The Potential of Light Electric Vehicles for Climate Protection through Substitution for Passenger Car Trips - Germany as a Case Study

Final Report of the LEV4Climate Study

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Content

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Motivation

Source:
Free photo Busy Road Traffic Street Berlin Germany City - Max Pixel (CC0), 04.03.2022

Introduction

Situation and Problem

Limiting the extent of climate change is among the greatest challenges facing humanity in the coming decades. Impacts of global warming might result in a crisis unprecedented in human history. Greenhouse gas emissions in many sectors must be drastically reduced worldwide. In this context, global emissions from transport are among the highest and fastest growing of any sector, and so it is one in urgent need of new concepts for transformation.

Source:
smoke coming out from pipe photo – Free Grey Image on Unsplash, 08.03.2021

Source:
cars on road during daytime photo – Free 中包公寓 Image on Unsplash, 08.03.2021

Possible Solutions

Significant reductions in greenhouse gas emissions in the transportation sector require changes in transport behavior, supported by technological progress and resource-saving vehicles. Replacing large and heavy vehicles with very small and light electric vehicles (LEVs) addresses the latter. LEVs have a more favorable weight to payload (passengers or goods) ratio and, in addition to low vehicle weight and small frontal area, the efficiency of electric propulsion minimizes energy consumption during operation. In contrast to large and heavy passenger cars, the traction batteries in LEVs could be considerably smaller, so that the consumption of critical raw materials is also reduced, thus lowering production-related greenhouse gas emissions.

Need for scientific investigation

While there is extensive research on new powertrain technologies for passenger cars, fewer studies are devoted to the question of how passenger cars can be replaced by more ecological vehicles. Despite their promising properties, LEVs currently still lead a niche existence on the market, in research, and on the political agenda. Fundamental questions remain unanswered including:

To what extent might LEVs reduce greenhouse gas emissions? How much CO_{2eq} might be saved?

This study is a first step which sets the ground for future work evaluating approaches and obstacles to realising the emissions-reduction potential of LEVs.

Source:
DLR

What is a Light Electric Vehicle and which Kind are available today or soon?

The market offers a rich variety of vehicles - from electric scooters to 4-wheelers. There are models with top speeds over 100 km/h, with and without cabin, with no, one, two or more seats and with different requirements in terms of age and driver's license possession. The graphics show examples of a wide range of LEVs.

Sources: source in each case is the manufacturer indicated on the picture, except for
Citroen: https://commons.wikimedia.org/wiki/File:Citro%C3%ABn_Ami_2020_(2).jpg
And Aixam: https://commons.wikimedia.org/wiki/File:Aixam_e-Coupe,_Paris_Motor_Show_2018,_IMG_0219.jpg

Goal and Scope of the Study – to what Extent can Light Electric Vehicles reduce Greenhouse Gas Emissions from the Transport Sector?

Light electric vehicles can reduce greenhouse gas emissions by replacing large and heavy vehicles. Emissions decrease for replacement of passenger cars with any type of propulsion, albeit to different extents. In order to quantify the theoretical potential of emission reduction, this study models a scenario in 2030, in which a major modal shift away from trips with full-sized passenger cars to LEVs has taken place. This analysis assumes today’s patterns of mobility are maintained, but using full sized cars only for those few trips which are very long or include many occupants. The work employs Germany as a case study for potential savings, given the national importance of cars as both a means of mobility and an economic sector.

Statistical data from a representative national survey serves as the basis for analysing which car trips can be substituted with LEVs. We use the characteristics of vehicles (e.g. speed, range, number of seats) and trips (e.g. distance) to determine which trips may be conducted in LEVs, and thus derive a total for substitutable car kilometers. Together with an assessment of greenhouse gas emissions per vehicle kilometer for both LEVs and the replaced vehicles (considering production via life cycle analyses and energy for vehicle use), a theoretical, calculative potential of greenhouse gas emissions savings is derived for Germany.

This analysis therefore quantifies the theoretical potential that LEVs offer for decreasing greenhouse gas emissions, underlining that further research in this area may be rewarding. Clearly, realising any of this potential requires applied measures to encourage the switch to them from full sized cars. Future work should therefore focus on what those measures may be including consideration of user acceptance and mode choice preferences.

Graphic: DLR

What is the Impact of Transport on Climate Change - how can it be mitigated?

Transport and climate change

Worldwide, transport is the source of around 16-27 % of greenhouse gas emissions*. In Germany, transport is responsible for 20 % of the national greenhouse gas emissions and therefore is one of the most significant drivers of climate change**.

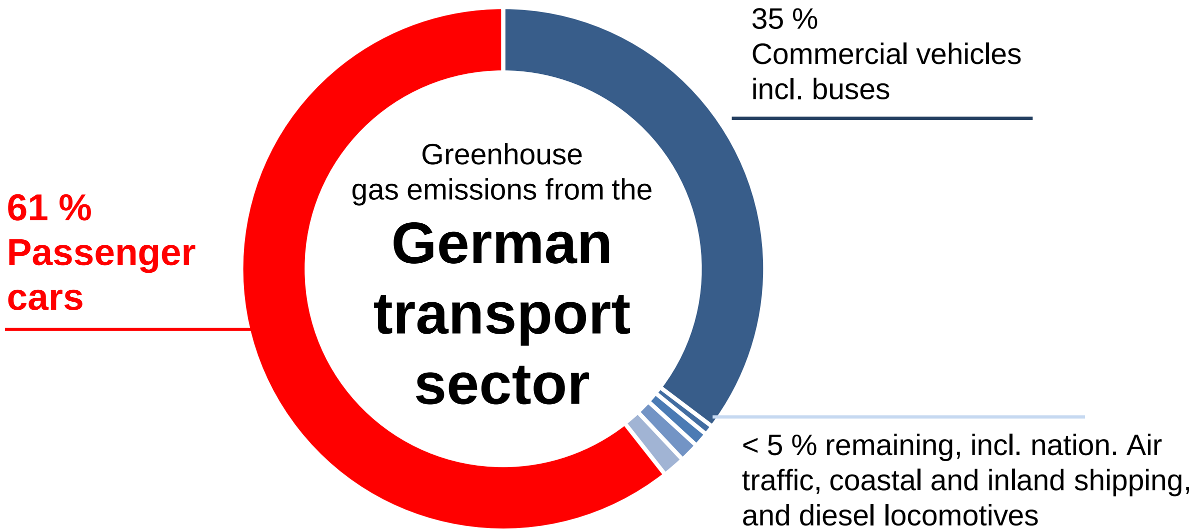
Trips with passenger cars cause 61 % of these transport emissions. This considerable share offers large potential for reductions.

Reduction of transport emissions

For effective climate protection in transport, many approaches must work together - the most effective is to avoid motorised traffic. In addition, trips can be shifted from motorised individual transport to more sustainable modes such as public transport and vehicles can themselves be engineered to use the fewest resources. Part of this approach to becoming more sustainable is to reduce the size and weight of the vehicles we use.

Avoid – Shift – Improve

This study explores the thought experiment of maintaining existing mobility patterns in Germany whilst applying the third of those approaches. For effective climate protection, all three of the above-mentioned solution approaches will have to be applied together.



graphic:
DLR based on UBA 2018
without CO_2 from biofuels

Profound changes are necessary to make mobility sustainable. If we miss climate protection targets, changes will also be profound.

* World Resources Institute 2020, IEA 2020
** UBA 2018

If Vehicles go entirely electric, will total Energy Consumption matter?

Electric cars cause fewer greenhouse gas emissions than those with internal combustion engines, even including production emissions, but wholesale conversion to electric mobility creates other problems:

- Total electricity demand grows with the switch away from fossil fuels.
- Further expansion in renewable generation capacity is required (45% of German electricity came from renewables in 2020*).
- The generation, transmission and storage of electrical energy itself consumes critical materials.
- The resources required are limited and their extraction often associated with environmental pollution and human rights violations.

This study looks at both the greenhouse gas emissions caused by the operation of vehicles and those caused by their production, including battery production. In the case of electric cars and LEVs, different sources, both fossil and renewable, of the electrical energy required for operation are taken into account.

source: Rr2000 (wikimedia)

source: Diego Delso (wikipedia)

Minimum absolute consumption and maximum energy efficiency are also relevant with renewable energy.

*UBA 2021

How do People move today - what are Characteristics of today's Car Trips?

The car is still the dominant means of transport in the everyday lives of Germans. In most cases, only one or two persons are in the car and the distances traveled are often short*:

Average occupancy rate

1.4

per car

57%

of all trips and 75 % of all person kilometers are made by car

80%

of trips under 20 km

98%

of all trips are shorter than 100 km

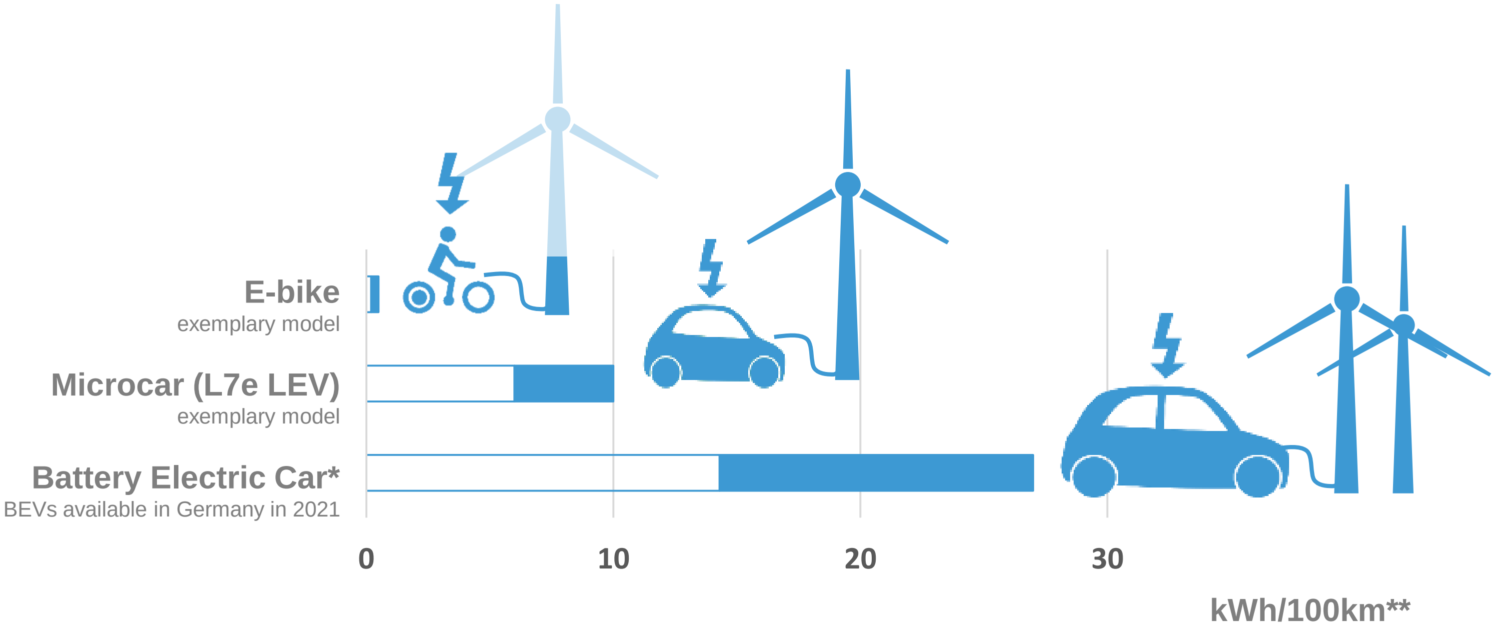
Correlation of emissions, mileage & trips

Greenhouse gas emissions attributed to vehicle propulsion are proportional to the number of vehicle kilometers, not to the number of trips. Thus, few long trips cause a relatively high share of emissions. Nevertheless, short to medium distance trips account for the majority of vehicle kilometers and hence also emissions:

- 60 % of passenger car mileage results from trips under 50 km*
- 75 % of passenger car mileage results from trips under 100 km*

* All Data: BMVI, n. d.

