to the no load current value (current for which there is no torque on the driving wheel)

Beyond the L1e-A category, there are so-called speed pedelecs, which can realize velocities of up to 45 km/h. These vehicles are, within this report, also referred to as mopeds and are therefore categorized as L1e-B vehicles. This also means that they must be driven on streets rather than bicycle lanes (which is however not the case in all EU countries, see Denmark[4]). Yet, these vehicles exhibit only small sales numbers compared to usual pedelecs (Guy 2019). Nevertheless, due to their potentially different use profiles from pedelecs, speed pedelecs are taken into account for the e-moped market calculations.

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[3] Cycle: Vehicle with min. two wheels and propelled solely or mainly by muscular energy of the person on that vehicle, in particular by means of pedals.

[4] https://www.sikkertrafik.dk/raad-og-viden/paa-cykel/speed-pedelecs

E-moped

Source: https://icon-library.net/icon/moped-icon-20.html

For the e-moped, the Regulation No 168/2013 of the European Parliament and of the Council is applied:

- Two-wheel vehicles (L1e-B[5]) or three-wheel vehicles with mass in running order of less than 270 kg and max. two seating positions (L2e-P)
- Max. design speed of not more than 45 km/h
- Max. continuous rated power is no more than 4 kW

E-motorcycle

Source: https://www.vectorstock.com/royalty-free-vector/motorcycle-black-simple-icon-vector-7395109

For the e-motorcycle, as for the e-moped, the Regulation No 168/2013 of the European Parliament and of the Council is applied.

- Two-wheel vehicle without sidecar (L3e) or with sidecar (L4e)
- Powered tricycles with three symmetrically arranged wheels (L5e-A)
- Max. continuous rated or net power of more than 4 kW
- Max. design speed of more than 45 km/h

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[5] Vehicle classification following Annex I of Regulation No 168/2013 of the European Parliament and of the Council.

1.1.2. Battery specifications

Battery types / cell chemistries

In general, the following battery types have been used for e-scooters and in some early pedelecs, e-mopeds or e-motorcycles:

- nickel metal hydride (NiMH)
- sealed lead acid batteries (SLA)
- lithium ion battery (LIB)

Mainly, the first two types have been used so far, but they are replaced almost entirely by LIB, since the latter have more adequate battery performance for traction applications (higher energy and power density, no memory effect).

The most used cell chemistry of the latest e-scooter, pedelec, e-moped and e-motorcycle models are lithium-manganese-nickel-cobalt (NMC) or in some cases lithium-iron-phosphate (LFP). These are the same cell chemistries that have been discussed in the original study for the use in electric vehicles (EV) and electrical energy storage systems (ESS).

Components of battery system

Battery Management System

All LIB batteries need a battery management system (BMS), for that reason, also light electric vehicles (LEV) such as e-scooters, pedelecs, e-mopeds and e-motorcycles have a BMS to monitor the battery pack (e.g. temperature, voltage) and control charging and discharging. For most e-scooters the BMS is kept very simple, with mechanisms for preventing overheating and overcharging only. Some pedelecs and e-mopeds and e-motorcycles, however, have a quite advanced BMS,[6] with several sensors and processors ensuring optimum battery utilisation (e.g. state of charge (SOC) between 20 and 80%). Still for all LEV applications, the majority of BMS seems to allow firmware updates. In general, the existence of a BMS is in line with the battery systems discussed in the original study

Figure 1 shows the wiring and BMS of a Samsung SDI battery pack for e-mopeds and Figure 2 shows the functionalities of a smart BMS for Super SOCO e-motorcycles.

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[6] https://www.samsungsdi.com/lithium-ion-battery/trans-devices/e-bike.html
https://www.samsungsdi.com/lithium-ion-battery/trans-devices/e-scooter.html
http://www.supersoco.com/second-phase/en/details-ts-technology.php

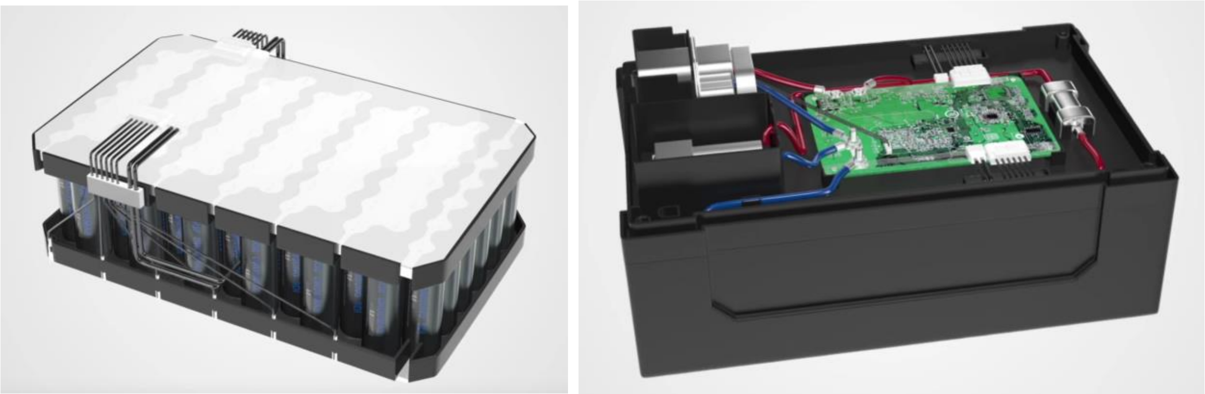
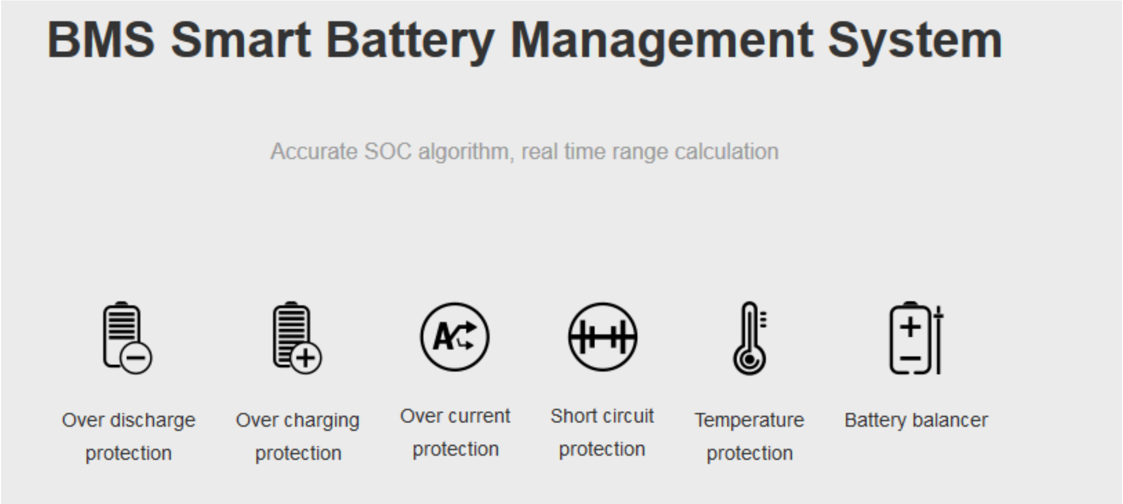


Figure 1: Wiring and BMS of Samsung SDI battery pack for e-mopeds Source: https://www.samsungsdi.com/lithium-ion-battery/trans-devices/e-scooter.html



BMS Smart Battery Management System

Accurate SOC algorithm, real time range calculation

Over discharge protection

Over charging protection

Over current protection

Short circuit protection

Temperature protection

Battery balancer

Figure 2: Functionalities of smart BMS of Super SOCO e-motorcycles Source: http://www.supersoco.com/second-phase/en/details-ts-technology.php

Thermal Management System

Most LEVs do not have active thermal management systems except for cut-off mechanisms in case of over-heating. Even batteries used in e-motorcycles (e.g. Harley Davidson LiveWire, Super SOCO models) generally only have passive cooling with aluminium ribs and special heat-conducting materials, but without fans. Here, the battery systems of LEVs and EVs or ESS discussed in the original study differ, since the latter have active thermal management systems with fans or even cooling pipes and heating. For that reason in LEVs, outside temperature and weather conditions have a higher impact on the battery than in EVs. Considering, that LEVs will be used all throughout the year, especially by commuters, and that LEVs are mostly parked outside, the susceptibility to temperature and weather is a very critical point.

