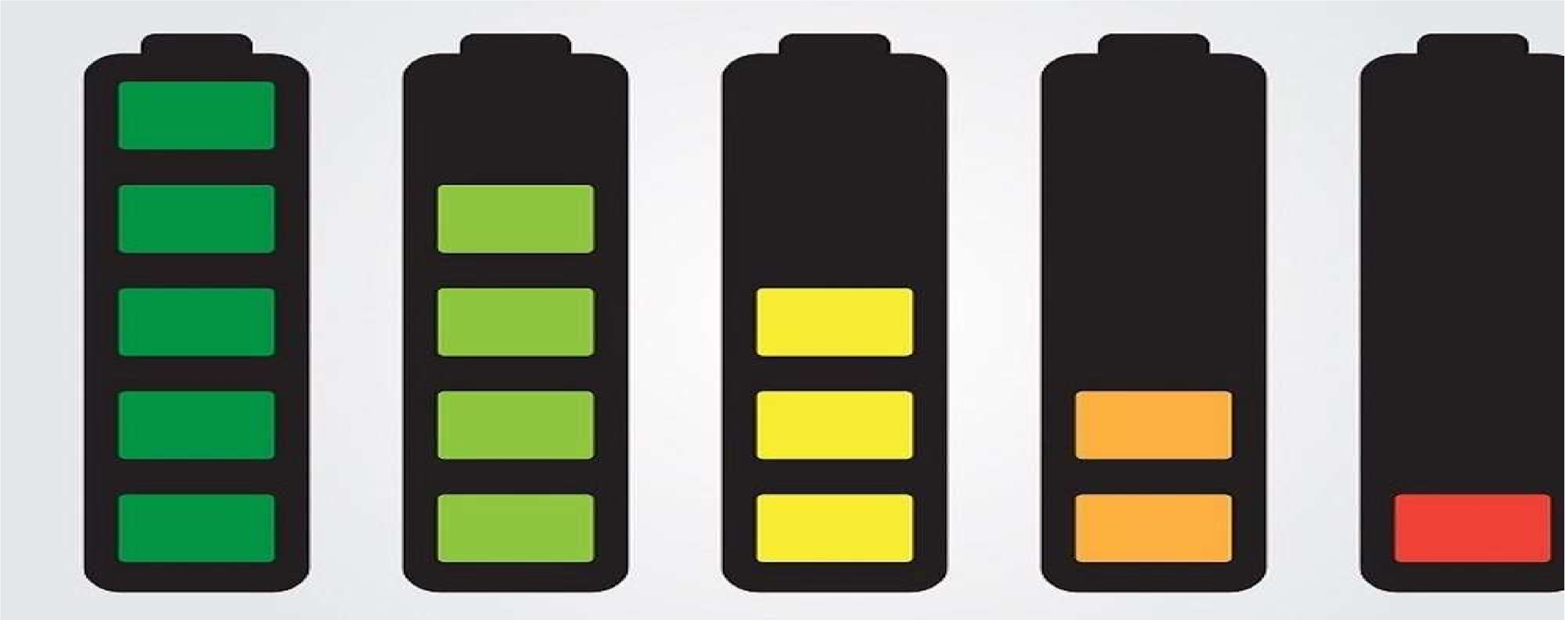

FOLLOW-UP FEASIBILITY STUDY ON SUSTAINABLE BATTERIES – STAKEHOLDER MEETING – TASK 1

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05.11.2019

AGENDA

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

1. Objectives
2. Definitions
3. Use Profiles
4. Battery & Technical Specifications
5. Market
6. Requirement Analyses
7. Cost-Benefit Analysis
8. Next Steps

TASK 1: 1. OBJECTIVES

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

- analyse to what extent **requirements** identified in the original study on performance, durability, carbon footprint, sustainability, responsible sourcing, reuse/repurpose, recycle etc. are **applicable to lighter mobility applications**
- analyse **implications of extending the scope** of an eventual regulation
- conduct **cost-benefit-analysis** and analyse enforcement and **verification issues**