Why could Trips with LEVs be more sustainable than with Passenger Cars?

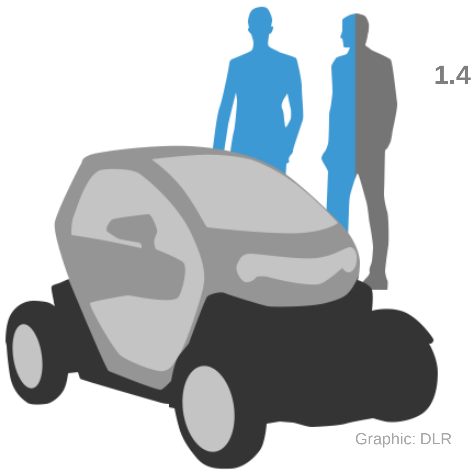


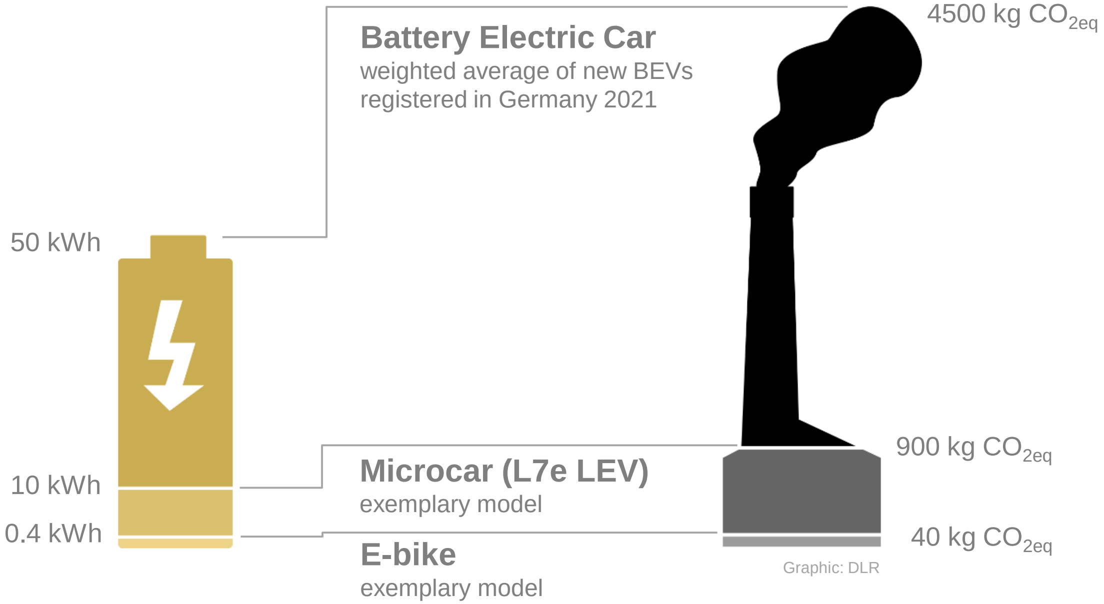
Lower energy consumption – fewer power plants

Lightweight design not only saves material, but also reduces energy demand for propulsion. A ‘heavy category’ 4-wheel LEV (Microcar, L7e) consumes 30-80 % less energy than a battery electric vehicle (depending if a small/large LEV is compared with a small/large car), albeit at lower top speeds**. So, for example, only half as many wind power plants are needed to generate the propulsion energy.

* BEV models available in Germany in 2021, WLTP combined w/o 5 % and 95 % percentiles, based on data from KBA and ADAC.
**Energy consumption is based on different driving cycles, e.g. urban ECE-15, WLTP.

Why could Trips with LEVs be more sustainable than with Passenger Cars?





Lightweight vehicles - high efficiency, less critical material

An exemplary „heavy“ 4-wheel LEV weighs around 500 kg. Average passenger payload in Germany is around 108 kg (1.4 persons per car)*. An average new car in Germany in 2020 weighs > 1600 kg.**

Efficiency of movement is broadly correlated with vehicle weight. However, main purpose of a vehicle is to move a payload - passengers and objects – not the car itself. As LEVs don't need much energy for moving the vehicle itself, LEVs are much more efficient than passenger cars.

Batteries

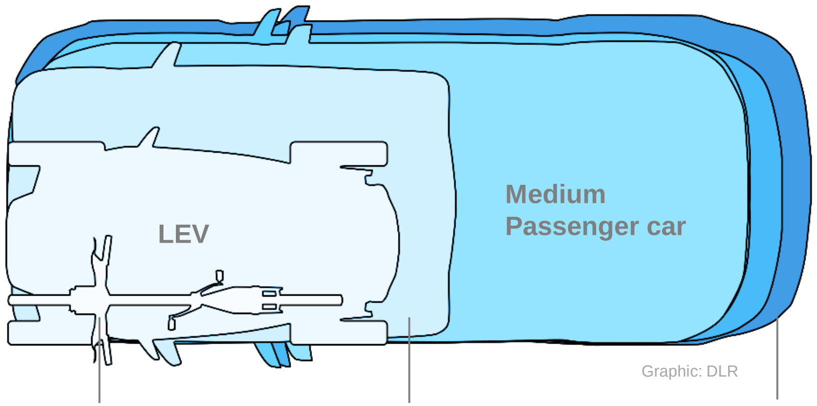
Due to the low amount of energy that LEVs need for propulsion, batteries can be small and hence production requires fewer critical raw materials. In addition, small batteries cause fewer production-related greenhouse gas emissions than large batteries: as greenhouse gas emissions increase proportionally with battery size (around 40 kg to 140 kg CO_{2eq} per kWh***), LEVs have an ecological advantage over heavier passenger cars with large batteries.

* Average weight of persons over 18 in Germany: 77 kg (GBE Bund, 2017) , average occupancy rate of passenger cars in Germany: 1.4 persons (BMVI, n. d.)
** KBA 2021
***depending on the supply chain (Kelly 2020)

Beyond Ecological Aspects – what other Advantages do LEVs offer?

Smaller footprint liberates space

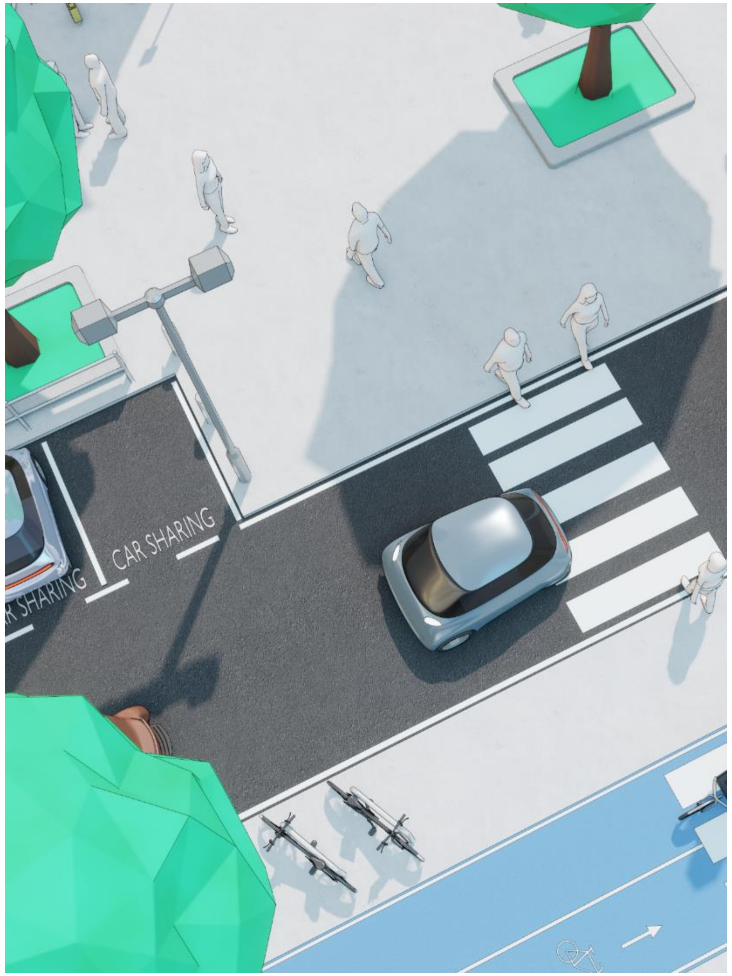
Space is a finite resource, especially in urban areas. Various categories of LEV occupy fractions of the area taken up by the average passenger car. This liberates space that be put to alternative uses.



Graphic: DLR

Need for research

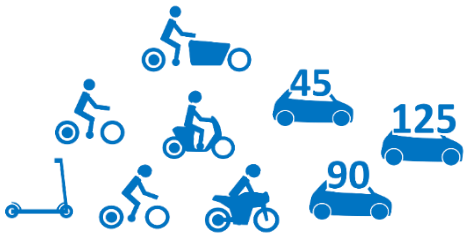
LEVs offer numerous benefits and can be part of more sustainable mobility. Currently, however, they are not widely deployed. Through research, issues such as customer acceptance, regulation, infrastructure measures, and safety can be better understood and solutions to remaining challenges can be created.



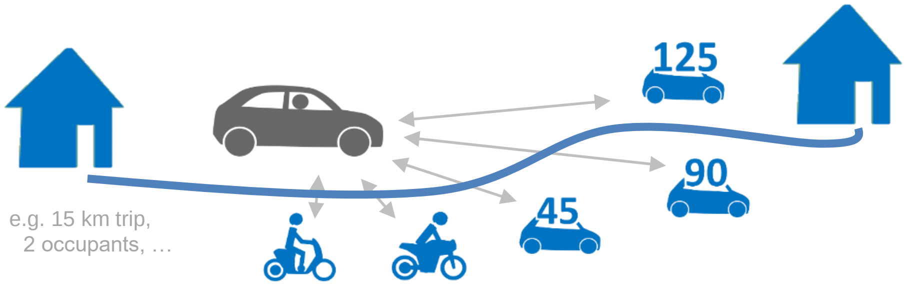
Graphic: DLR

LEV4Climate Study Settings

Modelling Approach for Calculating the Emission Reduction Potential

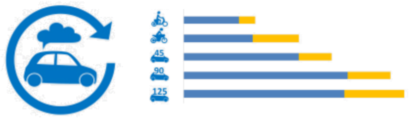


Which LEVs are considered?
Definition of exemplary set of LEVs and analysis criteria for trip substitution

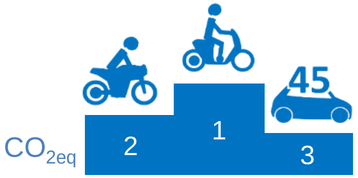


Which car trips can be substituted with which LEVs?
Analysis of passenger car trips reported in a representative national travel survey on an average day regarding substitutability with LEVs (Germany)

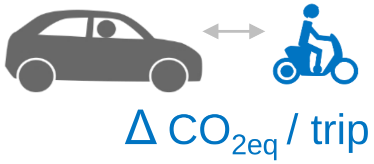
How many trips / vehicle km can be substituted?
Amount of substitutable trips and according vehicle mileage



How much are the life cycle emissions per LEV type?
Determination of CO_{2eq} emissions of LEVs and passenger cars



Which LEV suitable for trip substitution has the lowest emissions?
If several LEVs are suitable for trip: choice of the LEV with lowest CO_{2eq} emissions



How many CO_{2eq} can be saved per trip?
Difference of CO_{2eq} emissions between an average car and an LEV trip (emissions per km times trip length, 2030 scenario, Germany)

How many $CO2_{eq}$ can be saved?
Calculation of overall CO_{2eq} emission saving potential per trip, aggregation of all trips, upscaling for one year for Germany

Modelling Framework

Scope: Germany

LEVs: exemplary set of 2-, 3- and 4 wheel LEVs based on existing models, conservative estimation of technological developments for 2030 scenario

Assessment of trip substitution potential:

- **Analysis of** conventional personal motorised transport - **passenger car* roundtrips** (no min. length, all trips > 0 km considered)
- Multimodal trips: LEVs may replace a passenger car or a motorcycle
- **One passenger car will not be replaced by several LEVs** (in case of several persons travelling together)
- **No charging on round trips**: range of LEVs must match round trip length (roundtrip: may consist of several single trips, e.g. outward / return)
- Motorway use: if the average speed of a trip exceeds 100 km/h, it is assumed the trip includes motorways and hence the max. design speed of a substituting LEV must be ≥ 60 km/h (requirement for motorway use in Germany).
- Substitutable distance: introduction of a "relevant travel distance" per LEV category. The relevant travel distance defines a trip length that is well rideable with a respective LEV based on literature and expert assessments. It is shorter than the technical electric range.