Further Components

Battery packs of LEVs usually consist of one module, which is made up of several cells (for most e-mopeds and e-motorcycles, however, modular battery systems/packs are offered). This is in contrast to the battery system defined in the original study, which usually comprises several modules. High power DC charging (with more than 3.8 kW) is only possible with some e-mopeds and e-motorcycles. Most power electronics of LEVs do not allow higher charging power. EV and ESS, however, allow charging power of up to 350 kW.[7] For most e-mopeds and e-motorcycles exchangeable and modularly expandable batteries are available, while for most EV and ESS, as defined in the original study, that was not the case. Some e-scooter sharing companies want to work with exchangeable batteries as well.[8]

Technical specifications

Technical specifications of the LEV applications and the batteries used are outlined in Table 2, as well as calculations of Application Service Energy (AS), Functional Unit (FU) and energy losses.

The numbers for battery energy efficiency, self-discharge rate, average state of charge and charger efficiency are assumed to be identical to the parameters used in the original study. While the economic lifetime was defined after consultations with stakeholders, while the annual vehicle kilometres were derived from various sources (see section 1.1.3). The energy consumption and typical battery capacity was defined as average of various currently existing LEV models. Braking energy recovery is only offered in few e-scooters and pedelecs,[9] while it is offered in most e-mopeds and e-motorcycles. Still, we included braking energy recovery for all applications, thus representing a very conservative value when calculating the application service energy (AS).[10] The calendar and cycle life of batteries, as well as the state of health (SOH) at end-of-life (EOL) were derived from consultations with stakeholders. The underlying assumption is that the lifetime of LEV batteries is lower compared to EV batteries, since LEVs have a shorter economic lifetime and thus, lower lifetime requirements regarding batteries.

Table 2: Technical specifications of LEV applications and respective batteries as well as calculation of Application Service Energy, Functional Unit and energy losses. Values in bold are calculated values.

	Unit	**E-scooter**	**Pedelec**	**E-moped**	**E-motorcycle**
Economic life time of the *application*	a	1.5	10	10	10
Annual vehicle kilometres	km/a	2,360	1,392	2,959	7,800
Energy consumption	kWh/100km	1.0	0.8	4.0	10.0
Braking energy recovery in AS	% fuel consumption	20%	20%	20%	20%
All-electric range [km]	**km/a**	**32**	**60**	**80**	**112**
Maximum DOD (stroke)	%	80%	80%	80%	80%

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[7] https://newsroom.porsche.com/en/2019/technology/porsche-engineering-dc-energy-meter-high-power-charging-measuring-technology-electromobility-18140.html

[8] https://www.businessinsider.de/tier-und-co-stellen-e-scooter-mit-austauschbaren-akkus-vor-2019-10

[9] https://electrek.co/2018/04/24/regenerative-braking-how-it-works/
https://electric-scooter.guide/guides/electric-scooter-regenerative-brakes/

[10] For details on the consideration and impact of braking energy recovery and on all calculations carried out within Table 2, see Task 3 report of the original study

Typical capacity of the application	kWh	0.4	0.6	4.0	14.0
Min capacity of the application	kWh	0.2	0.3	1.5	4.0
Max capacity of the application	kWh	1.2	1.3	4.8	18.0
Battery calendar life (no cycling)	a	10	10	10	10
Battery cycle life (no calendar aging)	FC	1,000	1,000	1,500	1,500
SOH @ EOL	%	70%	70%	70%	70%
Application Service Energy (AS)	**kWh**	**42**	**134**	**1,420**	**9,360**
Maximum quantity of functional units (FU) over battery service life	**kWh**	**320**	**480**	**4,800**	**16,800**
Calculated batteries per economic service life (according to cycles/FU)	**-**	***0.1***	***0.3***	***0.3***	***0.6***
Battery energy efficiency	%	92%	92%	92%	92%
Energy consumption battery energy efficiency	**kWh**	**26**	**38**	**384**	**1,344**
Self discharge rate	%/month	2%	2%	2%	2%
Average SOC	%	50%	50%	50%	50%
Energy consumption self-discharge	**kWh**	**0.5**	**0.7**	**4.8**	**16.8**
Charger efficiency AC	%	92%	92%	92%	92%
Charge power AC	kW	3.8	3.8	3.8	3.8
Charger efficiency DC	%			93%	93%
Charge power DC	kW			50	50
Share AC charge	%	100%	100%	95%	80%
Energy consumption charger energy efficiency	**kWh**	**28**	**42**	**415**	**1,424**

1.1.3. Use profiles

Data about use profiles is obtained by combining different sources specifically outlined per vehicle type in Table 3. For the remainder of this report, these numbers are used as assumptions, which are calculated as average numbers in order not to skew the calculations to an extreme. This also means that there might be e-mopeds for example, which show annual mileages of 14,600 or even 21,900 km. However, these do not match the estimated lifetime of 10 years for this vehicle as stated in Table 2 but the lifetime will be below this value. This holds for maximum and minimum values depicted in Table 3. As there are many providers offering sharing services for the vehicles discussed in this study, these utilisation figures are included into the annual mileage where possible. However, the shared use applications are usually well above average, since service providers need to bring them into use as often as possible in order to generate revenue. This is why the numbers from shared use should be seen as upper boundary. On the contrary, privately used vehicles can be interpreted as lower boundary since these vehicles are in usage for the owner only. It has to be mentioned, that (internal combustion engine) motorcycles are mainly used for two purposes, which are leisure and commuting or daily transport. This leads to entirely different user profiles and requirements regarding range, charging (power) and battery cycle and calendar life. Motorcycles that are mainly used for leisure ride less kilometres per year, but more per ride. As described above, however, we cannot account for both use profiles, and use the European average values.

Table 3: Use profiles of studied vehicles

Vehicle	**Annual mileage [km]**	**Source of data**	**Assumptions made**
E-scooter	Average: 2,360 Shared use: 3,326 Private use: 1,395	Tack et al. (2019)	Private use: 3.1 trips per day (as in Nobis and Kuhnimhof 2018), 2 km per trip (as in shared use), 5 days per week and 45 weeks per year
Pedelec	1,392 [min 1,004; max 1,804]	Castro et al. (2019)	
E-moped	2,959	Papadimitriou et al. (2013)	
E-motorcycle	7,800	Williams et al. (2017); Delhaye and Marot (2015a/b)	

1.2. Subtask 1.2 – Market

AIM OF SUBTASK 1.2:

The aim of this subtask is a review of historical market data on sales and stocks of LEVs. Based on historical data and further assumptions, forecasts on the potential future development of sales will be made.

1.2.1. E-scooter market

E-scooters are transport vehicles that just recently found their way into European markets. The majority of e-scooters is provided by sharing services such as Lime, Voi, Bird etc. that equip an increasing number of cities with the scooters for shared use. The firms do not provide complete information about the amount of distributed scooters and the regulating institutions have not yet established a registration system that provides comprehensive data on the amount of scooter-registration in Europe.

Data basis

In order retrieve market figures and to develop a projection of future e-scooter sales we build on the following base:

- E-scooters are considered a new phenomenon with scarce availability of historical and current data
- Only some data on status-quo in some major and smaller European cities is available
- We selected countries with differences in geographical region, cultural patterns etc., shown in Table 4, to account for possible differences in diffusion characteristics:
  - Germany, Sweden, Spain, Switzerland, Region Eastern Europe
  - Data for biggest cities or capitals as well for a sample medium size city of ~ 300,000

From the analyzed data, there is no clear trend observable to which extent the density of e-scooters per 1,000 inhabitants is related to the city-size. Furthermore, the observed cities show a large variance in e-scooter density per 1,000 inhabitants.