TASK 1: 2. DEFINITIONS

Definitions of Electric Scooters, Bicycles, Mopeds and Motorcycles (Light E-Mobility Vehicles (LEV))

E-Scooter

- Single occupancy
- No human power required for driving, but for starting
- Country-specific requirements
- Max. 20-25 km/h
- **Battery: ca. 0.2 – 1.2 kWh**

E-Moped

- Max. two persons
- No human power required
- Country-specific requirements (2-3 wheels)
- Max. ca. 45 km/h
- **Battery: ca. 1.5 – 4.8 kWh**

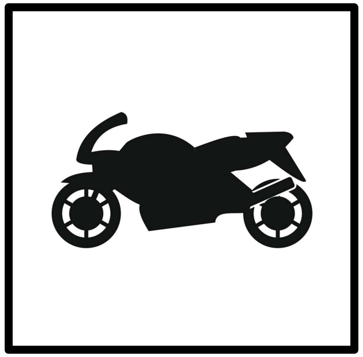
Source: https://icon-library.net/icon/moped-icon-20.html

Pedelec

- or Electrically power assisted bicycle (EPAC)
- Single occupancy
- Electric engine supports human power up to 25 km/h
- Dealt with as usual bicycles
- **Battery: ca. 0.3 – 1.3 kWh**

E-Motorcycle

- Max. two persons
- No human power required
- Country-specific requirements (2-3 wheels)
- **Battery: ca. 4.0-15.5 kWh**



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

Sources: https://www.radfahren.de/service/e-bike-akku/, https://www.auto-motor-und-sport.de/tech-zukunft/alternative-antriebe/marktuebersicht-elektro-tretroller-e-scooter-im-schnell-check/, https://www.spiegel.de/auto/aktuell/e-scooter-oder-e-tretroller-wie-denn-jetzt-a-1274754.html, https://www.adac.de/rund-ums-fahrzeug/tests/elektromobilitaet/e-roller/, https://www.zeromotorcycles.com/zero-ds/

TASK 1: 3. USE PROFILES

Use profiles of Electric Scooters, Bicycles, Mopeds and Motorcycles

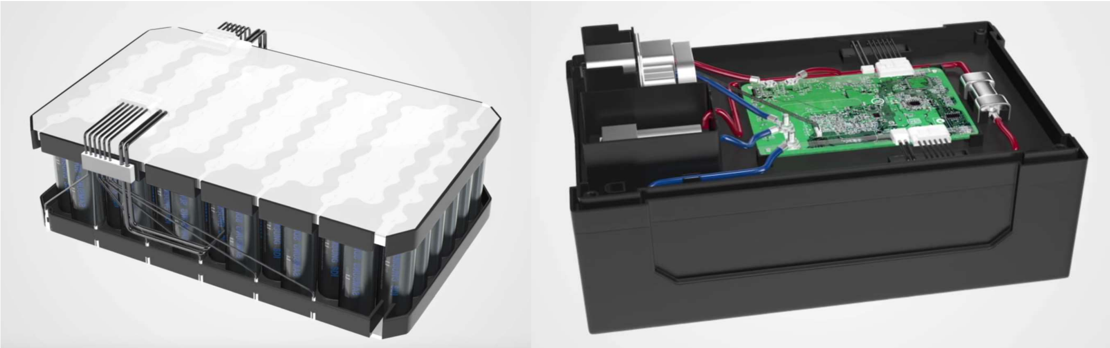
Vehicle	Annual mileage [km]	Source of data	Assumptions made
E-Scooter	Average: 2.360 Shared use: 3.326 Private use: 1.395	Tack et al. (2019)	Private use: 3.1 trips per day (as in MiD 2017), 2 km per trip (as in shared use), 5 days per week and 45 weeks per year
Pedelec	1.392 [1.004; 1.804]	Castro et al. (2019)	
E-Moped	Average: 8.695 Shared use: 14.600 [7.300; 21.900] Private use: 2.790		Private use: 3.1 trips per day (as in Nobis and Kuhnimhof 2018), 4 km per trip (as in shared use), 5 days per week and 45 weeks per year
E-Motorcycle	7.800	Williams et al. (2017); Delhaye and Marot (2015a/b)	