Assessment of emission reduction potential:

- **Replaced passenger cars: weighted averaged emission factor based on a technology mix of passenger cars in 2030** (including gasoline and diesel vehicles, battery electric vehicles, plug-in hybrid electric vehicles, fuel cell electric vehicles, compressed natural gas vehicles)
- **Production and use considered (end-of-life excluded) for LEVs and passenger cars**
- For LEV production generic material composition is used
- **Calculation of reduction potential for one average day** based on representative survey, **upscaling for one year**
- Electricity mix for vehicle operation: well to wheel scenario for Germany 2030, based on literature
- Processes for vehicle production: ecoinvent database and literature
- The service life of the vehicle battery is assumed to be the same as the service life of the entire vehicle

- **Changes in mobility behavior, social changes, as well as political measures are not modelled**.
- **The study does not examine whether individuals would be willing to replace their car and whether an LEV is suitable for all journeys made by a person in a year.** Assumption: in the 2030 scenario there will be solutions for non-substitutable trips (e.g. modal shift, car sharing, car rental).
- LEV properties: exemplary, representative average values unavailable due small sales numbers, diversity of models and limited statistical data.

* In addition to cars, motorcycle trips are evaluated (very low share). As motorcycles account for only 1.4% of emissions (source: EEA 2021, GHG Emissions for Germany (Database)), they are not considered for emission calculation

Methodology – Choice of Categories and exemplary Models for the Analysis

A fleet of exemplary LEV models forms the basis for deriving the potential of LEVs to replace car trips and the associated greenhouse gas emission savings. The exemplary models were selected as follows.

What type of vehicles were analysed for defining the vehicle set used for modeling?

A market analysis and comparison of the technical parameters of a multitude of LEV models forms the basis for the selection of the vehicle set. The analysis includes series models that are available on the market, models with announced sales launch for 2022 and models that have been tested in pilot projects. The market analysis included electric scooters and electrically assisted bicycles as well as 2-, 3- and 4 wheelers as defined in Regulation (EU) No 168/2013.

What were the criteria to choose LEV categories and exemplary models?

The selection process aimed for:

- A broad spectrum of properties and capabilities capable of satisfying a full range of use cases and thus offering a high trip substitution potential
- Choices that overall capture the differences between LEV categories and models
- Limiting the number of selections to maintain an achievable modelling effort leading to comprehensible and memorable results
- Models with low CO_{2eq} expected emission values, e.g. having a battery capacity corresponding to a required range, and not significantly higher

As a result, selected vehicles differ significantly regarding maximum speed, range, seating capacity, number of wheels and weather protection and wherever possible, they have relatively small batteries.

Does the analysis consider all kind of LEVs?

The market offers a large variety of LEV models, that are very diverse regarding target group, intended application, design and technical features. In order to support clarity of the results and in view of the objective of the study - namely to derive a basic potential for LEVs compared to passenger cars - the number of LEV categories is limited. The selection of vehicles was made after careful consideration and includes a broad spectrum, but not all possible forms of LEVs. The selection does not make any statement about the potential market success of individual categories. For example, there are very interesting bicycle models for people with physical limitations that are not integrated here and that further expand the potential.

Selected LEV Categories

Regulation (EU) No 168/2013*

E-scooter	E-bike	E-bike+	L1e	L1e	L3e	L5e	L6e	L7e

E-scooter	E-bike	E-bike+	Speed Pedelec	Moped	Motorcycle	Microcar 125	Microcar 45	Microcar 90

The number behind the name indicates the top speed of the exemplary model. The maximum design speed is limited by law to 45 km/h for category L6e, to 90 km/h for category L7-e** and is not limited for category L5e.

For each category, an exemplary LEV model that is (soon) available on the market serves as basis for definition of technical parameters. Most parameters such as weight, technical electrical range, seating capacity etc. are used for the analyses without adjustments. With regard to the modeling of a scenario for the year 2030, an increased lifetime mileage resulting from technological progress is assumed. Although it can be expected that other technical parameters may also improve, these were left at the current level in order to make a conservative estimate.

*Regulation (EU) No 168/2013 on the approval and market surveillance of two- or three-wheel vehicles and quadricycles, See attachment
** depending on sub-categories

Characteristics of the LEVs included in the analysis

	Exemplary LEV model max. speed		unit	E-Scooter 20 km/h	E-bike 25 km/h	E-bike+, 25 km/h	Speed Pedelec 45 km/h	Moped 45 km/h	Motorcycle 120 km/h	Microcar 45 45 km/h	Microcar 90 90 km/h	Microcar 125 128 km/h
Trip substitution criteria	Relevant travel distance	- One way	km	4	15	15	30	30	45	40	70	70
		- Round trip	km	8	30	30	60	60	90	80	140	140
	Number of occupants		-	1		1 + 3 children (up to 7 years)	1	2 (excl. children < 10 years); no accompanied shopping trips		2		3*
	Trip purposes (suitability)		-	All, excl. shopping / accomp. / some professional trips**	All, excl. accompani-ment / some shopping and professional trips***	All (accomp: children), excl. some shopping and professional trips***	All, excl. accompani-ment / some shopping and professional trips***	All, excl. some shopping and professional trips***				
	Street category		-	excl. highway					All	excl. Highway	All	
	Max. age of driver		years	18-70						18 - 99		
	Weather conditions		-	All, without heavy rain, snowfall, or icy roads						All conditions		
	Impairments (suitability)		-	none						Walking impairment		
Input $CO2_{eq}$	Technical electr. range (nomin.)		km	65	120	70	70	100	130	110	200	256
	Battery capacity		kWh	0.6	0.4	0.4	1.2	2.7	8.5	6.1	14.4	25
	Weight (incl. battery)		kg	20	25	51	29	100	231	440	571	454
	Energy consumption		kWh/100 km	0.8	0.3	0.6	1.7****	2.7	7.7	5.5	7.2	10.0
	Lifetime mileage		km	16,000	50,000	50,000	70,000	70,000	100,000	70,000	160,000	160,000

* for trip purpose shopping limited to 2

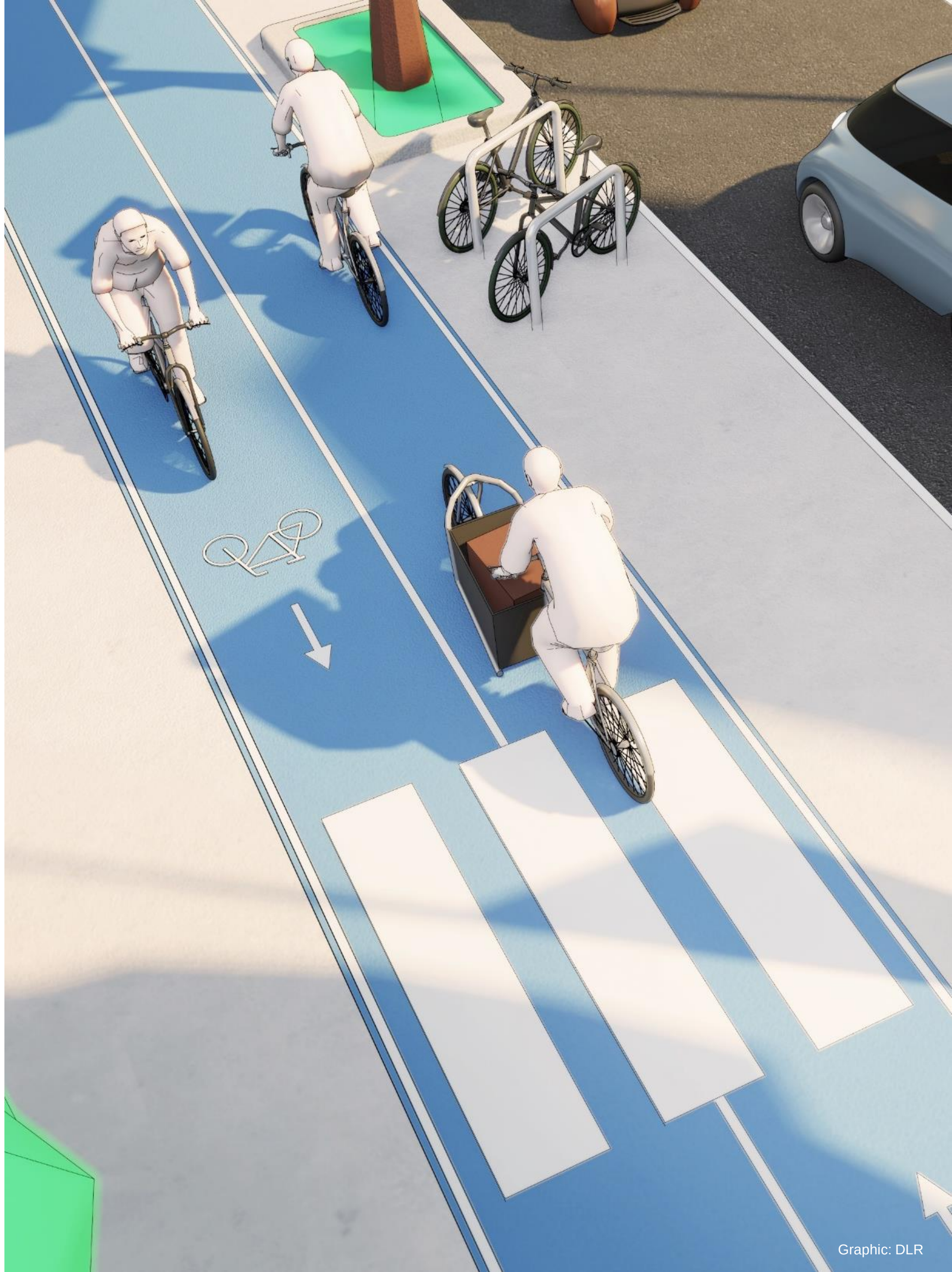
** social service, transport of passengers or goods, "other“