Table 4: E-scooter density in variety of European cities, 2019

Country	City	Inhabitants	E-scooters total	E-scooters / 1000 inhabitants	Source
Germany	Berlin	3,600,000	4,425	1.23	http://scooters.civity.de/
Germany	Münster	300,000	378	1.26	http://scooters.civity.de/
Sweden	Stockholm	950,000	1,500	1.58	https://www.thelocal.se/20190531/swedish-transport-agency-calls-for-ban-on-electric-scooters-after-fatal-crash
Sweden	Malmö	300,000	700	2.33	https://www.thelocal.se/20190531/swedish-transport-agency-calls-for-ban-on-electric-scooters-after-fatal-crash

Switzerland	Zürich	409,000	1,500	3.67	https://nzzas.nzz.ch/schweiz/tier-bird-circ-e-scooter-sind-erst-der-anfang-ld.1497280?reduced=true
Switzerland	Basel	172,000	400	2.33	https://nzzas.nzz.ch/schweiz/tier-bird-circ-e-scooter-sind-erst-der-anfang-ld.1497280?reduced=true
Spain	Madrid	3,260,000	10,000	3.07	City of Madrid
Eastern Europe	Sofia	1,240,000	150	0.12	https://www.trendingtopics.at/bulgaria/lime-escooters-just-launched-in-sofia-heres-how-they-work/

Forecast

Without the official registration numbers, there is hardly any possibility to track private scooter registration / sales right now. The main focus lies on the given data from the sharing service providers, since assumptions on private sales lack any basis. Thus, the market development for private e-scooters is not explicitly projected. Within the scope of this study, the estimation remains a rough projection of possible amounts of scooters. The market is expected to be very volatile and deviation is likely to occur.

Projection approach:

- The actual e-scooter stock in supplied cities varies around 2.5 e-scooters per 1,000 inhabitants. In the projection, a quick dissemination is expected for most bigger European cities until 2030, finally all supplied cities will converge to 2.5 e-scooters per 1,000 inhabitants until 2050. Due to a possible slower uptake in some countries, until 2030, an average of 2 e-scooters is projected for supplied cities.
- Some cities show higher numbers of e-scooter density right now. However due to the below mentioned suggestion of actual oversupply by the sharing service providers and increasing reservations of the population towards the e-scooters, a saturation at 2.5 is expected, which is below the maximum density observable right now. Due to the scarce data sources, any further distinction would also build on hypothetical assumptions.
- Estimation of number of e-scooter via inhabitants and density of 2 / 2.5 e-scooters per 1,000 inhabitants, where the dissemination of shared scooters is only considered for cities with more than 200 000 inhabitants
- ~ 290 European cities of more than 200,000 inhabitants identified. Multiplication of the latest available inhabitant numbers for the selected cities by 2 / 2.5 e-scooters per 1000 inhabitants.
- The calculation leads to an estimate of 380,000 e-scooters in stock in 2030 and 475,000 e-scooters in stock in 2050

- Considering the quick death rate and thus replacement rate according to estimated lifetime of 15 months leads to around 300,000 yearly e-scooter in 2030 and 380,000 yearly e-scooter sales in the year 2050

Assumptions:

- E-scooters are only used in urban areas
- Saturation at actual density rate of pilot cities, thus no increase in the density of e-scooters per 1,000 inhabitants over 2.5 e-scooters per 1,000 inhabitants in 2050
- Lower value of average of 2 e-scooters per 1,000 inhabitants in 2030, due to lower rise in especially Eastern European countries
- Service providers are fighting over market shares right now, which might result in oversupply of targeted cities. Actual numbers might overestimate long-term supply
- Increases in numbers of e-scooters driven by an increasing number of cities that are supplied by the sharing service providers
- Projected dissemination across all cities > of 200,000 inhabitants (or cities that had 200,000 within in the past 5 years) (Source: Eurostat database, urb_cgc, “Population on 1 January by age groups and sex - cities and greater cities”)

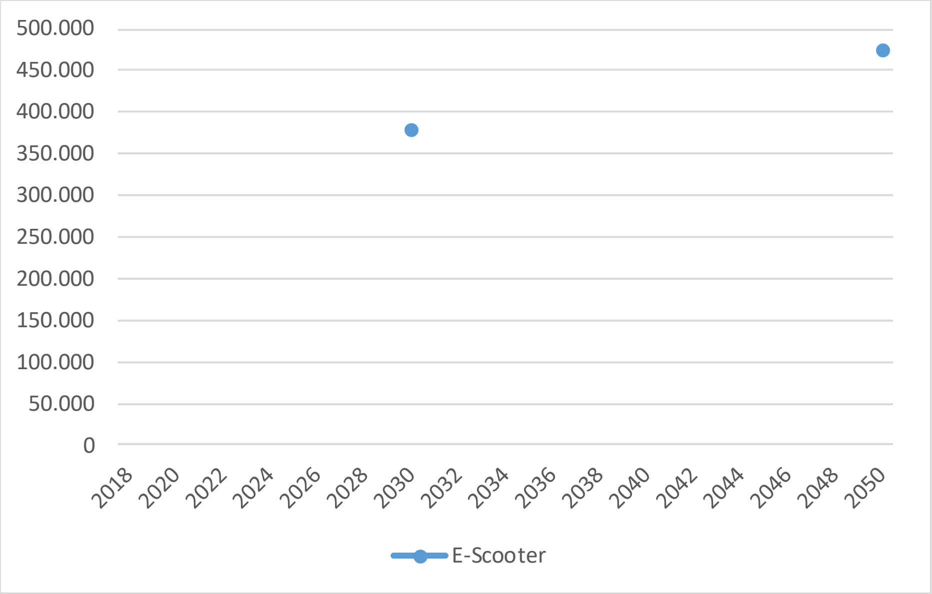

Figure 3: E-scooter sales for 2030 and 2050 EU-28

1.2.2. Pedelec market

The pedelec market has been growing quickly over the past 10 years. The strong positive trend for total European pedelec sales has recently been driven by early adopters, mainly in central Europe. Due to the higher speed and longer range, compared to conventional bikes, as well as the possibility e.g. for elderly Europeans to use pedelecs, when conventional bikes would no longer be an option, sales are likely to increase in other countries as well.

Data basis

- CONEBI, the Confederation of the European Bicycle Industry, publishes numbers on pedelec sales for EU-28 countries

- Upward trend in total pedelec sales, especially in central Europe

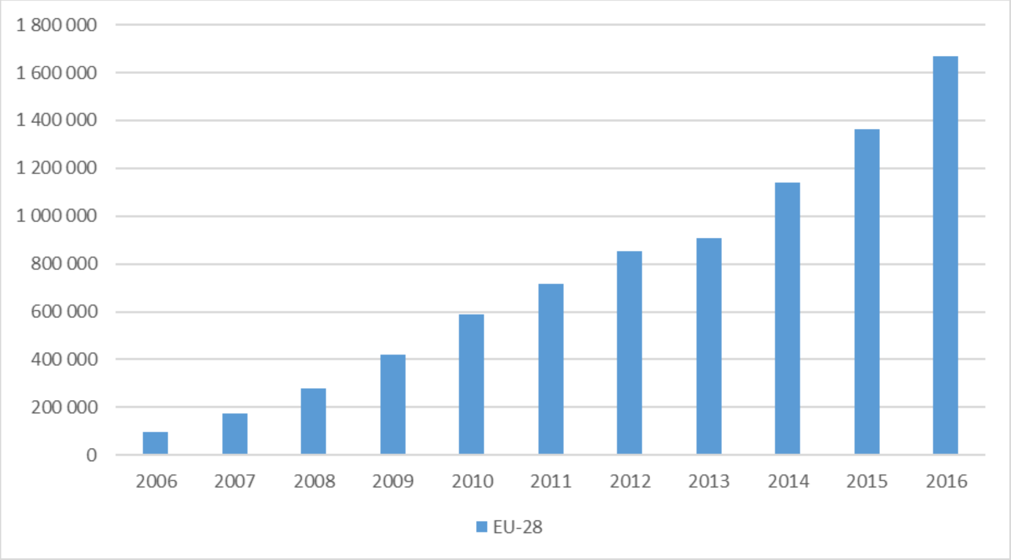

Figure 4: Development of pedelec sales EU-28 (CONEBI, 2017)

Forecast

According to the ECF, the European Cycling Federation, there is large potential in cycling, if cycling was prioritized in traffic regulations (ECF, 2019). Especially pedelecs would profit while the number of conventional bike sales are expected to remain at a constant level. Pedelecs are considered rather an additional vehicle than a replacement of conventional bikes due to partly different application fields.