Battery types and cell chemistries:

- nickel metal hydride (NiMH)
- sealed lead acid batteries (SLA)
- **lithium ion battery (LIB)** -> lithium-manganese-nickel-cobalt (NMC) or lithium-iron-phosphate (LFP)
- ➢ comparable to original study

Components

- cylindrical cells with BMS
- mostly updatable firmware
- ➢ comparable to original study



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

- no thermal management
- ➢ contrast to original study
- ➢ higher impact of outside conditions

TASK 1: 4. TECHNICAL SPECIFICATIONS

data input?

	Unit	E-Scooter	Pedelec	E-Moped	E-Motorcycle
Economic lifetime of the application	a	3	10	20	20
Annual vehicle kilometres	km/a	2.360	1.392	8.695	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	32	60	80	112
Maximum DOD (stroke)	%	80%	80%	80%	80%
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	15,5
Battery calendar life (no cycling)	a	10	10	20	20
Battery cycle life (no calendar aging)	FC	1.000	1.000	1.500	1.500
SOC @ EOL	%	60%	60%	60%	60%

data input?

TASK 1: 4. TECHNICAL SPECIFICATIONS

$$AS = Lifetime\ application * annual\ VKT * energy\ consumption * (1 + recovery\ braking)$$

$$\mathrm{FU} = Typical\ battery\ capacity\ application * DOD * Cycle\ life$$

Application Service Energy (AS)	**kWh**	**85**	**134**	**8.347**	**18.720**
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)	-	0,3	0,3	1,7	1,1
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**	**9,6**	**33,6**
Charger efficiency AC	%	?	?	?	?
Charge power AC	kW	?	?	?	?
Charger efficiency DC	%	?	?	?	?
Charge power DC	kW	?	?	?	?
Share AC charge	%	100%	100%	95%	80%
Energy consumption charger energy efficiency	**kWh**	**28**	**42**	**415**	**1.424**

TASK 1: 5. MARKET

data input?

Market of E-Scooters

Database

- New phenomenon, scare availability of historical and actual data
- Only some data on status-quo in some major and smaller European cities
- Selection of countries with differences in geographical region, cultural patterns etc.
- Germany, Sweden, Spain, Switzerland, Region Eastern Europe

Projection approach

- Establishment of European country clusters e.g. highly multimodal countries, medium, low
- Identification of cities > 250 000 and cities > 800000
- Estimation of number of E-Scooter via inhabitants and density
- Death rate and thus, replacement rate according to estimated life-time