*** professional: transport of passengers or goods, "other“; shopping: “other goods”

**** corresponds to 70 km per fully charged battery (1,2 kWh)

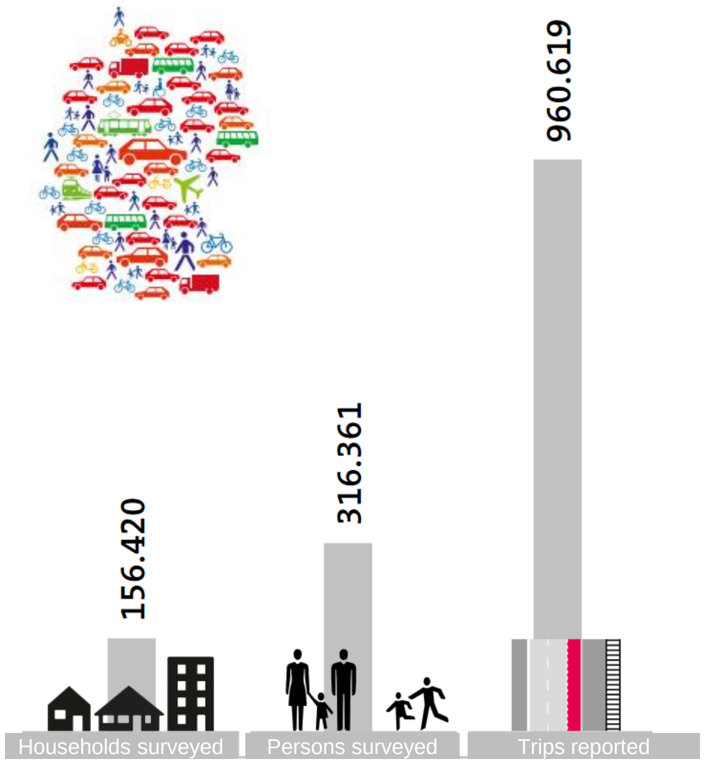
DLR

Trip Substitution Potential



Graphic: DLR

Data Base to identify the Substitution Potential of current Car Trips



Source: Mobilität in Deutschland 2017

Mobility in Germany / „Mobilität in Deutschland“ (MiD)

- German national travel survey
- Conducted 2002, 2008 and 2017; planned for 2023

MiD 2017

- Field phase: May 2016 – September 2017
- Surveyed approximately 960k trips by 316k people from 156k households
- Dataset also records household, personal, trip and car information
- Trip information includes e.g., trip length, trip purpose, modes used, weather, number of passengers, average speed, starting point
- Weighting and extrapolation factors available: enable calculation of representative figures for day-to-day mobility of German resident population during the survey period

Methodological Approach to identify the Substitution Potential of LEVs

Basis: large-scale National Mobility Survey in Germany (MID 2017)

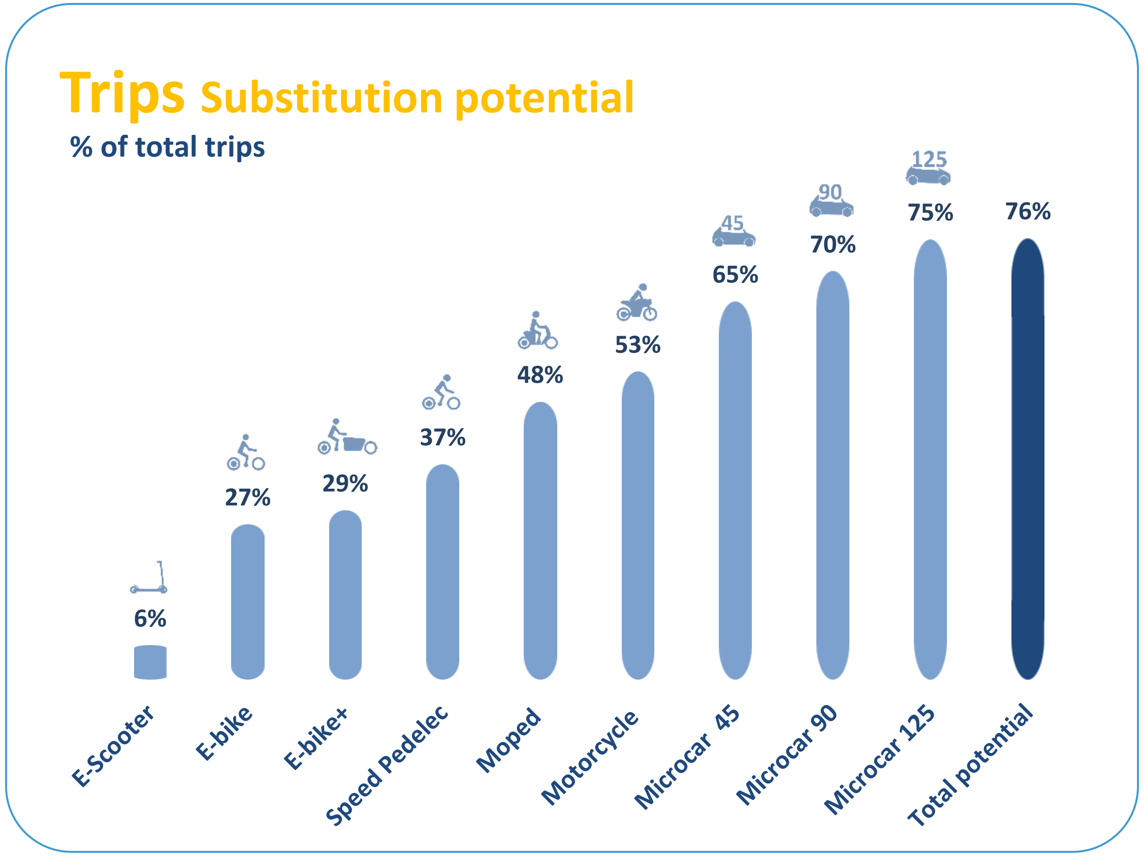
To decide whether each motorised trip could be undertaken using an LEV, trip characteristics are compared with LEV properties*. For example, whether any LEV has enough seats for the group making the trip or whether the trip length is possible. The following shows a worked example.

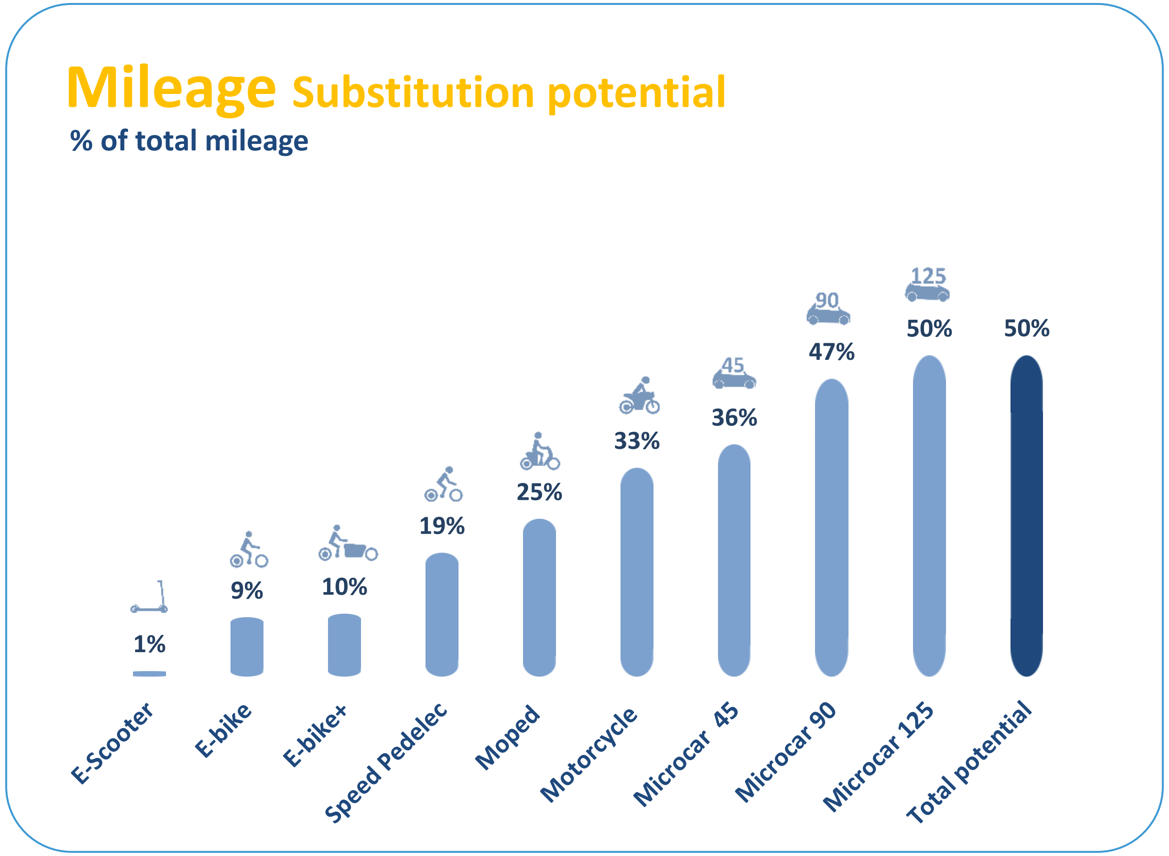
Criteria	Exemplary trip reported in the large-scale National Mobility Survey in Germany (MID 2017)	Scenario E-bike+ E-bike+ is used here to explain our methodological approach. Same procedure with all selected vehicles.	check
Trip length	8 km (one-way)	Up to 15 km (single trip), up to 30 km round trip	✓
Trip purpose	Commuting	All trip purposes, excluding: • Accompaniment (except children under 7 years) • Professional trips: transport of passengers or goods and "other“ • Shopping trips: "other goods"	✓
Age (driver)	59	18 – 70 years	✓
Weather	Snowfall	Without heavy rain, snowfall, or icy roads	X
Impairments	None	Only people without any health or mobility impairments	✓
Number of persons	1	1 + 3 (only children up to 7 years)	✓

*Page 17 provides an overview of all LEV properties.

Results: Substitution Potential (% of Possible Trips and Mileage)

Identification of the potential maximum substitution share by LEV category: How many car trips can be substituted e.g. with an E-bike+? Analysis of all reported trips shows that 76 % car trips could be substituted by LEVs.