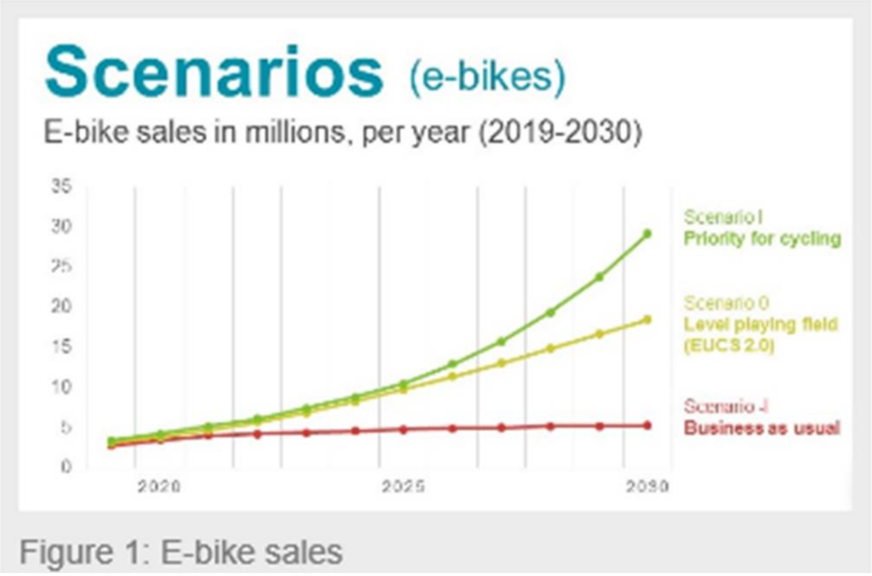

Figure 5: ECF e-bike sales scenarios (equivalent to pedelecs in this study) (ECF, 2019)

Projection Approach

- Since a direct shift to prioritizing cycling might not be reached, an estimation of future pedelec sales between Scenario 1 and Scenario 0 of the ECF until 2030 is expected: sales increase to 20 mio. pedelecs in 2030

- This means continuing trends from the observed development
- Constant yearly sales of 20 mio. pedelecs would come along with a long-term saturation at about 30% pedelec ownership rate (~200 mio. pedelecs in Europe) among the 740 mio. Europeans from 2040 on, considering an upper limit economic lifetime of 10 years
- This might be a rather optimistic long-term projection of pedelec ownership rates. A continuous increase can be projected for the upcoming years until 2030 in order for the ownership stock to grow and due to higher exchange rates due to occurring technical weaknesses of a fairly new product. However, afterwards sales numbers are likely to stagnate and even to decrease, to reach a long term saturation of about 20 % maximum. This would mean yearly sales around 14 mio. pedelecs, considering an economic lifetime of 10 years.

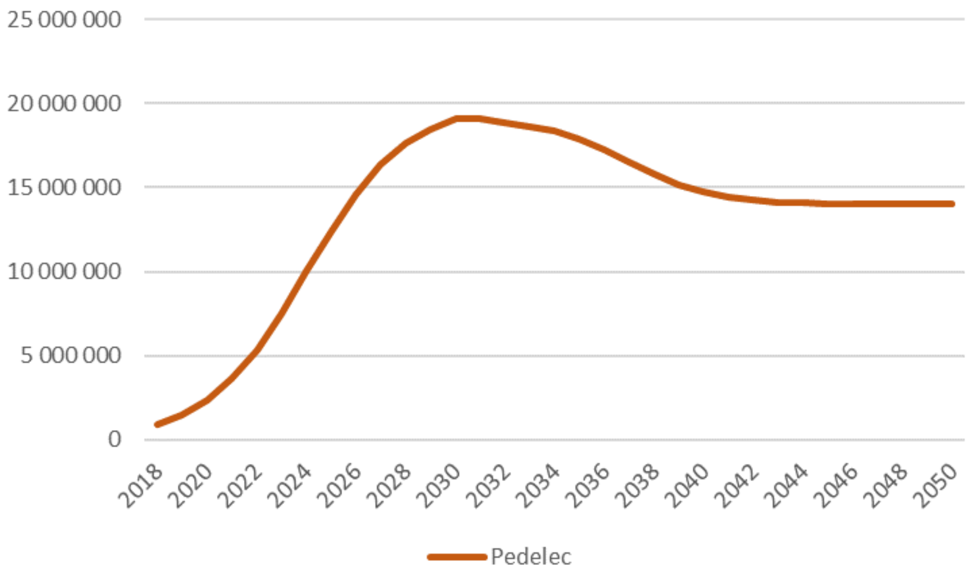

Figure 6: Forecast pedelec sales 2050 EU-28 (own calculation)

1.2.3. E-moped market

Mopeds are well known motorized vehicles that are used in rural as well as urban areas. Considering their range as well as the maximum speed, they have always been applied for shorter distances. The characteristics of electrified mopeds, e-mopeds, do not differ much from conventional mopeds and can easily be substituted. In the past years, an increasing number of shared moped providers has launched e-moped fleets in European cities. Right now, the price for the electrified version of a moped is high, compared to the alternative equipped with an internal combustion engine. The application field of e-mopeds includes longer distances compared to pedelecs that favor or require higher travel speeds. Consequently, these distances can also be traveled with speed pedelecs. The degree of potential substitution between speed pedelecs and e-mopeds is hardly predictable. However, due to comparable use profiles and battery capacities, the distinction must not necessarily be made within the scope of the study.

Data basis

- Eurostat database with many blank spots on countries' registration numbers
- ACEM, the European Association of Motorcycle Manufacturers, publishes numbers on two-wheeler registrations
- Past years: Falling registration numbers
    - Young adults shift from mopeds to cars as first vehicle or use bikes
- Rising numbers of e-mopeds

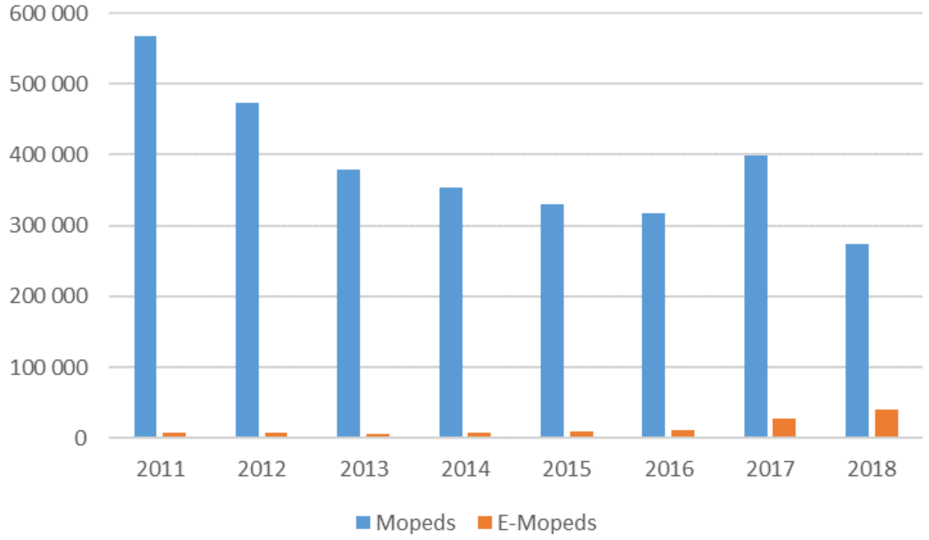

Figure 7: Development of moped and e-moped sales EU-28 (ACEM CIACEM database, 2019)

Forecast

The potentially rising relevance of e-mopeds as a transport mode, especially in urban areas as a substitute for cars, drives the high expectation towards e-mopeds to retrieve historic registration numbers. Urbanization is strengthening this trend and it is also supported by potential bans of conventional mopeds from urban areas, which are for example planned in Amsterdam and in other Dutch cities. Due to the small changes in driving patterns, e-mopeds are expected to quickly substitute conventional moped sales.