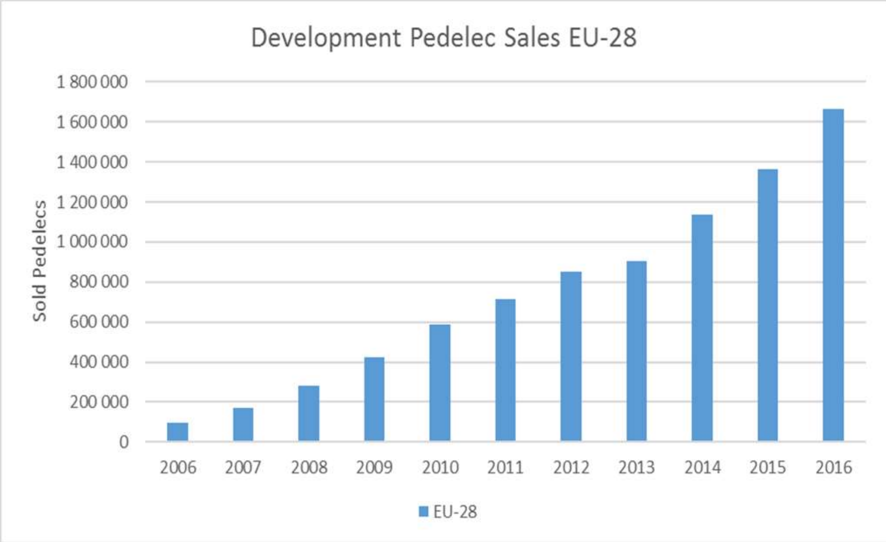
Assumptions

- Differences in diffusion in European regions
- E-Scooters only in urban areas
- Saturation at actual density rate of pilot cities
- Projected dissemination across all cities > 250 000 inhabitants

TASK 1: 5. MARKET

data input?

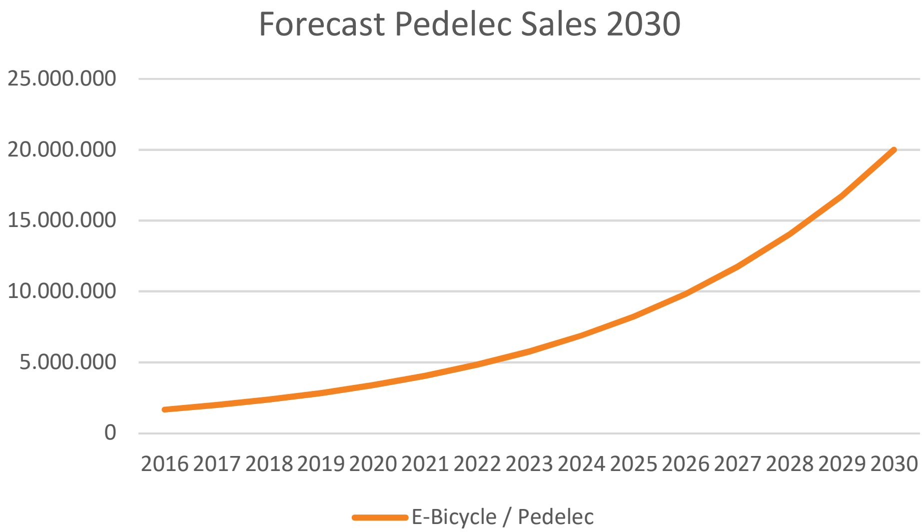
Market of Pedelecs



http://www.conebi.eu/wp-content/uploads/2018/09/European-Bicyle-Industry-and-Market-Profile-2017-with-2016-data-update-September-2018.pdf

Figure 2: Conventional bike sales

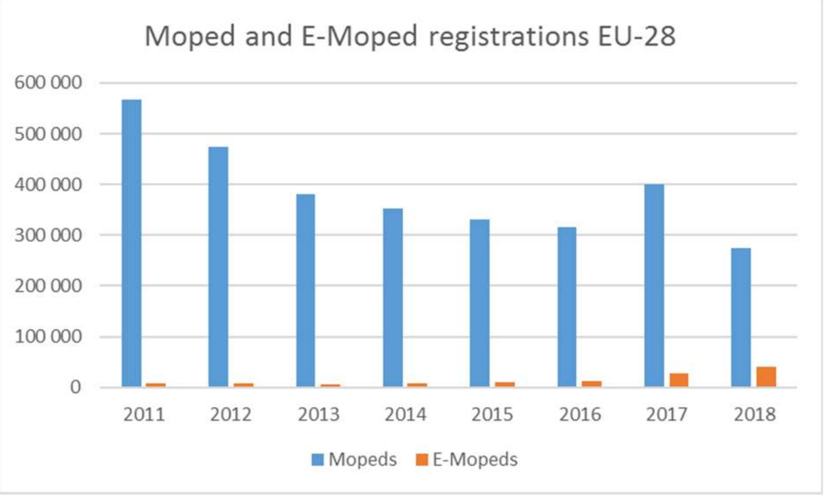
https://ecf.com/news-and-events/news/what-would-happen-if-we-prioritised-cycling



- Saturation at 100 % (→ 60 %) pedelec ownership rate (in relation to total bike market) among Europeans, economic lifetime of 5-7 years

data input?