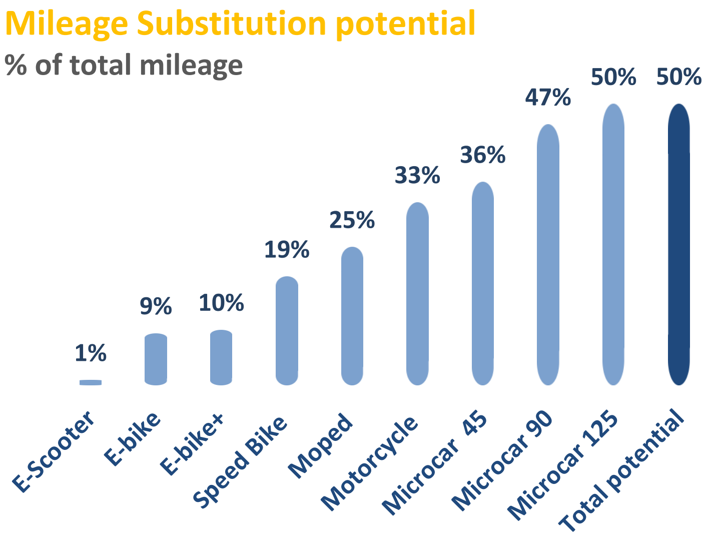


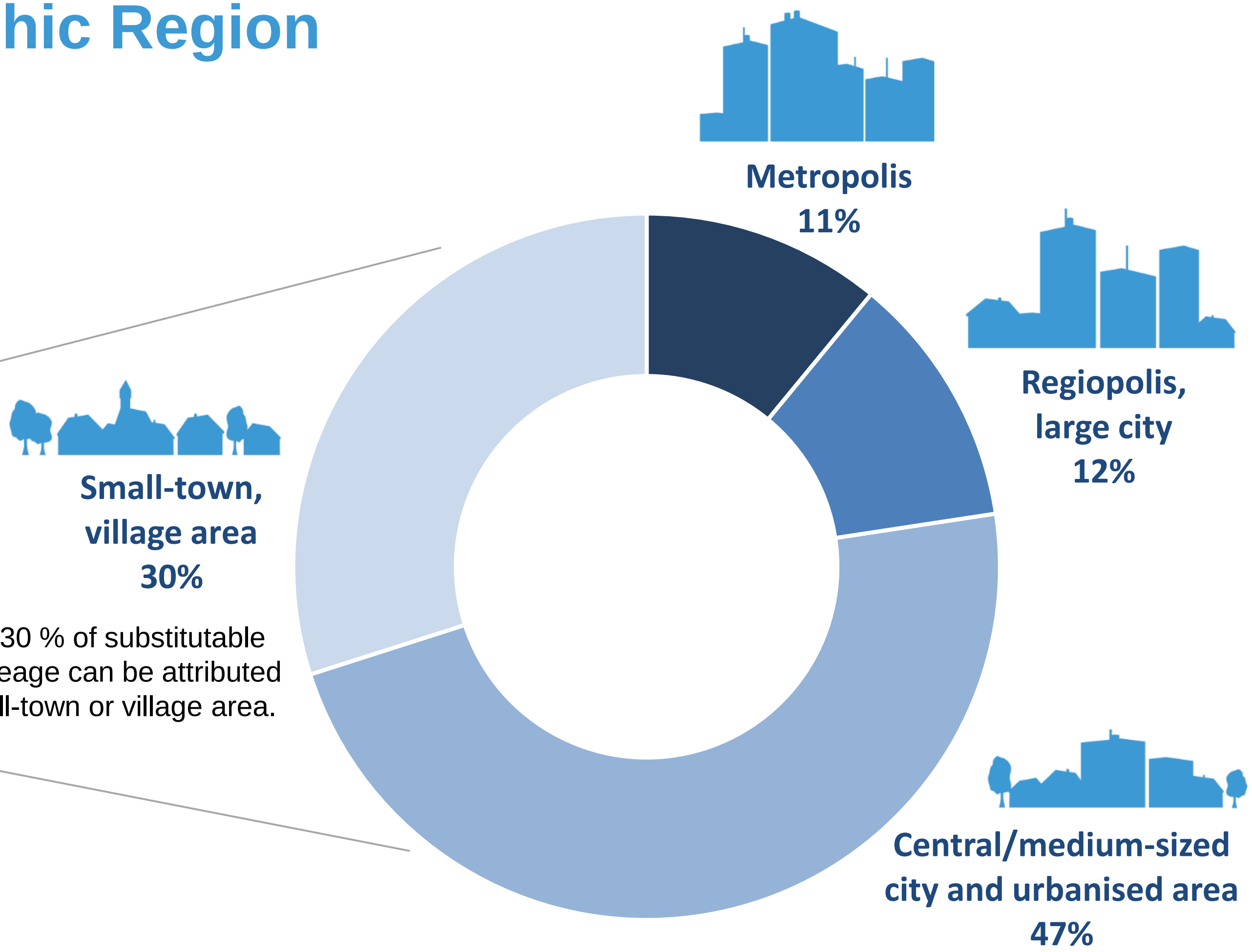
Read: For example, a Microcar 125 vehicle (max. speed 125 km/h) could in theory be used to undertake 75 % of motorised trips. In effect therefore, given it has broadly the greatest capabilities of all LEVs, this almost equals the maximum absolute substitution potential.

Substitution Potential by geographic Region

Substitutable mileage

The total substitution potential is distributed across regions as follows:

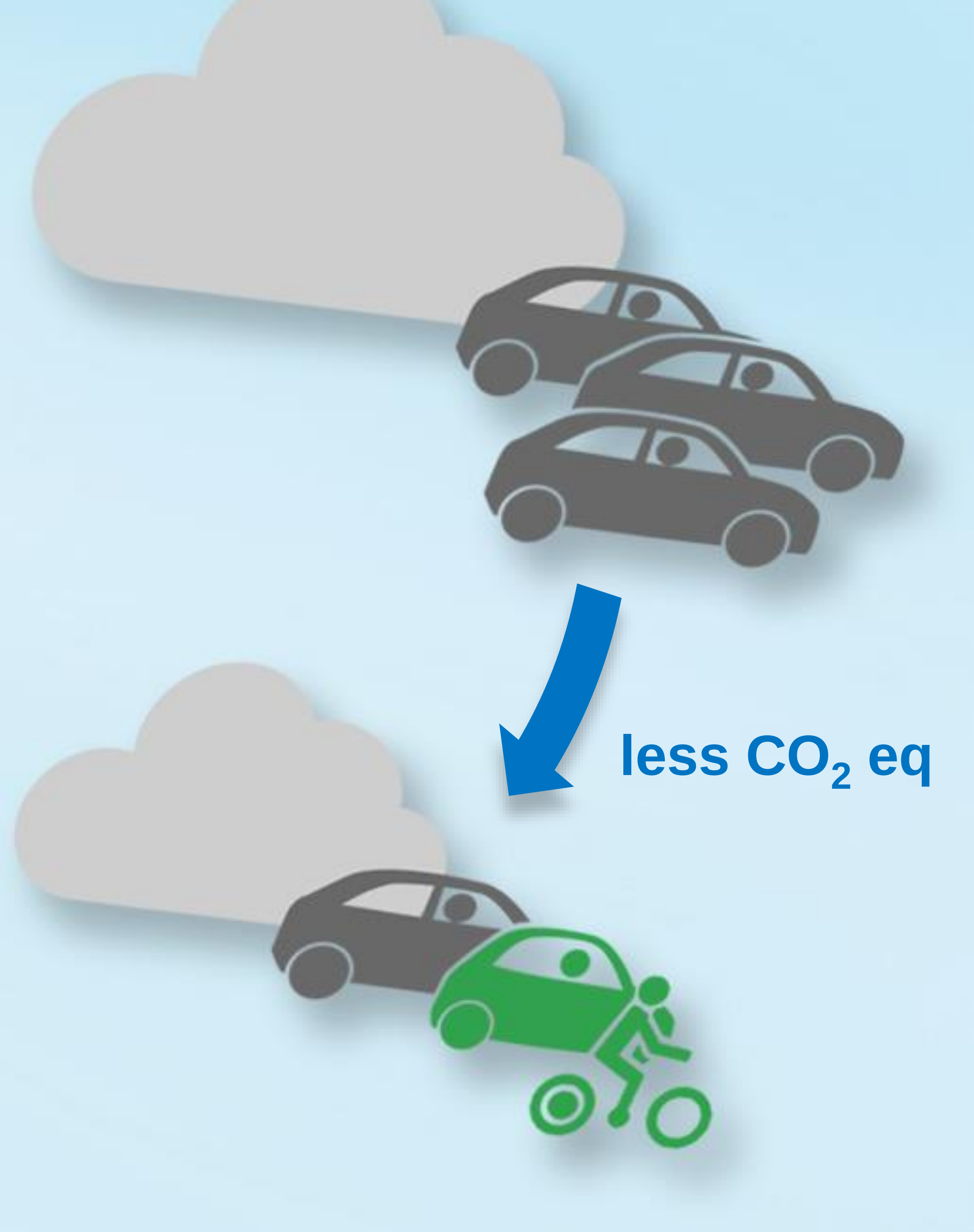




Read: 30 % of substitutable car mileage can be attributed to small-town or village area.

The regional types are part of the BMVI's spatial typology for mobility and transport research (RegioStaR). For definition of the types see: BMVI 2018 and BMVI n.d.

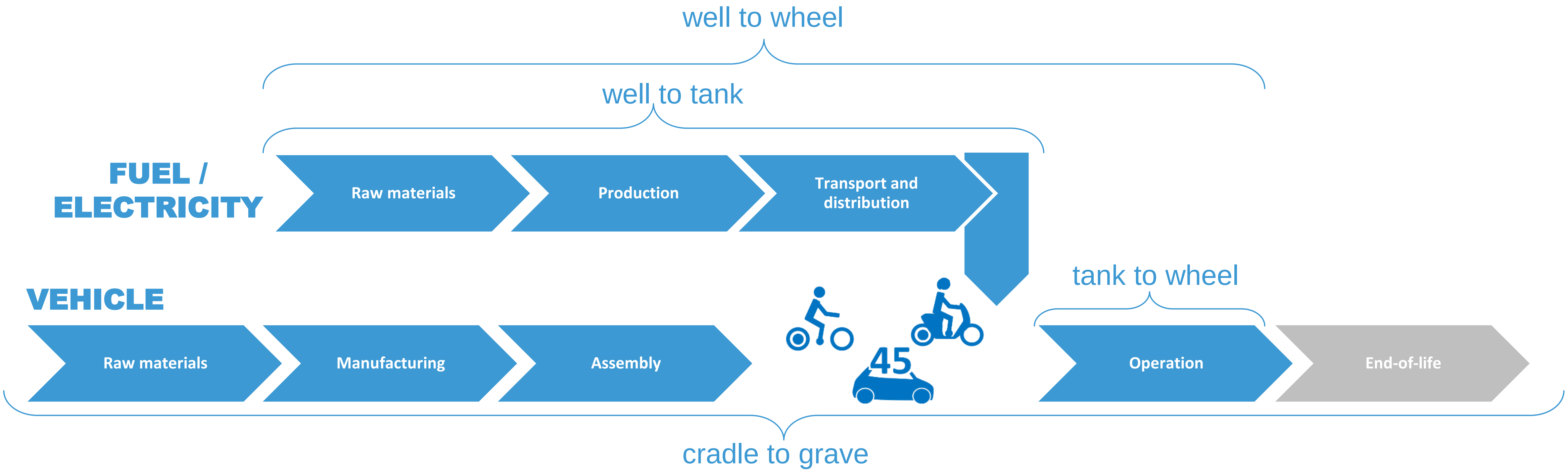
Emission Reduction Potential



Graphic: DLR

Methodological Approach: Assessment of Carbon Footprint

- Assessment of greenhouse gas emissions from production and use of different vehicles
- Definition of typical vehicle characteristics in terms of:
  lifetime mileage, electricity consumption, battery capacity, vehicle weight, electricity mix, material mix
- Basis for calculation of overall potential of emission reduction by substituting trips with LEVs using results of the trip analysis