Projection approach

- Rising trend in moped sales: back to 500,000 mopeds per year in 2030, up to 600,000 in 2050 (EC, 2017)
- Quick diffusion of e-mopeds: ~90 % of registrations electrified in 2030, ~100 % of registrations electrified by 2050

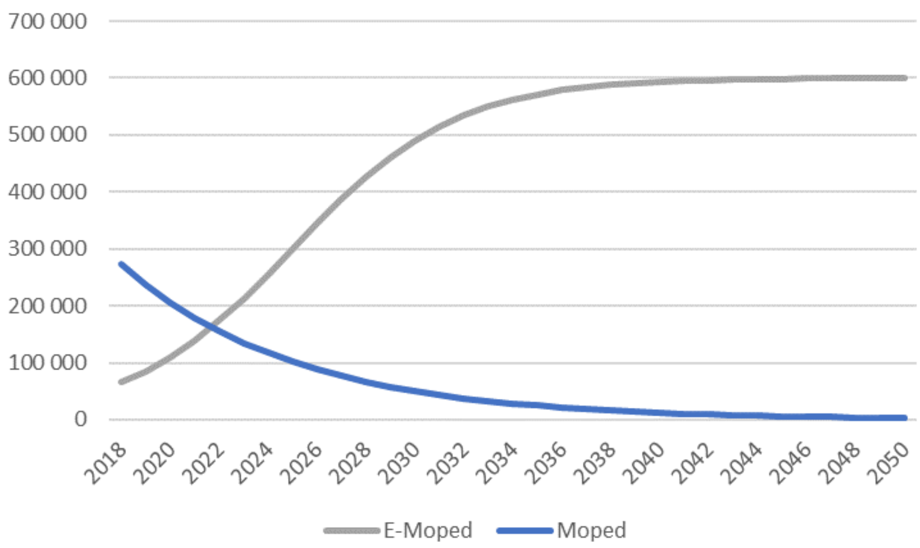

Figure 8: Forecast moped and e-moped sales 2050 EU-28 (own calculation)

1.2.4. E-motorcycle market

Motorcycling plays big role as a hobby, fascination driving, but also as means of daily transportation (Delhaye and Marot, 2015a). The share of cyclists, using motorbikes in leisure/hobby/sport is comparably high. These rides are usually short ride, thus the share of vehicle kilometres in that category might be smaller. However, hobby-cyclists might react differently to alternative powertrains, compared to commuting cyclists. One has to weigh characteristics as the motor sound of a combustion engine against e.g. the immediate torque but limited range of an electric drive. This question of personal preferences is hard to answer regarding long-term developments. Motorcycles have not yet been provided on a shared base, in the following only privately owned motorcycles are considered.

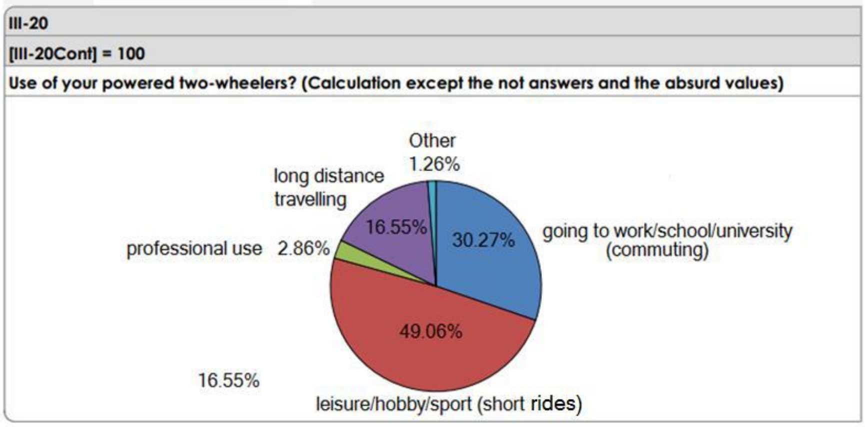

Figure 9: Use of motorcycles (Delhaye and Marot, 2015a)

Data basis

- Eurostat database with many blank spots on countries' registration numbers
- ACEM, the European Association of Motorcycle Manufacturers, publishes numbers on two-wheeler registrations
- During the past years, registration numbers have been fluctuating, no trend observable

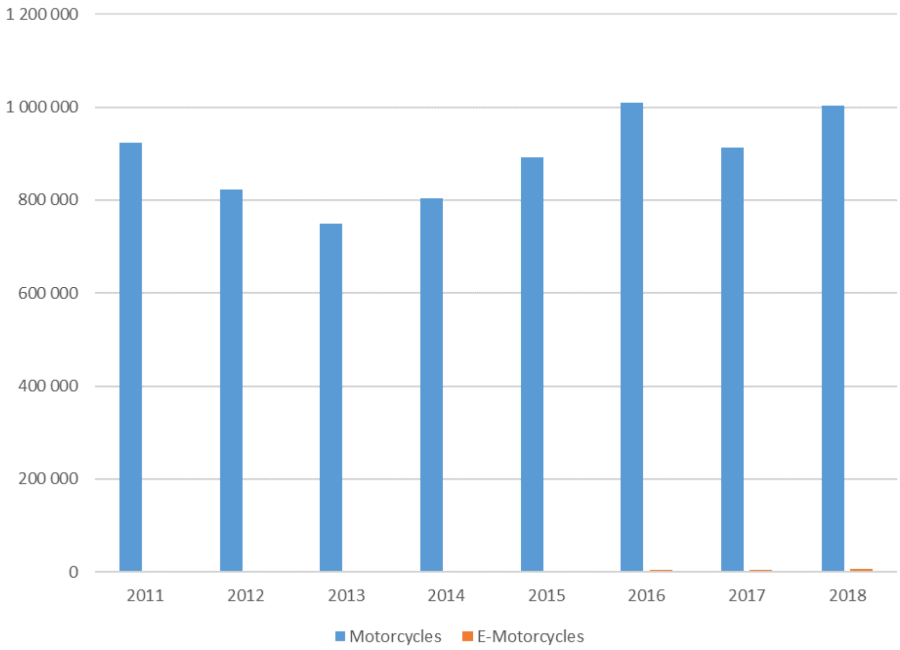

Figure 10: Motorcycle and e-motorcycle registrations EU-28 (ACEM, 2019)

Forecast

Electrified motorcycles represent a suitable alternative choice for motorcyclists. Compared to e-mopeds, the price difference between conventional motorcycles and the electrified versions is relatively smaller. This might encourage motorcyclists to quickly adopt the new technology. In the visions for future cities, two-wheelers play an important role. This might also positively influence the total sales of motorcycles. However, especially hobby motorcyclists might not change their preferences and remain buying motorcycles with combustion engines, also because of the limited range of e-motorcycles.

Projection approach

- Yearly sales of motorcycles constant at around 1,000,000 in total until 2030 (upper limit of recent yearly sales), considering a 55 % share of e-motorcycles in sales
- Further rise to a total of 1,250,000 until 2050 (baseline in EC, 2017): around 1,100,000 e-motorcycles are sold, while a remainder of 150,000 motorcycles (~10 %) is still sold with combustion engines for fascination driving users

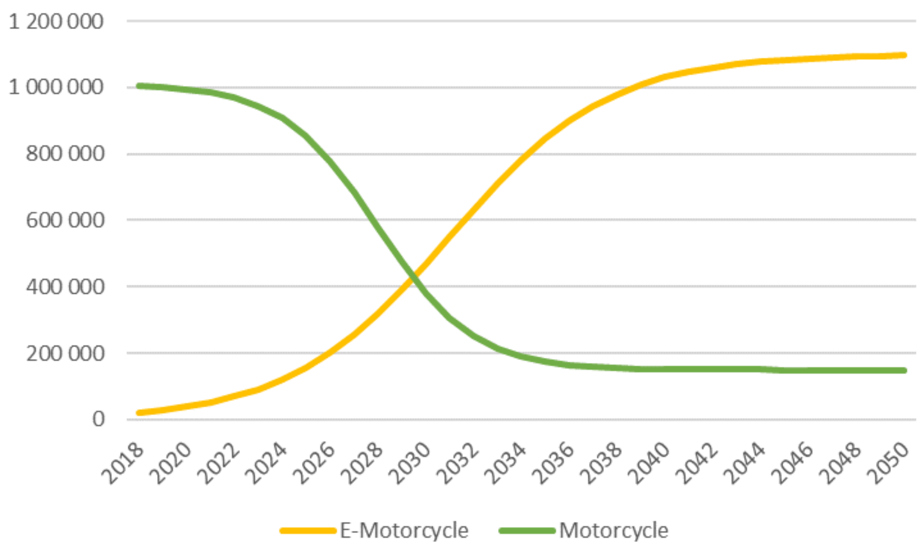

Figure 11: Forecast motorcycle and e-motorcycle sales 2050 EU-28 (own calculation)

1.2.5. Total battery demand

Projections of LEV sales for 2020, 2030, 2040 and 2050 were multiplied by typical battery capacity of application (see Table 2) in order to derive total battery capacity demand. The results can be seen in Figure 12. In the years 2020 and 2030 battery capacity demand from pedelecs play the most important role, while after then demand is dominated by e-motorcycles. Battery demand from e-scooters and e-mopeds only plays a subordinate role, due to their low sales but also low battery capacity per vehicle.