Market of E-Mopeds



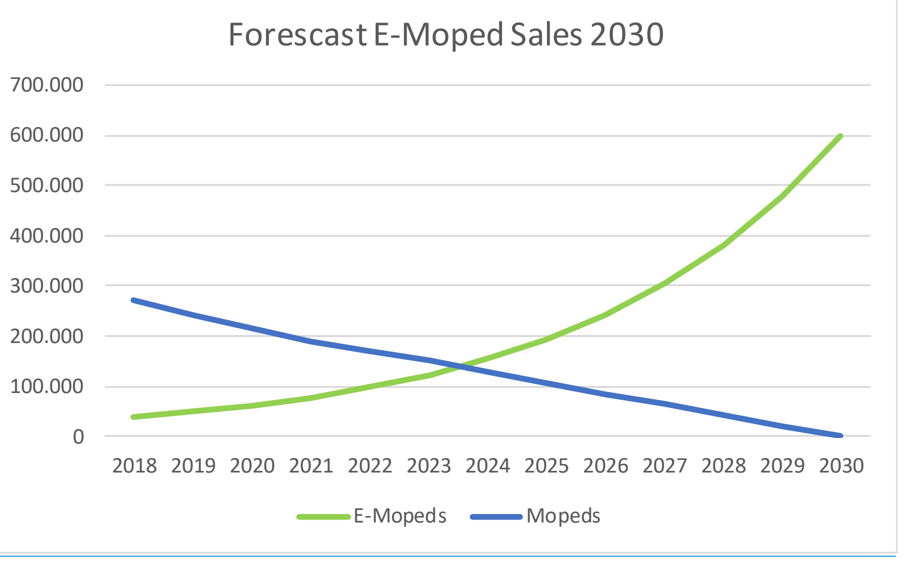
ACEM CIACEM database

Forecast

- High expectation towards E-Mopeds to retrieve historic registration numbers
- Rising relevance as a transport mode, especially in urban areas

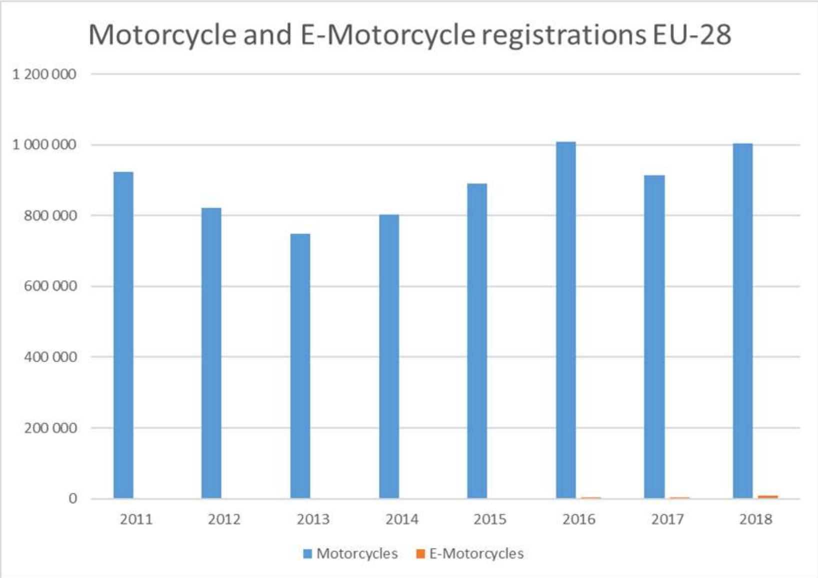
Projection approach

- Rising trend in moped sales: back to 600 000 mopeds per year in total
- Quick diffusion of E-mopeds: 100% of registrations electrified in 2030



data input?