Methodology: Emissions Modelling

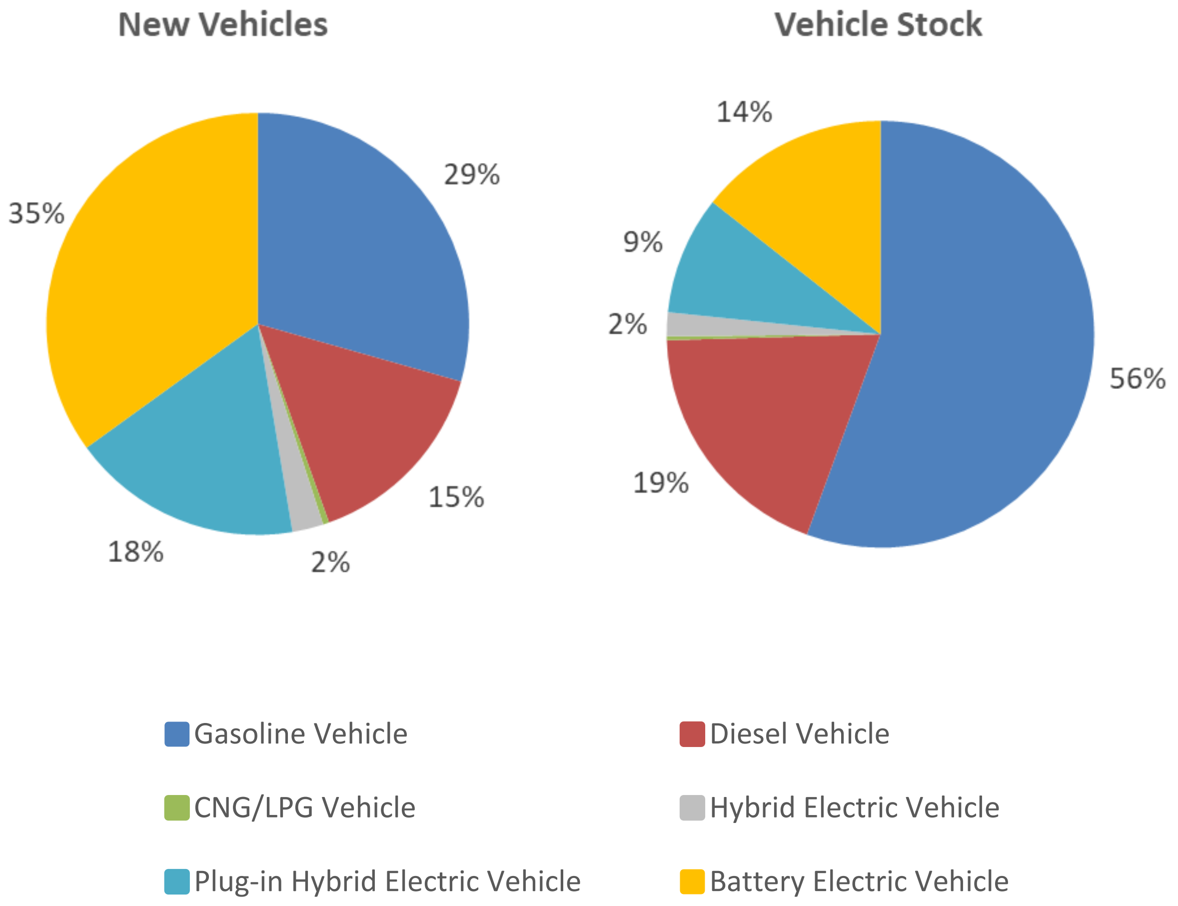
LEVs

- Vehicle production is modelled for e-scooter, e-bicycle, e-moped and 4-wheeler and applied to other vehicles
- Battery production and energy supply for vehicle operation calculated based on technical properties of each vehicle
- Scenarios for Energy mix in 2030 for LEVs and passenger cars:

228 gCO_{2eq}/kWh (present day 450 gCO_{2eq}/kWh)

Passenger Cars

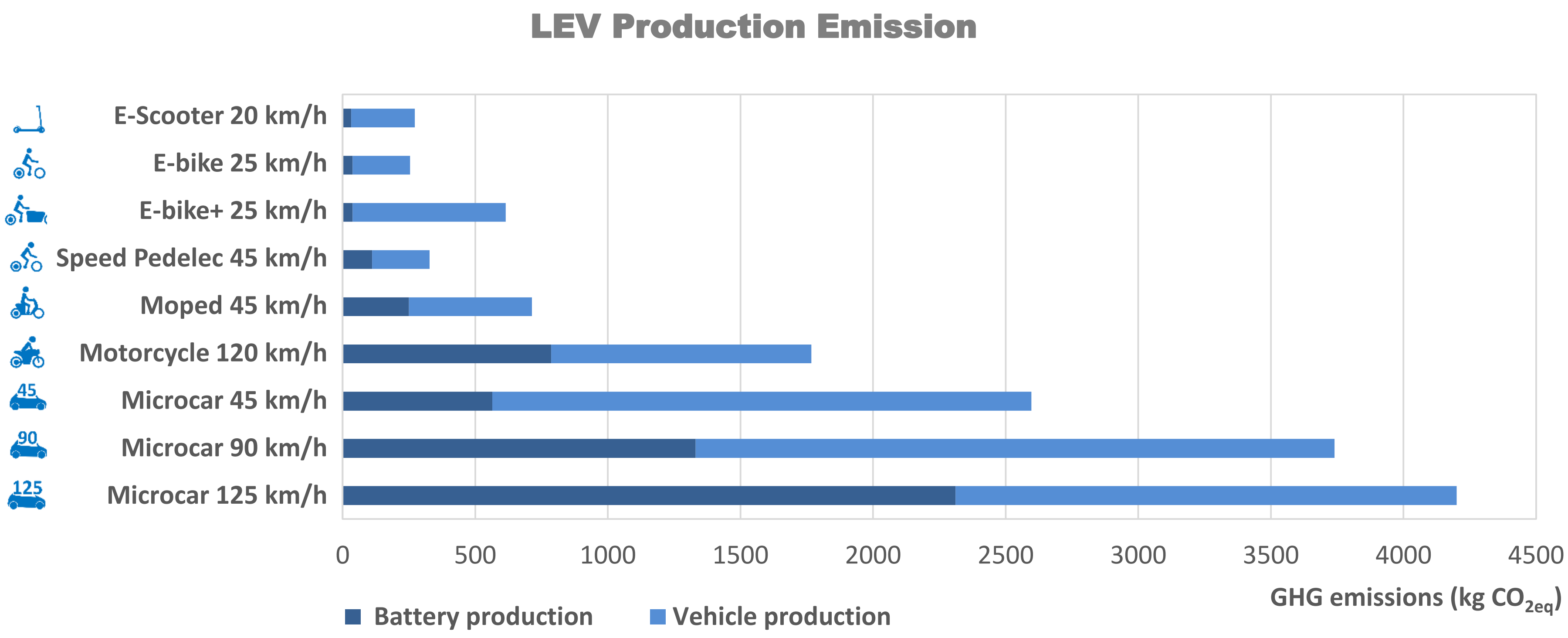
- Passenger car market: Trend scenario for 2030*
- ICE vehicles still dominate vehicle stock
- BEV share is 35% in new vehicle market and 14% in vehicle stock
- Vehicle life time mileage for all drive train types: 200,000 km



* Kopernikus-Projekt Ariadne 2021

Results: Emissions resulting from LEV Production

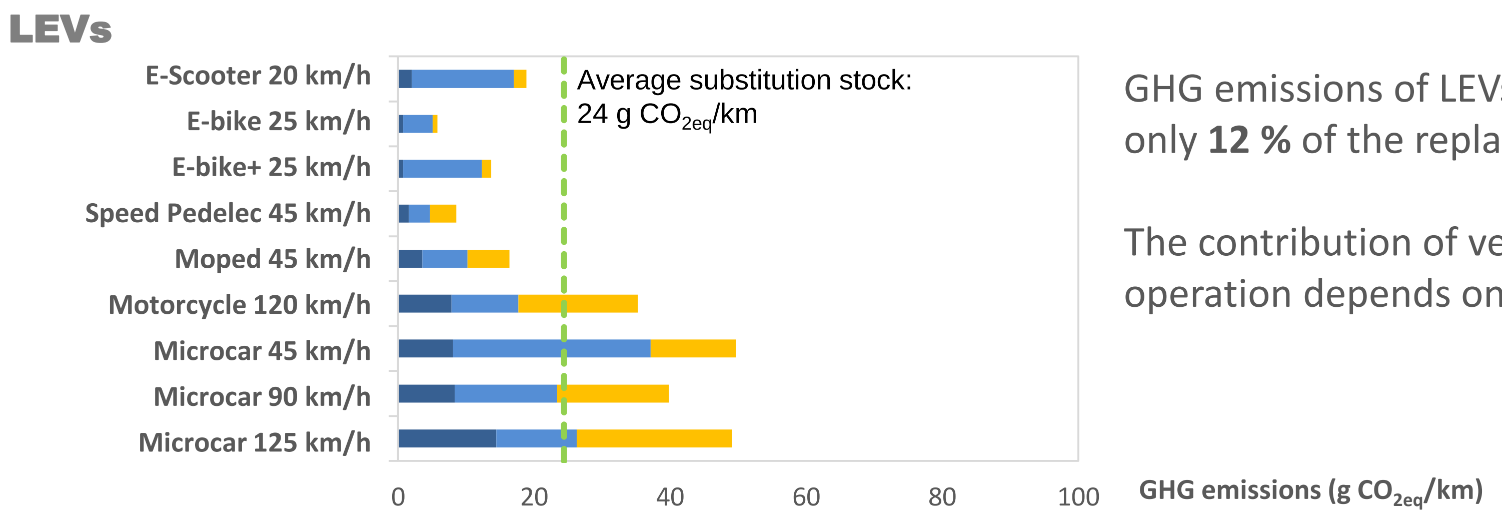
- Battery size and capacity is a decisive factor for the overall greenhouse gas (GHG) emissions
- High performance LEVs reach the emission level of small passenger cars



For comparison: the production of a battery-electric mid-size passenger car generates around 11 000 - 14 000 kg*

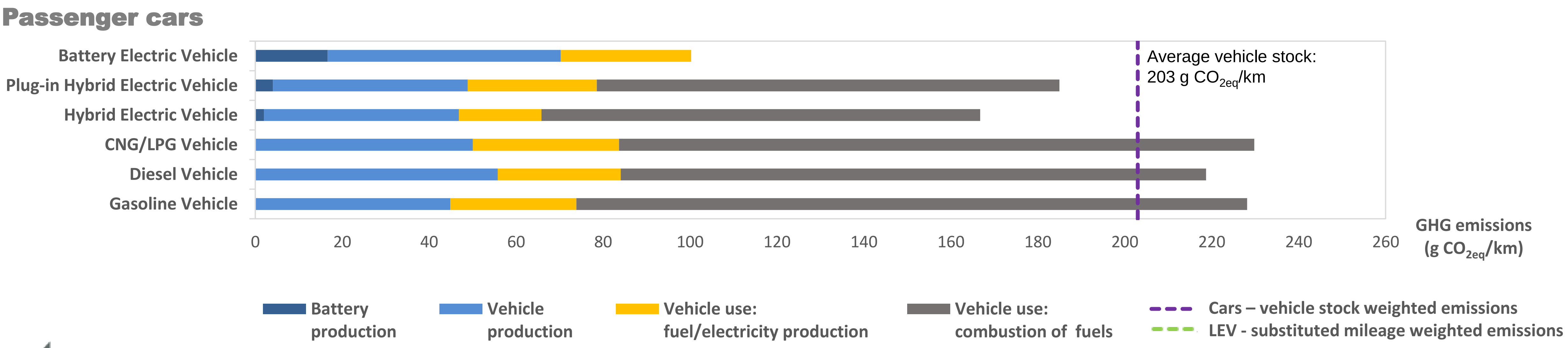
* Reference vehicle: e-Golf and VW ID.3 – VW 2021

Results: Life Cycle Emissions per Kilometer



GHG emissions of LEVs (substituted mileage weighted average) are only **12 %** of the replaced passenger car greenhouse gas emissions.