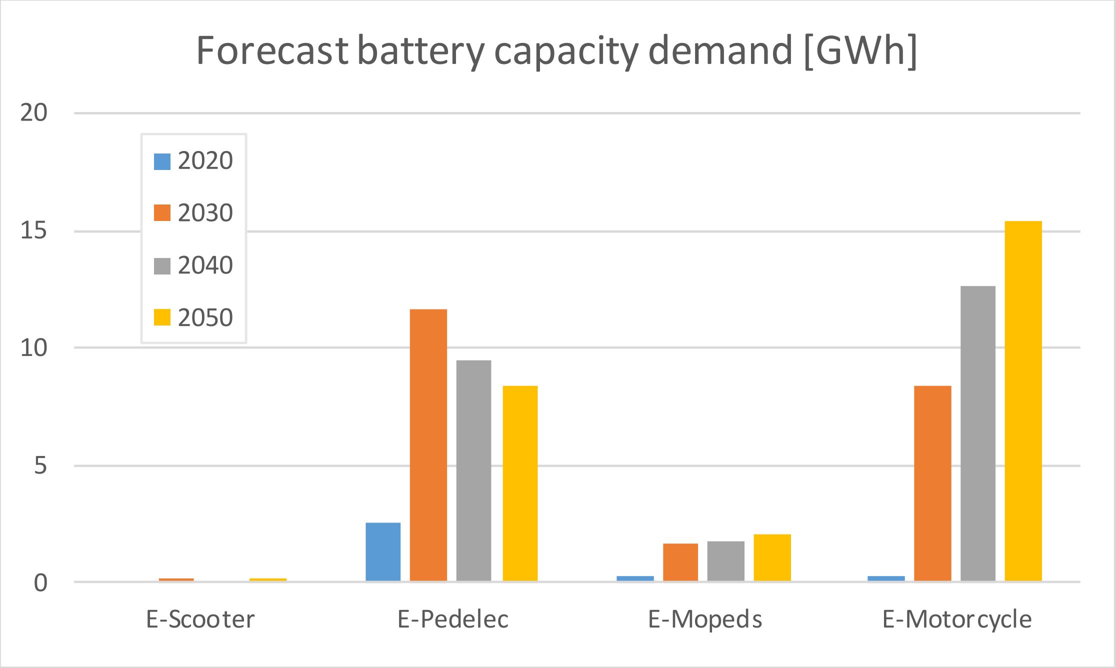

Figure 12: Forecast of battery demand from LEV, EV and ESS in GWh.

Figure 13 shows the forecasted battery capacity demand from EV and ESS in GWh until 2050 according to Task 2 report of the preparatory study. It is important to note, that maximum battery capacity demand from LEVs adds to 26 GWh in 2050, while demand for ESS alone in 2050 is at 260 GWh. Thus, in terms of battery capacity demand, LEVs mainly play a certain role within the next decade.

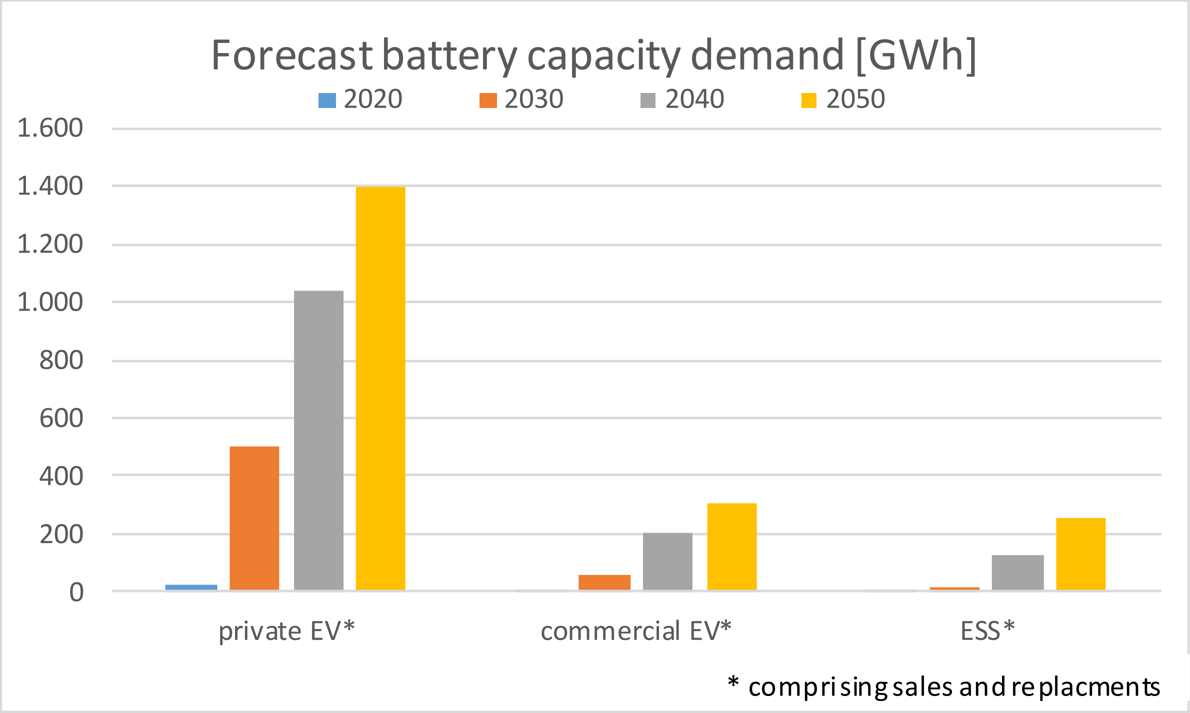

Figure 13: Forecast of battery demand from EV and ESS in GWh until 2050. Source: Task 2 report of preparatory study.

1.3. Subtask 1.3 – Analysis of requirements

AIM OF SUBTASK 1.3:

The aim of this subtask is to analyse all requirements discussed in the preparatory study Task 7 "Policy Scenario Analysis" according to their applicability to LEV, based on the previous subtasks. This includes analyses of requirements for battery lifetime, battery management systems, information provision about batteries, traceability of batteries, carbon footprint information and for battery design and construction.

1.3.1. Requirements for lifetime of battery packs and battery systems

In order to win the trust of the European public and end users a long service life and a minimisation of energy waste are important factors. This could be achieved by minimum battery pack and battery system requirements regarding lifetime and efficiency, possibly assured by warranties. Thus, the carbon footprint per functional unit can be reduced.

This could lead to a proposal for maximum capacity fade, maximum internal resistance increase and minimum round-trip efficiency for battery systems/modules/packs brought on the market for the intended applications

In order to ensure acceptable test durations, thresholds can be stated for half of the battery's service life (in cycles). As a consequence not a full lifecycle test is needed, but a half-life test is sufficient. Examples from the original study's Task 7 are given in Table 5.

Table 5: Examples of minimum performance and durability requirements after half of the service life for battery electric passenger vehicles (BEV)

Application	**Remaining capacity** (relative to the declared value)	**Maximum internal resistance increase**	**Minimum round-trip energy efficiency**	**Standards** (provisional -see notes on review)
PC BEV	90 % @ 750 cycles	30 % @ 750 cycles	90 % @ 750 cycles	ISO 12405-4:2018 Cycle-life test according to Dynamic discharge application

Discussion of requirements

- According to chapter 1.1.2 cycle life and EOL of LEV batteries is lower compared to EV and ESS (according to original study) since the applications have different requirements. Consequently, performance requirements and test duration for LEVs should be set lower.
- The test duration, even for a half-life test, is very long. Especially when adding it to the typical engineering development process needed for a LEV, which is shorter compared to EVs.
- Efficiency of batteries for LEV is expected to be similar to EV and ESS since same cell chemistries are used.
- However, test standards for LEV test / drive cycles are only partially available (see Table 6)

- Furthermore, no representative data on actual user behaviour and drive cycles is available, since LEVs are a quite new phenomenon
- Also, user behaviour is very unpredictable, especially for e-scooters and pedelecs.
- Finally, there are entirely different use profiles for LEVs. For e-scooters, pedelecs and e-mopeds in shared use the annual kilometres are much higher than those in private use. Also, there are different use profiles of leisure versus commuting e-motorcycle riders.