Market of E-Motorcycles



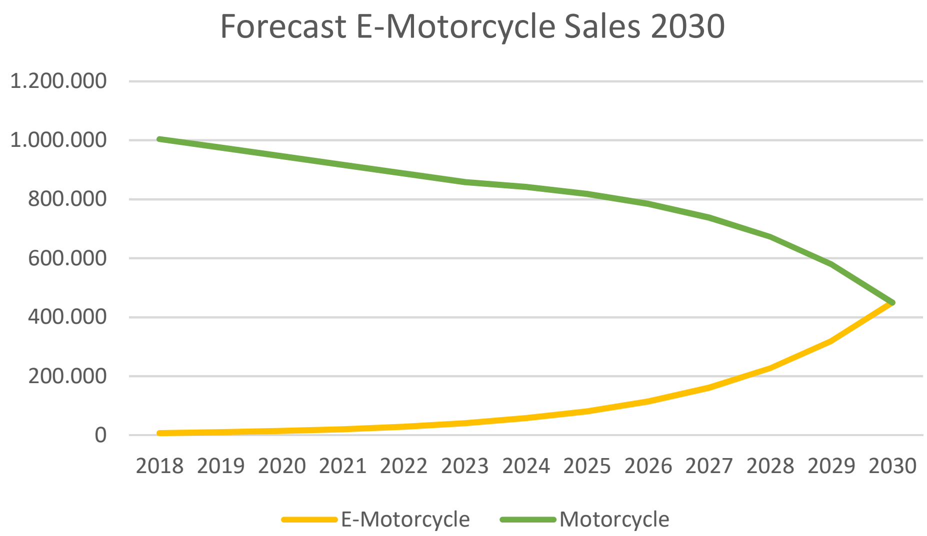
ACEM CIACEM database

Forecast

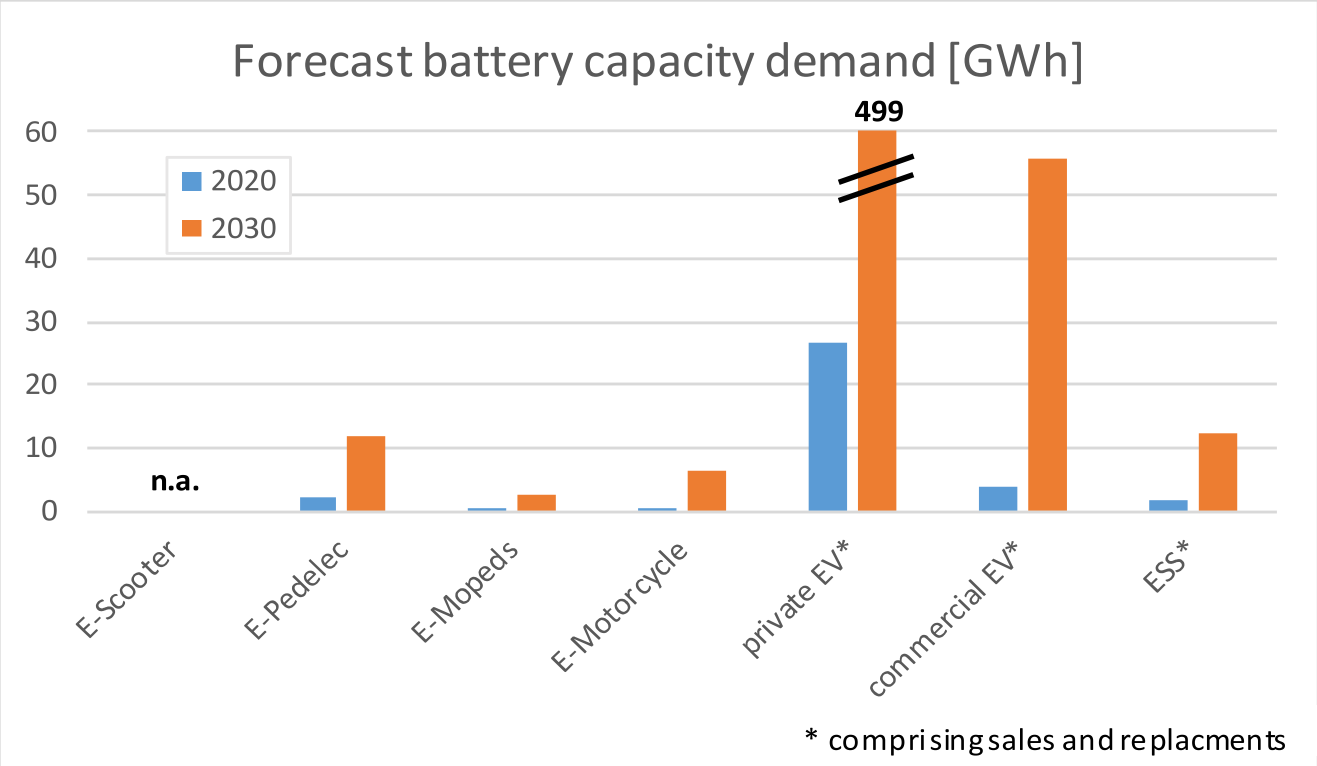
- • Motorcycling plays big role as a hobby, fascination driving, but also as means of daily transportation