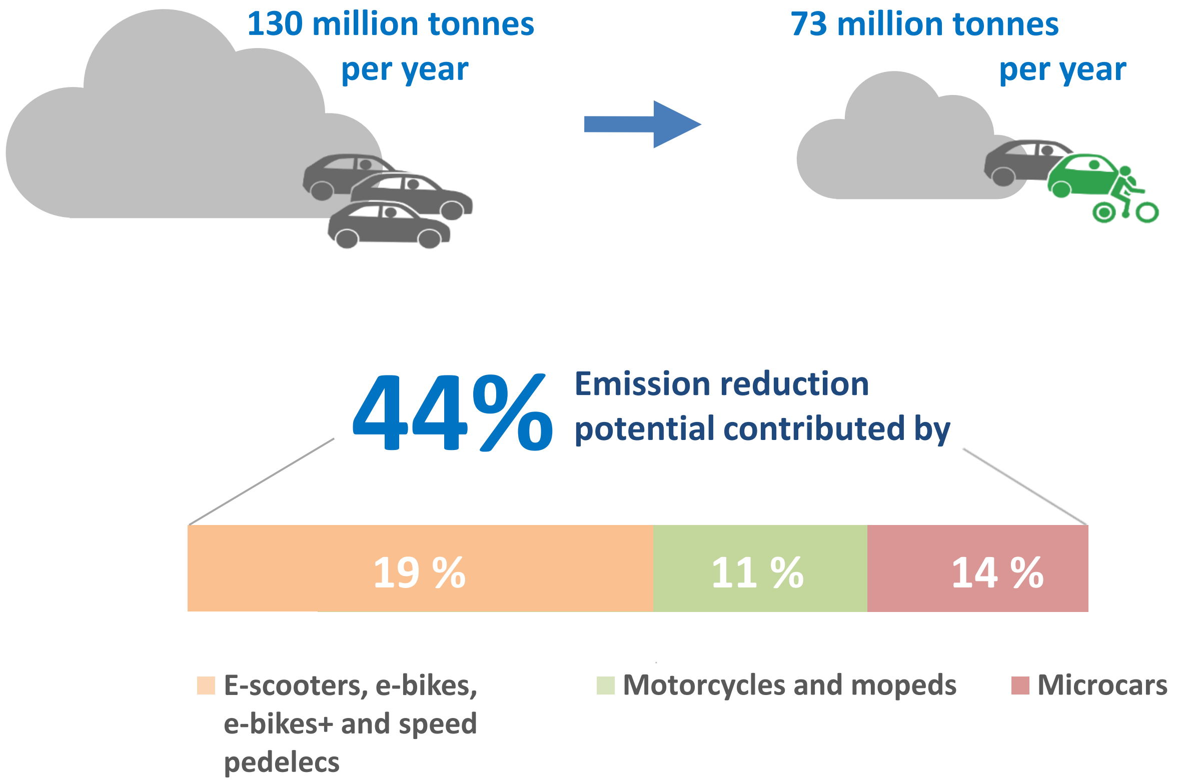
The contribution of vehicle and battery production vs. vehicle operation depends on the type of drive-train.



Results: Emission Reduction Potential by LEV Substitution

CO_{2eq} emissions before LEV substitution

CO_{2eq} emissions after LEV substitution



- Overall saving for baseline scenario is **44%** of entire passenger car emissions before substitution
- Achieved with **50 %** of mileage substitution

In absolute numbers:

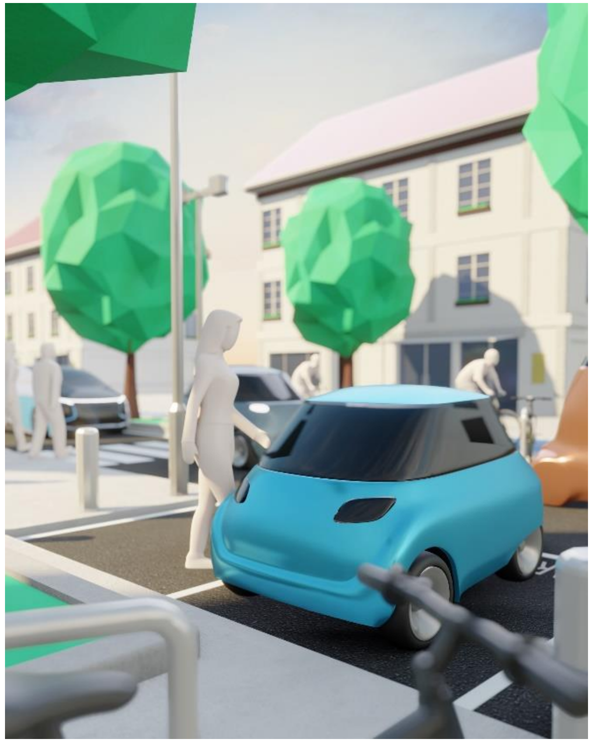
- 157 kilo tonnes CO_{2eq} per day reduced from 356 kilo tonnes CO_{2eq} per day without substitution
- This is equivalent to a reduction of 57 Mio tonnes CO_{2eq} per year

Summary, Discussion, Conclusion

Graphic: DLR

Summary and Discussion

- Up to **44 % less CO_{2eq}** could in theory be emitted by replacing three quarters of German trips and half of miles currently driven in conventional motor vehicles, saving 57m tonnes CO_{2eq} per year.
- On average, **for the trips substituted by LEVs, 88 % of the emissions could be saved** compared to cars.
- This figure is sufficiently high to suggest that further research into LEV potential is likely to be worth pursuing.
- This does not take into account any social, political, LEV acceptance or mobility behaviour changes.



Graphic: DLR

Discussion

- **Plausibility:** the fact that 75 % of the trips are suitable to be driven with LEVs may be surprisingly at first glance, but considering that 80 % of the trips are less than 20 km, the result is plausible.
- **Realisation of potential:** achieving even part of this potential will require fundamental changes to encourage a switch away from long-standing mobility habits to using LEVs, including push and pull measures such as incentives, rewards, speed limitation, internalization of external costs and infrastructure adaption.
- **Private car replacement:** the study does not examine possible changes of the vehicle stock and whether individuals would be willing to replace their car or whether an LEV is suitable for all journeys made by a person in a year. In case it is not, different solutions would be possible, such as travelling non-substitutable trips by train, avoiding trips or using car sharing.
- **LEVs for urban and rural areas:** LEVs enable sustainable yet individual mobility and could thus be interesting for target groups that are difficult to reach with environmental transport services. LEVs could also be a sustainable solution for times and areas where public transport poses challenges due to low passenger volumes.
- **LEVs and other paths to sustainable mobility:** For effective climate protection in transport, many approaches must work together – the most effective option is to avoid motorised traffic. In addition, trips can be shifted from motorised individual transport to more sustainable modes such as public transport or LEVs and vehicles can be optimised so that few resources are consumed. **Avoid – Shift - Improve**

Conclusion and Outlook

The potential of LEVs to support climate change mitigation is significant. This promise suggests further investigation of their wider social, ecological, economic, safety and planning implications is urgently called for.

Important questions include:

- What factors and specific changes are necessary to realise a significant proportion of LEVs' emissions-reduction potential?
- What adjustments must be made and what obstacles removed to increase acceptance and use of LEVs?
- What potential do LEVs hold for urban logistics, and in which sectors?
- How can transport systems and vehicles be designed to maximise LEV safety?
- What opportunities would extensive LEV adoption offer in urban planning?
- How can adoption of LEVs be accelerated?
- Which paths towards greater use of LEVs are promising?

Without fundamental changes in many fields, LEV's potential will not be extensively realised.

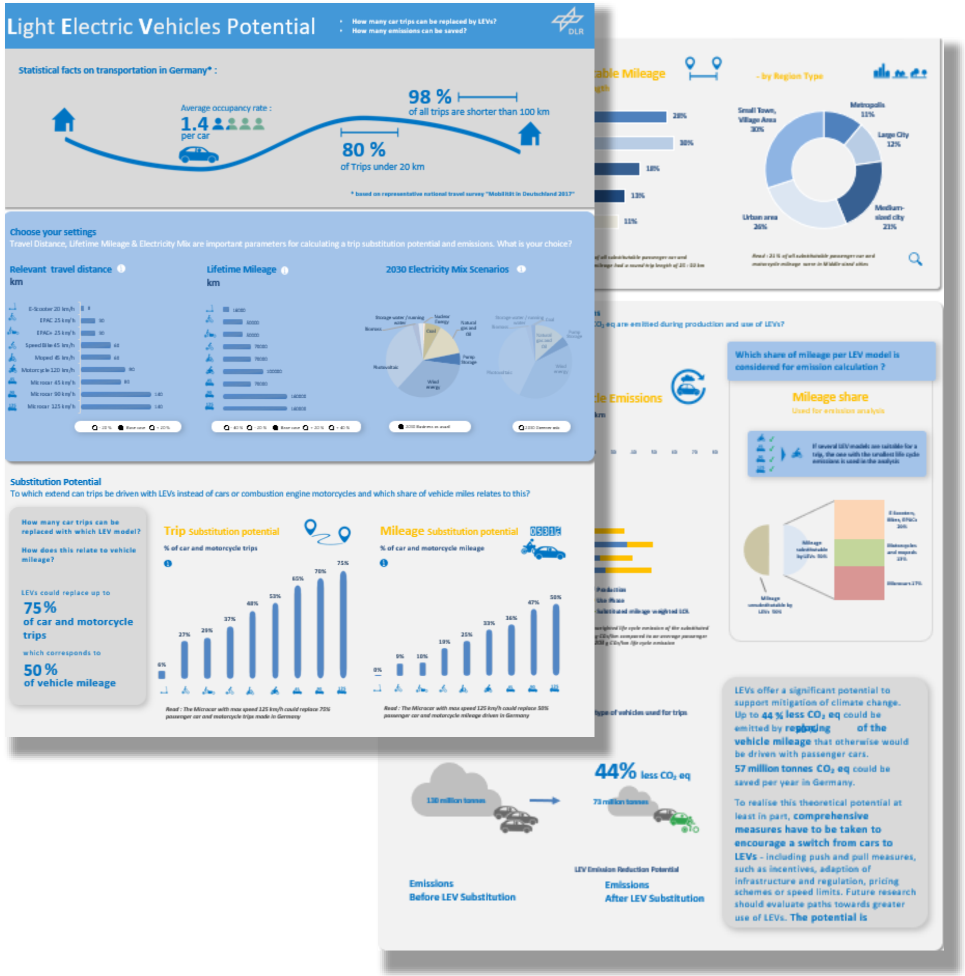
LEVs also promise considerable advantages beyond reducing emissions, for example improving quality of urban life.

Explore the potential of LEVs with an Interactive Tool!

The potential for transport greenhouse gas emissions reduction through LEV vehicle substitution depends on the boundary conditions chosen. Among the main factors are the relevant travel distance, vehicle longevity (lifetime mileage) and the generation source of the electricity. The interactive tool allows the reader to explore more deeply the potential of LEVs, and in particular to:

- Evaluate LEV potential for various scenario settings
- Choose relevant travel distance, vehicle lifetime mileage and electricity mix
- Export individual settings and results to a pdf document

The tool will be available online soon.