Table 6: Test standards for LEV

	Battery level & type	**LEV type**	**Cyclelife**	**Drive cycle**
Performance				
ISO 18243 (2017)	Li-ion: battery system	Mopeds, motorcycles	x	
ISO 13064-1 (2012)	Li-ion: battery application system	Mopeds, motorcycles		x
IEC 63193 (in prep.)	Lead-acid: modules	Two-wheelers (mopeds), three-wheelers (e-rickshaws & delivery vehicles), golf cars & similar light utility vehicles, similar multi-passenger vehicles	x	x
IEC 62620 (2016)	Li-ion: cell to battery system	Fork-lift truck, golf cart, AGV, industrial	x	
EN 50604-1:2016	Secondary lithium batteries for LEV			
Safety				
ANSI-CAN-UL2271 (2018)	All battery types: modules to battery system	Bicycles, scooters and motorcycles, wheel chairs, Golf carts, All-terrain vehicles, Non-ride-on industrial material handling equipment, Ride-on floor care machines and lawnmowers, personal mobility devices		
EN 15194 (2017)	All battery types: battery application system	Electrically power assisted cycles (EPAC)		

IEC 62619 (2016)	(see IEC 62620)			
Other				
IEC 61851-3-4 (in prep.)	All battery types: battery application system	Electrical bicycle, motor-bike, scooter, wheelchair, robot, EV		

It has to be mentioned, that for vehicles outside the L-categories (see section 1.1.1), other and further technical regulations and (test) standards apply, such as the EU battery directive (2006/66/EC), machinery directive (2006/42/EC), restriction of hazardous substances directive (2002/95/EC) or the standard for secondary lithium batteries for light EV (EN 50604-1:2016), for secondary cells and batteries containing alkaline or other non-acid electrolytes (EN62133-2) and many more.

Conclusion

- In general requirements applicable to all LEV
- Thresholds have to be adapted
- Test standards not available for all LEVs and not all parameters are covered
- Data on actual drive cycles required

Furthermore, a proposal for a minimum battery pack/system warranty per product could be introduced, including calendar life, energy that can be stored over lifetime, remaining capacity, internal resistance increase, energy efficiency (see Table 7).

Table 7: Examples of warranties

Application	**Warranty period**	**Minimum warranty**				**Methods**
	Calendar life warranty	Minimum **energy that can be stored over life-time in** kWh	**Remaining capacity** (relative to the declared value)	Maximum **internal resistance** increase	Minimum round-trip **energy efficiency**	Standards (provisional -see notes on review)
PC BEV	10 years	Declared capacity [kWh]x750	80%	60%	80%	ISO 12405-4:2018 Cycle-life test according to Dynamic discharge application

Discussion of requirements

- Outside temperature / weather conditions have higher impact on LEV batteries, because they have no thermal management and less "mass" (vehicle) and packaging around them. Thermal influences heavily impact ageing of batteries, thus warranties might be hard to fulfil

- Warranties can only be assessed under laboratory / benchmark conditions, since no data on real drive cycles are available
- Warranty period exceeds assumed lifetime of e-scooters and matches lifetime of other LEV applications, thus, for e-scooters a warranty period of 2 years and for the other LEV applications of 5 years seems more reasonable

Conclusion

- Influence of outside conditions too high for warranties
- Because of lack of active thermal management LEV manufacturer would have little opportunities to safeguard compliance with warranties
- Testing if warranty is fulfilled or not might be very costly in relation to LEV product value (battery cost between 200€ and 2000€), especially for e-scooter, pedelecs and e-scooters

1.3.2. Requirements for battery management system

A BMS with partially open data has multiple benefits. It would increase consumer confidence to invest in such applications, as feedback on battery status and ageing would be available. Furthermore, the resale of applications would be eased, since information on the use history would be available. In addition, it could help to support warranty claims, reduce repair costs and facilitate second life applications.

BMS allowing firmware updates would especially facilitate second use of batteries, since for the new applications manual effort such as exchanging the BMS and re-attaching cables for voltage measurements could be avoided.

Discussion of requirements

- BMS is available for all LEV and firmware updates are possible for most LEV, however, a potential firmware update, as the original firmware, has to comply with existing regulation, thus it requires a certain effort.
- Information for determination of state of health, lifetime information by statistics, general battery information etc. are hard to determine and probably not available for all LEV, since they have less sensors than EV BMS. This is especially true for e-scooters and pedelecs, while e-mopeds and e-motorcycles have several sensors.
- BMS open data diagnostics connector for second life use requires additional space, however space is very limited, especially in small LEVs. Adaptors for the existing connectors in LEVs might be a solution.
- Second life / repurposing of e-scooter and pedelec batteries might not be economically viable, due to their low battery capacities. For e-mopeds and e-motorcycles, however, there might be second life potential. With 1.5 to 16 kWh their battery capacities cover the range of residential ESS' capacities and they might also be aggregated to the dimensions of commercial ESS.
- Battery pack capacities of e-scooters and pedelecs might be too low to justify the high effort of repurposing. For some e-mopeds (e.g. $\geq$ 2 kWh) and for e-motorcycles, however, repurposing can make sense

Conclusion

- Requirements mostly applicable, but only useful for LEVs with high battery capacities of $\geq$ 2 kWh, such as most e-mopeds and e-motorcycles in general, since the battery capacity of other LEVs might be too low for second life / repurposing
- Requirements should be applied to e-mopeds and e-motorcycles

1.3.3. Requirements for information provision

To allow repair, reuse, repurposing and especially recycling of batteries, information about the battery is required. Not all of that information necessarily has to be stored per individual battery, but rather per battery model or type. The information especially concerns the material composition of batteries and thus, recycling of batteries. Batteries can be recycled more easily and with less material waste, when information on their cell chemistry (cathode and anode chemistry, electrolyte chemistry) is available. Beyond that, information on the content of recycled material including critical raw materials would be helpful. Additionally, the information is helpful, when sorting cell or modules for second life applications. That requirement could be implemented with a bar code, QR code or similar on each battery system, packs and module, with an EAN number and serial number. These numbers would be listed in a central database.

Conclusion

- Requirements applicable
- Information might be also interesting for end-user (specifications / compatibility of third-party batteries, repair in a specialized repair shop)

1.3.4. Requirements on traceability

One important aspect in the public debate on lithium-ion batteries are labour conditions and environmental impact of the extraction of raw materials for batteries. Thus, the traceability of raw materials can be set further to tracing battery modules and packs. The idea is to have serial numbers on each battery module and pack that is linked to a database tracking them. Furthermore, this database has to be linked to a material database for ethical mining.

Discussion of requirements

- Batteries of e-scooters and pedelecs have low capacities and thus, only account for a very small amount of material demand.
- The effort for tracing materials might consequently be too high

Conclusion

- Requirements applicable
- Information might be also interesting for end-user (sustainability)

1.3.5. Requirements on carbon footprint

The previous study showed that manufacturing of a battery consumes much more energy compared to its storage capacity. For some applications, that amount of energy is even bigger than the energy stored over the battery's lifetime (number of functional units). Thus, a "capacity Energy Efficiency Index" (cEEI), ratio of declared storage capacity relative to the embodied primary or gross energy requirement for manufacturing or a "functional Energy Efficiency

Index" (fEEI) as ratio between functional unit or kWh stored over its lifetime relative to the embodied primary or gross energy requirement for manufacturing could be introduced. Beyond that, information requirements on the energy sources used during battery production could be set, enabling the determination of the carbon footprint. Embodied energy and carbon footprint cannot be neglected.

Conclusion

- So far, use phase cannot be modelled accurately, due to missing data
- Only few standards for LEVs are available
- Requirements hardly applicable at the moment

1.3.6. Requirements on battery design and construction

Harmonized battery design would simplify repair, replacement, reuse and recycling of batteries. Mandatory addition of dismantling information to an open access database, an R-R-R-R index (repair, re-use, repurpose, recycle) and a mandatory DC charging/discharging interface that supports vehicle-to-grid mode (V2G) and a vehicle-to-test mode (V2test) to verify the performance and information criteria would be measures to implement these requirements. This could lead to easy assembly and disassembly standards, standardized interfaces for hardware and software, thermal interfaces, dimensions and connections etc.