Projection approach

- Registration of motorcycles constant at around 900 000 (no rise due to subordinate role in future urban mobility)
- Slow diffusion of E-Motorcycles: 50 % of registrations electrified in 2030

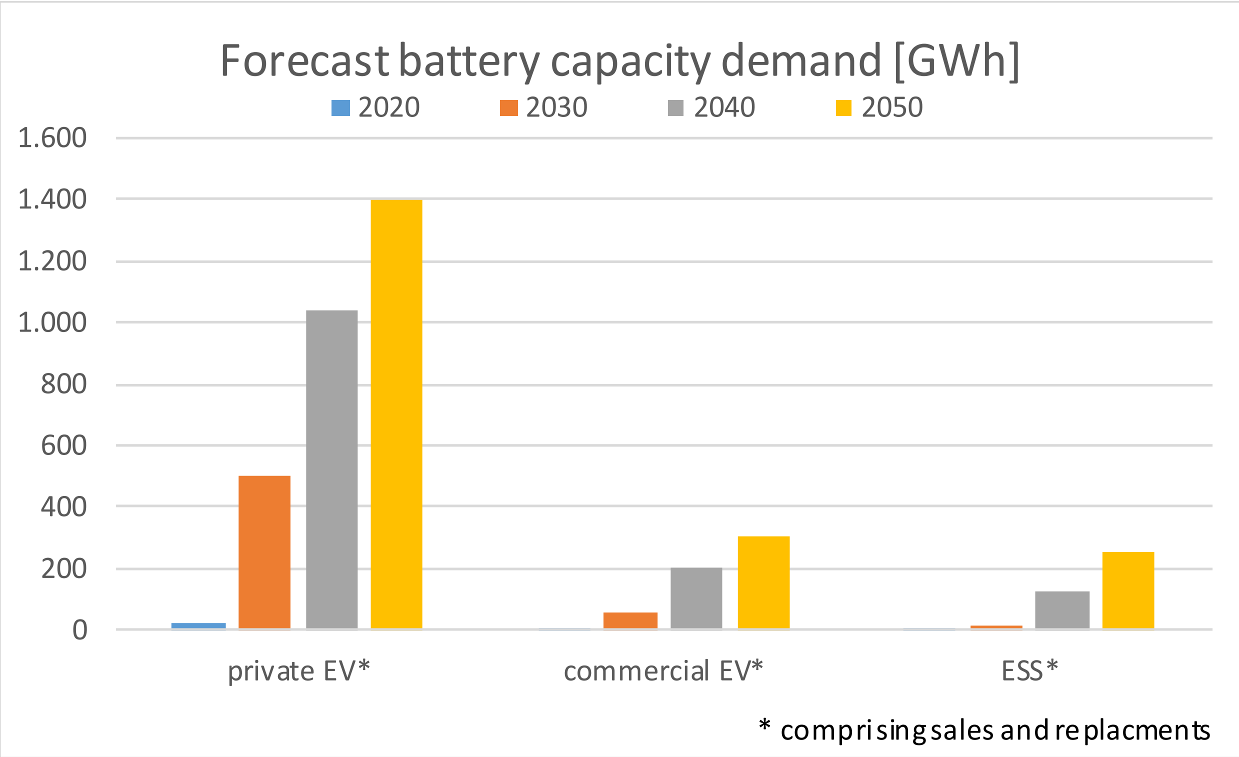


Battery capacity demand resulting from light e-mobility applications



TASK 1: 5. MARKET

Battery capacity demand resulting from light e-mobility applications



TASK 1: 6. APPLICABILITY OF REQUIREMENTS

feedback?

Proposed requirements		type of requirement applicable to LEV in general
Minimum battery pack/system lifetime requirements	minimum requirements	yes • Test standards to be developed for some parameters / applications
	warranties	no • 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
Requirements for battery management systems		yes • BMS available for all LEV and firmware updates possible for most LEV • Information for determination of State of health, lifetime information by statistics, general battery information etc. hard to determine and probably not available for all LEV, since they have less sensors than EV BMS • BMS open data diagnostics connector for second life use not required, since EOL of LEV batteries is lower compared to EV, so that no second life / repurposing seems realistic for LEV batteries • Furthermore, battery pack capacities of E-Scooters, Pedelecs and E-Mopeds too low to justify high effort of repurposing

TASK 1: 6. APPLICABILITY OF REQUIREMENTS

feedback?

Proposed requirements	type of requirement applicable to LEV in general
Requirements for providing information about batteries and cells	yes • Quite small amount of materials per battery systems
Requirements on the traceability of battery modules and packs	yes • Quite small amount of materials per battery systems
Specific requirements for carbon footprint information and considering the option for a threshold	yes/no • So far, use phase cannot be modelled accurately, due to missing data for all LEV • Only few standards for LEVs are available