German Aerospace Center for LEVA-EU

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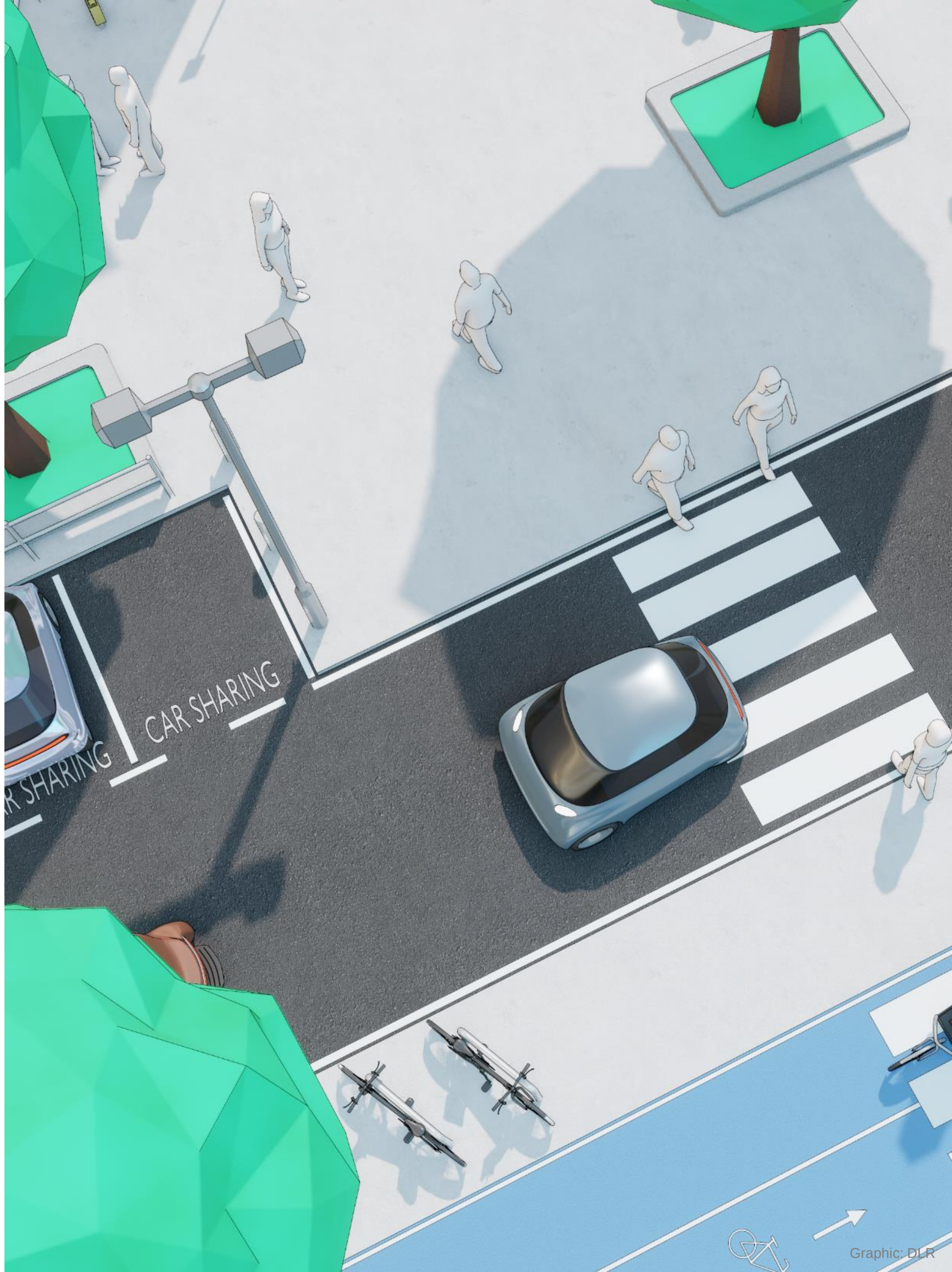


Graphic: DLR

Introduction of the Research Team

German Aerospace Center

Mascha Brost

Institute of Vehicle Concepts

Technical vehicle parameters, project coordination

Simone Ehrenberger

Institute of Vehicle Concepts

Analysis of CO_{2eq} emission reduction potential

Laura Gebhardt

Institute of Transport Research

Analysis of trip substitution potential

Isheeka Dasgupta

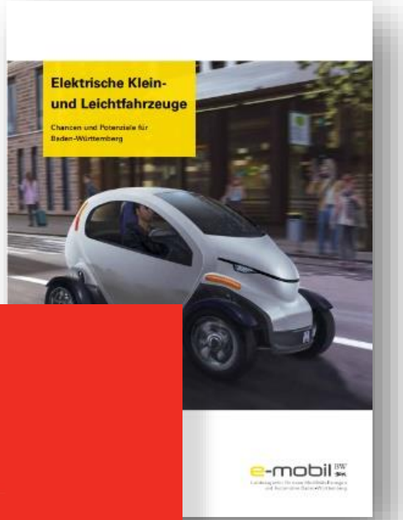
Institute of Vehicle Concepts

Analysis of CO_{2eq} emission reduction potential, emission calculator tool

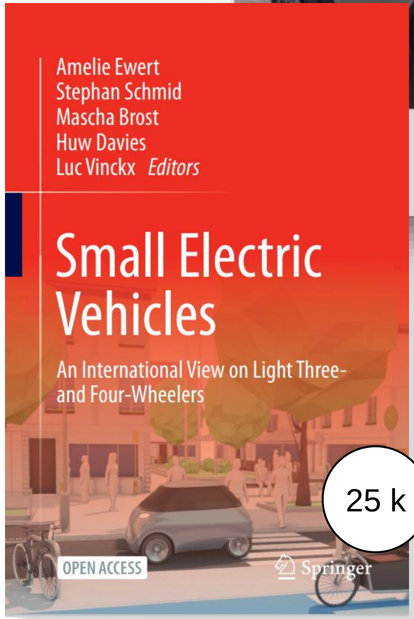
Robert Hahn

Institute of Vehicle Concepts

Visualisation of the results, graphical conception of the tool



Elektrische Klein- und Leichtfahrzeuge | e-mobil BW



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Small Electric Vehicles - An International View on Light Three- and Four-Wheelers | Springer

Vehicle categories according to Regulation (EU) No 168/2013

Category	L1e Light two-wheel powered vehicle		L2e Three-wheel moped		L3e Two-wheel motorcycle					L4e Two-wheel motor-cycle with side-car	L5e Powered tricycle		L6e Light quadricycle		L7e Heavy quadricycle				
Sub-category	L1e-A Powered cycle	L1e-B Two-wheel moped	L2e-P Three-wheel moped for passenger transport	L2e-U Three-wheel moped for utility purpose	L3e-A1 Low-per-formance motorcycle	L3e-A2 Medium-per-formance motorcycle	L3e-A3 High-per-formance motorcycle	L3e-AxT Enduro motor-cycles	L3e-AxT Trial motor-cycles	-	L5e-A Tricycle	L5e-B Commercial tricycle	L6e-A Light on-road quad	L6e-B (BP/BU*) Light quadri-mobile	L7e-A (A1/A2) Heavy on-road quad	L7e-B Heavy all terrain quad		L7e-C Heavy quadri-mobile	
Sub-sub-category																L7e-B1 All terrain quad	L7e-B2 Side-by-side buggy	L7e-CP Pass-enger transport	L7e-CU Utility purposes
Velocity	≤ 25 km/h	≤ 45 km/h	≤ 45 km/h		-								≤ 45 km/h		-	≤ 90 km/h	-	≤ 90 km/h	
Power	≤ 1 kW	≤ 4 kW	≤ 4 kW		≤ 11 kW	≤ 35 kW	-						≤ 4 kW	≤ 6 kW	≤ 15 kW	-	≤ 15 kW		
Mass**	-		≤ 270 kg		power/ weight ratio ≤0.1 kW/kg	power/ weight ratio ≤0.2 kW/kg	-	≤ 140 kg	≤ 100 kg	-	≤ 1000 kg		≤ 425 kg		≤ 450 kg	≤ 450 kg: transport of passengers ≤ 600 kg: transport of goods		≤ 450 kg	≤ 600 kg
Length	≤ 4000 mm													≤ 3000 mm	≤ 4000 mm			≤ 3700 mm	
Width	≤ 1000 mm		≤ 2000 mm											≤ 1500 mm	≤ 2000 mm			≤ 1500 mm	
Height	≤ 2500 mm																		
Number of seats	-		≤ 2		-			1		≤ 4 (inkl. ≤ 2 in side car)	≤ 5	≤ 2	≤ 2		≤ 2 (A1: straddle seats)	≤ 2 straddle seats	≤ 3 (2 side-by-side)	≤ 4	≤ 2

The parameters shown represent only a selection of the criteria specified in the regulation. The regulation is available via:
Regulation (EU) No 168/2013 on the approval and market surveillance of two- or three-wheel vehicles and quadricycles

* BP: passenger transport, BU: utility purposes **mass in running order without propulsion batteries

Bibliography

- BMVI – Federal Ministry of Transport and Digital Infrastructure (2018): Regionalstatistische Raumtypologie (RegioStaR) des BMVI für die Mobilitäts- und Verkehrsforschung. Arbeitspapier, Versions V1.1. BMVI, Division G 13 „Forecast, Statistics and Special Surveys". Retrieved from: https://www.bmvi.de/SharedDocs/DE/Anlage/G/regiostar-arbeitspapier.pdf?__blob=publicationFile [24.02.2022].
- BMVI – Federal Ministry of Transport and Digital Infrastructure (n.d.): RegioStaR – Regional Statistical Spatial Typology for Mobility and Transport Research. BMVI, Division G 13 „Forecast, Statistics and Special Surveys". Retrieved from: https://www.bmvi.de/SharedDocs/DE/Anlage/G/regiostar-raumtypologie-englisch.pdf?__blob=publicationFile [24.02.2022].
- BMVI (no date): MiD 2017 – Mobilität in Deutschland. Mikrodaten (Public Use File). Available online: www.clearingstelle-verkehr.de [20 November 2021] .
- GBE Bund (2017): GESUNDHEITSBERICHTERSTATTUNG DES BUNDES Durchschnittliche Körpermaße der Bevölkerung (Größe in m, Gewicht in kg). http://www.gbe-bund.de/oowa921-install/servlet/oowa/aw92/dboowasys921.xwdevkit/xwd_init?gbe.isgbetol/xs_start_neu/&p_aid=3&p_aid=34219392&nummer=223&p_sprache=D&p_indsp=-&p_aid=35196731 [25.10.2019]
- IEA (2020): Global CO2 emissions by sector in 2019. https://www.iea.org/reports/greenhouse-gas-emissions-from-energy-overview/emissions-by-sector#abstract [15.03.2022]
- KBA (2021):Fahrzeugzulassungen (FZ) Neuzulassungen von Kraftfahrzeugen nach Umwelt-Merkmalen Jahr 2020, FZ14. https://www.kba.de/SharedDocs/Downloads/DE/Statistik/Fahrzeuge/FZ14/fz14_2020_pdf.pdf?__blob=publicationFile&v=3, p. 18 [04.03.2022]
- Kelly (2020): Kelly, Jarod C.; Dai, Qiang; Wang, Michael (2020): Globally regional life cycle analysis of automotive lithium-ion nickel manganese cobalt batteries. In: Mitigation and Adaptation Strategies for Global Change 25 (3), p. 371–396. DOI: 10.1007/s11027-019-09869-2.
- Kopernikus-Projekt Ariadne (2021): Ariadne-Report: Deutschland auf dem Weg zur Klimaneutralität 2045 - Szenarien und Pfade im Modellvergleich. https://doi.org/10.48485/pik.2021.006
- Nobis, C., Kuhnimhof, T. (2018): Mobilität in Deutschland – MiD Ergebnisbericht. Studie von infas, DLR, IVT und infas 360 im Auftrag des Bundesministers für Verkehr und digitale Infrastruktur (FE-Nr. 70.904/15). Bonn, Berlin. www.mobilitaet-in-deutschland.de .
- UBA (2018): Emission sources transport 2016 (without CO_2 from biofuels), Nationale Trendtabellen für die deutsche Berichterstattung atmosphärischer Emissionen. Dessau, via https://www.bmu.de/fileadmin/Daten_BMU/Pools/Broschueren/klimaschutz_in_zahlen_2018_bf.pdf, p. 28 and 39 [04.03.2022]
- UBA (2021): Beitrag der erneuerbaren Energien zum Endenergieverbrauch in Deutschland. https://www.umweltbundesamt.de/themen/klima-energie/erneuerbare-energien/erneuerbare-energien-in-zahlen#ueberblick, [04.03.2022]
- VW (2021): „Die CO_2-Bilanz des Elektro-Fahzreugs", https://www.volkswagenag.com/de/news/stories/2021/02/e-mobility-is-already-this-much-more-climate-neutral-today.html "Von der Wiege bis zur Bahre" https://www.volkswagenag.com/de/news/stories/2019/04/from-the-well-to-the-wheel.html#" [07 March 2022]
- World Resources Institute (2020): Emissions by sector for 2016, Climate Watch, the World Resources Institute (2020) via https://ourworldindata.org/emissions-by-sector#energy-electricity-heat-and-transport-73-2 [04.03.2022]