Discussion of requirements

- E-scooter and pedelec battery capacities are most probably too small for V2G applications. Beyond that, DC charging is only possible for few e-motorcycles
- Especially e-scooter and pedelec batteries are already repaired, not by the OEM though, but by specialized repair work shops, thus warranty is lost.
- Due to warranty losses and feared safety risks, most end-users buy new batteries.
- Beyond that, a major problem is that decommissioned pedelec batteries, for example are currently not returned to manufacturers by customers, but kept in their possession
- Often not the battery modules but other electronics (e.g. BMS) is damaged, thus a modular design of the battery system would be favourable
- E-scooter batteries are not very maintenance friendly and at the moment, especially e-scooters in shared use, are treated as use-and-throw things with short lifetimes, which makes eased recycling necessary
- Some e-mopeds and e-motorcycles already have exchangeable batteries, thus repurposing is easier
- Already now, 50 to 70 percent of pedelec battery materials can be recovered.[11]

Conclusion

- Requirements are applicable with benefits for end-users

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[11] https://www.velototal.de/2019/08/27/second-life-f%C3%BCr-batteriezellen/

1.4. Subtask 1.4 – Qualitative impact assessment and cost-benefit-analysis

AIM OF SUBTASK 1.4:

The aim of this subtask is to analyse the implications of extending the scope and to conduct a cost-benefit-analysis (CBA), both in a qualitative manner.

1.4.1. Qualitative impact assessment

1.4.1.1. Environmental impacts

Usually, the energy consumption during the use phase of products is the most important environmental impact for products covered within the ecodesign regulative framework. However, the original study showed that for battery systems the situation is more complex. Therefore, in addition to the electricity consumption and the GHG emissions, the demand of critical raw materials will be discussed in a qualitative manner.

In accordance with the original study, the three main phases of the product will be differentiated when discussing the impacts:

- Production (raw materials use and manufacturing)
- Use phase
- End of Life

Electricity consumption

Due to the much lower battery capacity demand resulting from LEVs in comparison to EVs or ESS also the total electricity consumption of LEVs will be much lower.

This study showed lower relative electricity consumption (application service energy and resulting losses) of LEVs during the use phase in relation to the battery capacity, than EVs or ESS. Consequently, the electricity consumption during the production phase of batteries for LEVs might outweigh the electricity consumption during the use phase of LEVs. Thus, especially requirements addressing a longer utilisation of batteries, potentially in a second-life application, are promising, since they allow a better ratio of utilisation to production electricity consumption and a higher yield of the electricity employed during production. That mainly applies to BMS and battery design and construction requirements, since they enable easier repurposing.

Furthermore, because of the lower impact of the use phase, requirements such as information provision, traceability and battery design and construction, enabling easier recycling seems also more beneficial for LEVs in comparison to EVs or ESS

Greenhouse gases

Regarding the production phase, the best option to reduce greenhouse gas (GHG) emissions, as described in task 7 of the original study, is the electricity mix. Shifting to electricity from renewable energy sources can significantly decrease the GHG emissions during the production phase. A reduction of up to 99 % seems to be feasible.

A slight reduction of GHG during the use phase might be achieved with requirements for lifetime, which focus on a low internal resistance or a high round-trip energy efficiency. Warranties related to that, might also support slight GHG emissions reductions.

Material demand

Requirements that increase the recycling rates of batteries and percentage of recoverable materials, such as information provision, traceability and battery design and construction requirements have the potential to decrease the material demand.

Additionally, as already discussed, requirements extending the lifetime with regards to a second-life, result in a better yield of material effort to employable functional unit.

1.4.1.2. Socio-economic impacts

Socio-economic impacts refer to:

- Purchase costs: they are driven by the market sales and the purchase price of the battery systems.
- Running costs: only the electricity costs in the use phase are considered
- EOL costs: including the replacement costs and the decommissioning costs

The relative cost impacts of the requirements are expected to similar to those calculated in task 7 of the original study.

Lifetime requirements require extensive testing and thus, are quite cost-intensive. While information provision or carbon footprint requirements might only have minor impact on the costs, traceability requirements require a bigger effort resulting in higher costs. The latter is also true for requirements on batter design and construction.

1.4.1.3. General impacts

Regarding the impacts of a potential regulation, it has to be noted, that the LEV manufacturing industry has a different industry structure than for example the automotive industry has. While car manufacturers are big, multi-national companies, LEV manufacturers are usually small or medium-sized enterprises (SME). For the latter it is very difficult to implement a comprehensive regulation, because of limited human and financial resources. While car manufacturers and big suppliers can quite easily procure the resources for finding adequate new suppliers, reengineering a specific product or component or fulfilling new information requirements in order to be compliant with new regulations, for SMEs in LEV manufacturing that might consume a substantial amount of their resources. Furthermore, one-time costs for the implementation of a regulation can be attributed to a lot more produced units (in value but also in numbers) in the automotive than in the LEV industry.

On the other hand, one could assume, that big automotive OEM having long-term relationships with their (battery) suppliers, have more difficulties to make a quick shift to other, regulation-conform batteries more difficult than for small SMEs in the LEV industry, who can easily change suppliers.

1.4.2. Qualitative cost-benefit-analysis

In Table 8 a brief qualitative cost-benefit-analysis is carried out, summarizing the insights of this study.

It is assumed, that the costs will be added to the purchase price and thus, be paid by the customer/end-user

Table 8: Qualitative cost-benefit-analysis

	CBA LEV	
Requirements	**End-user**	**Manufacturer**
Minimum requirements for lifetime	- higher battery price - life-time and other performance criteria with lower criticality for LEVs because of lower economic lifetime and low impact of use phase - performance criteria hard to understand for end-customer + longer battery durability or fewer replacements required + beneficial for second-life utilisation, thus leading to lower impacts	- costs hard to determine, but will be noteworthy, since special meters, standards, data etc. are required - verifying minimum life cycle requirements will also entail costs - engineering and research required - high costs and duration for tests + increased end-customer trust and thus, more sales from OEM + competitive advantage with well performing batteries
Warranties	- higher battery price + longer battery durability or fewer replacements required + warranty is a known tool to the consumer, would provide the necessary trust in the product and would equally contribute to increasing lifetime of poor products + warranty also gives direct control to the consumer, empowering him further to select the right products.	- testing if warranty is fulfilled or not is very costly in relation to product value (battery cost between 200€ and 2000€) + increased end-customer trust and more sales from OEM + competitive advantage with well performing batteries
Requirements for battery management system	- higher battery price - space required for connector + warranty claims might be assessed with BMS + firmware updates improve battery performance + easier resale	- costs <5€ per battery - firmware updates also have to comply with regulation, leading to increased effort - critical information might be accessible by competitors - might lead to compliance issues + increased end-customer trust + potential improvements from big community + reduced effort for second-life application

Requirements for information provision	- higher battery price + information might be interesting for end-user (specifications, compatibility of third party batteries, own repair)	- high costs of setting up and updating database + easy distribution of data sheets and repair information
Requirements on traceability	- higher battery price + information might be interesting for end-user (sustainability and environmental concerncs) + promotion of ethically mined materials	- high costs of setting up and updating database + improved image
Requirements on carbon footprint	- higher battery price + better conscience + lower carbon footprint	o data availability is similar to initial scope
Requirements on battery design and construction	- higher battery price - new batteries might still be preferred (battery exchange for smart phones not frequently used) + repair instead of replacement is likely to cheaper + also leads to lower battery waste and new capacity demand	- high engineering effort, but quite low operational effort (screws instead of glue, sealing issues) - since battery design is closely aligned to specific application, requirements could decrease performance of batteries

1.5. Concluding remarks

There are aspects that have not be discussed in the previous section, but that are relevant for a potential regulation:

- Customers of e-scooters and pedelecs tend to keep the vehicles as well as the batteries even after their end of life, thus a regulation should address that issue, by ensuring recycling streams.
- Furthermore, safety issues are more important for LEVs, especially for e-scooters and pedelecs, since their batteries are usually charged indoor, where fire would have severe consequences

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