Other minimum battery pack design and construction requirements to support reusability/recyclability/recoverability including a R-R-R-R index	yes • LEV battery capacities too small for V2G and for most LEVs DC charging no issue • Especially E-Scooter and Pedelec batteries are already repaired, not by the OEM though, thus warranty is lost. • 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-Scooters are not very maintenance friendly • E-Mopeds and E-Motorcycles already have exchangeable batteries

TASK 1: 7. COST BENEFIT ANALYSIS

feedback?

Requirements	End-user	Manufacturer
Minimum Requirements for lifetime	- higher battery price + longer battery durability or replacement	- costs hard to determine, but will be noteworthy - engineering and research required - high costs and duration for tests + increased end-customer trust and more sales from OEM + competitive advantage with well performing batteries
Warranties	- higher battery price + longer battery durability or replacement	- 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 - critical information might be accesible by competitors + increased end-customer trust + potential improvements from big community

TASK 1: 7. COST BENEFIT ANALYSIS

feedback?

Requirements	End-user	Manufacturer
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)	- high costs of setting up and updating database + improved image
Requirements on carbon footprint	- higher battery price + better conscience	- likely exessive engineering and operational cost (>500 K/model + >50 €/unit)
Requirements on battery design and construction	- higher battery price + repair instead of replacement is a lot cheaper	- high engineering effort, but quite low operational effort (screws instead of glue, sealing issues)

TASK 1: 8. NEXT STEPS

1. improve market analysis and forecasts
2. conduct deeper cost benefit analysis
3. **integrate stakeholder feedback and data**

Sources: