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

Presentation of the LEV4Climate Study

March, 24th 2022, Brussels
The Future is Electric and Light – Policy Session

Mascha Brost, Simone Ehrenberger, Isheeka Dasgupta, Robert Hahn, Stephan Schmid
DLR Institute of Vehicle Concepts

Laura Gebhardt, Mirko Goletz
DLR Institute of Transport Research

German Aerospace Center (DLR)
Prepared for LEVA-EU

German Aerospace Center – Knowledge for Tomorrow

DLR Institute of Vehicle Concepts

Dr. Stephan Schmid
Brussels, March 24th 2022

Fields of activity

- Aeronautics and aerospace
- Energy and transport
- Digitisation and security
- Planning and implementation of German aerospace activities
- Project executing agency for research funding

We shape the mobility of the future – sustainable, cost-effective and user-oriented

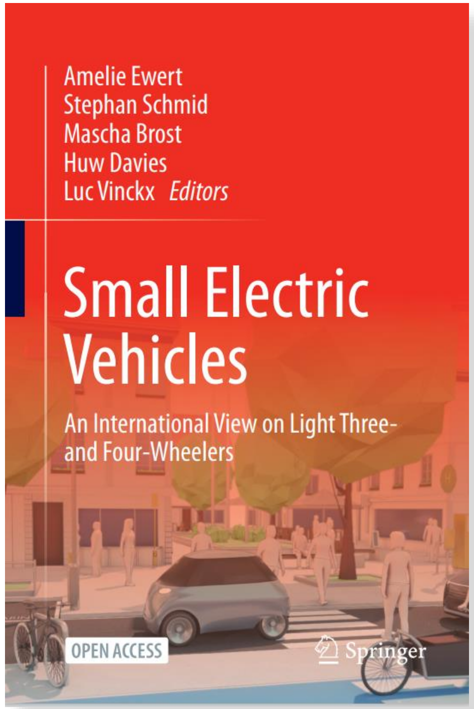
Our three principles

PROTECTING THE CLIMATE

SECURING MOBILITY

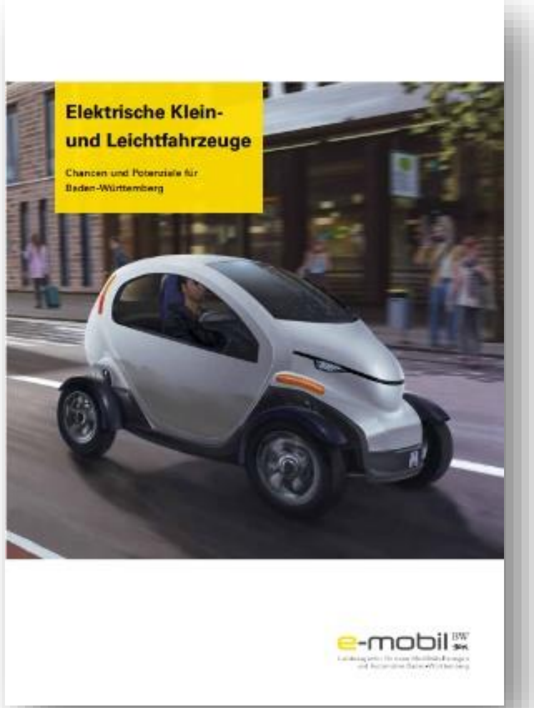
SHAPING TRANSFORMATION

Research on Light Electric Vehicles at DLR

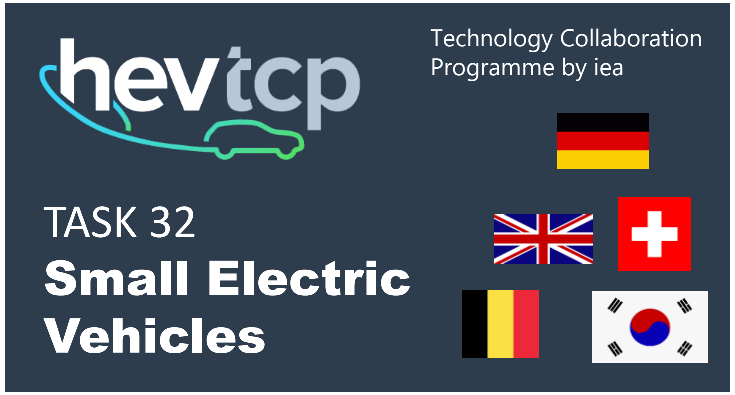


Small Electric Vehicles - An International View on Light Three- and Four-Wheelers | Springer

25 k Downloads
OPEN ACCESS



Elektrische Klein- und Leichtfahrzeuge | e-mobil BW



Operating Agent:
Stephan Schmid

Germany
Switzerland
Republic of Korea
Belgium
United Kingdom

Start: April 2016
Completion: May 2021

HEV-TCP (ieahev.org)

SLRV
Safe Light Regional Vehicle

https://verkehrsforschung.dlr.de/public/documents/2019/Safe_Light_Regional_Vehicle_Booklet_eng.pdf

Introduction of the LEV4Climate Research Team
German Aerospace Center

Mascha Brost

Institute of Vehicle Concepts

Project coordination, technical vehicle parameters

Simone Ehrenberger

Institute of Vehicle Concepts

Analysis of CO_{2eq} emission reduction potential

Laura Gebhardt

Institute of Transport Research

Analysis of trip substitution potential

Mirko Goletz

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

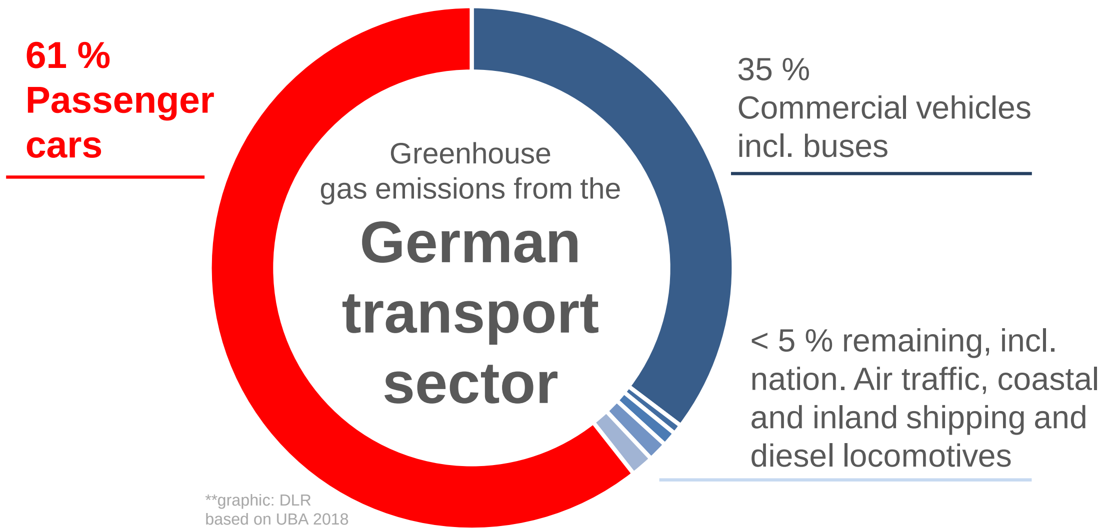
Visualisation of the results, graphical conception of the tool

The Potential of Light Electric Vehicles for Climate Protection Through Substitution for Passenger Car Trips - Germany as a case study

Motivation & Introduction to Light Electric Vehicles

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

Greenhouse Gas emissions from Transport in Germany & Reduction Potential



**graphic: DLR
based on UBA 2018

Source:
white and blue plastic tool photo – Free Electronics Image on Unsplash, 08.03.2021

In Germany, transport accounts for 20 % of greenhouse gas emissions, of which almost two-thirds come from passenger cars*. Substitution of car trips therefore offers great potential.

Also if vehicles go entirely electric, total energy consumption will matter: even with renewable energy, consumption must be minimised and energy efficiency maximised.

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

*UBA 2018

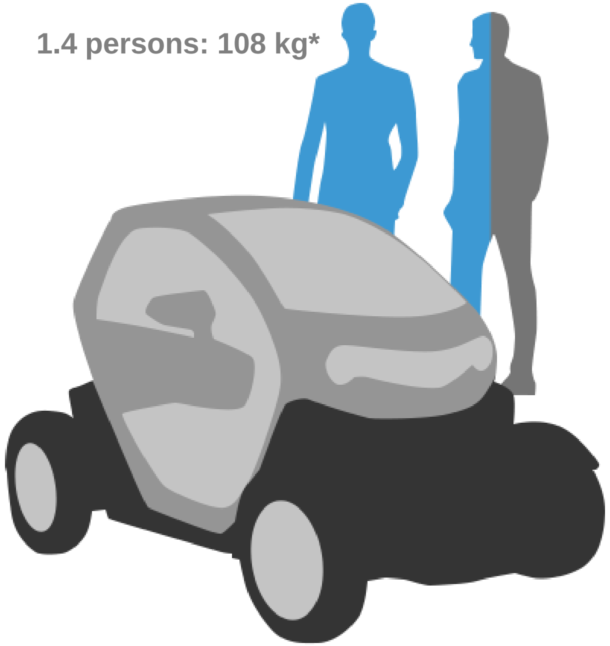
What is a Light Electric Vehicle and which Kind are available today or soon?

The market offers a rich variety of Light Electric Vehicles (LEVs) - from electric scooters to 4-wheelers. There are models with and without cabin, with no, one, two or more seats, with top speeds over 100 km/h 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

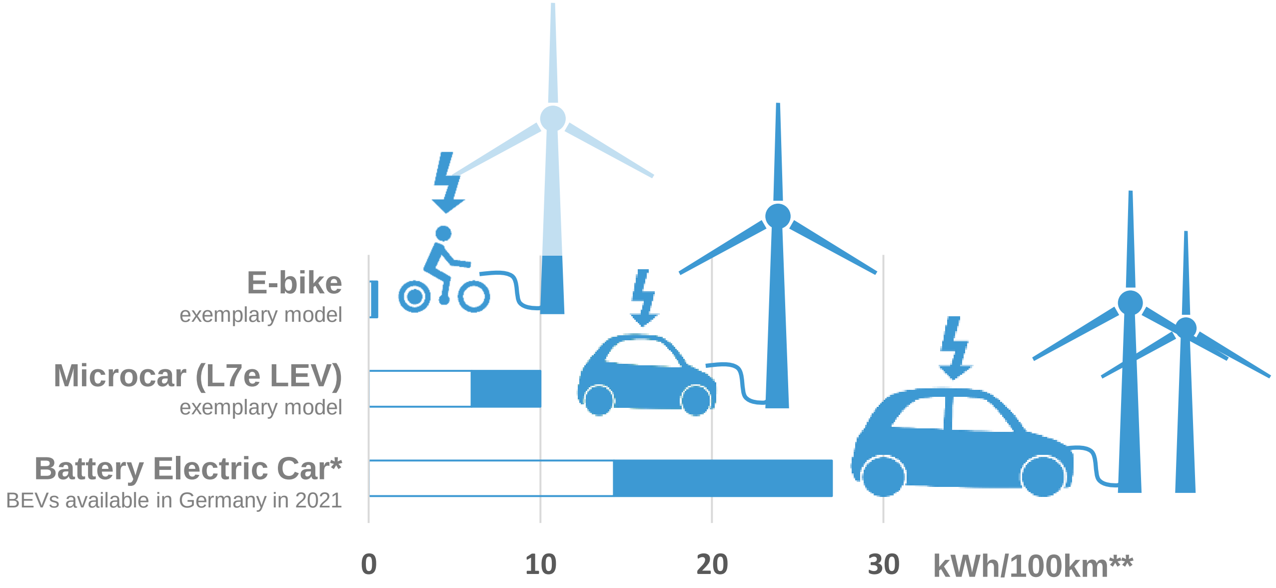
Lightweight Construction saves Energy

1.4 persons: 108 kg*



LEV:
~500 kg

Average new car:
~ 1600 kg**



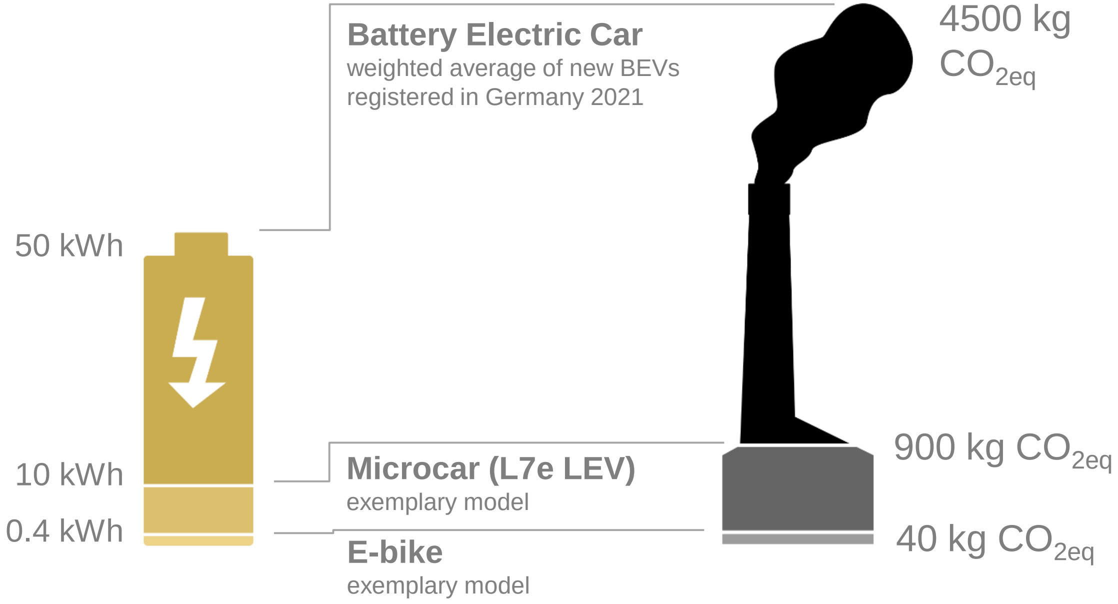
Low weight, high efficiency

Lower energy consumption – fewer power plants

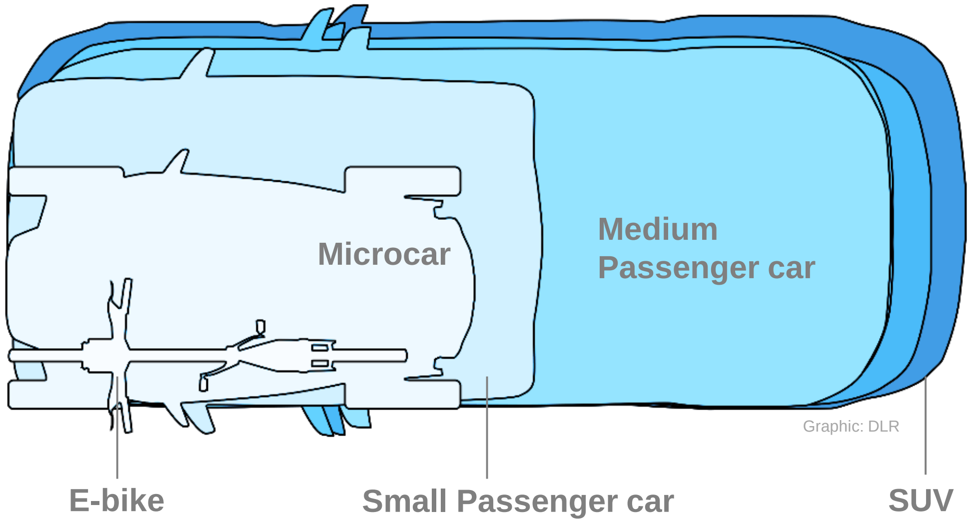
* Average weight of persons over 18 in Germany: 77 kg (GBE Bund, 2017) , average occupancy rate of passenger cars in Germany: 1.5 persons (BMVI, n. d.)
** KBA 2021

* 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.

Small Batteries and small Footprint



Smaller batteries – less production related emissions



Small footprint liberates space

Research Questions:

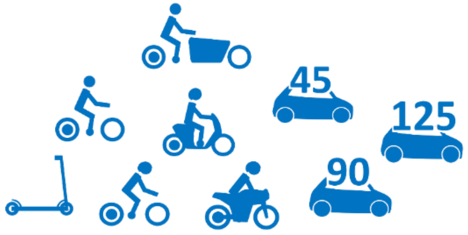
To what extent might LEVs substitute car trips?

How much CO_{2eq} might be saved with LEVs?

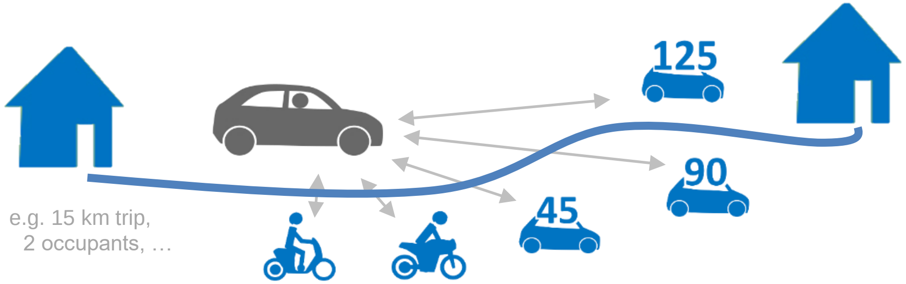
LEV4Climate Study - Approach

Graphic: DLR

Modelling Approach for Calculating the Emission Reduction Potential

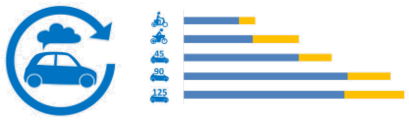


Which LEVs are considered?
Definition of exemplary set of LEVs and analysis criteria for trip substitution

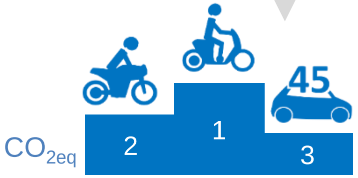


Which car trips can be substituted with which LEVs?
Analysis of car trips reported in a representative national travel survey on an average day regarding substitutability with LEVs (Germany)

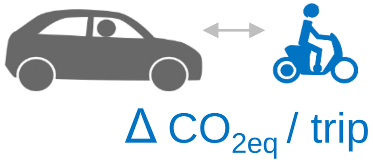
How many trips / vehicle km can be substituted?
Amount of substitutable trips and according vehicle mileage



How much are the life cycle emissions per LEV type?
Determination of CO_{2eq} emissions of LEVs and 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 a car and an LEV trip
(emissions per km times trip length, 2030 scenario, Germany)

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

Changes in mobility behavior, social acceptance, as well as political measures are not modelled.

DLR

LEV Categories for the Analysis

Regulation (EU) No 168/2013*

L1e L1e L3e L5e L6e L7e

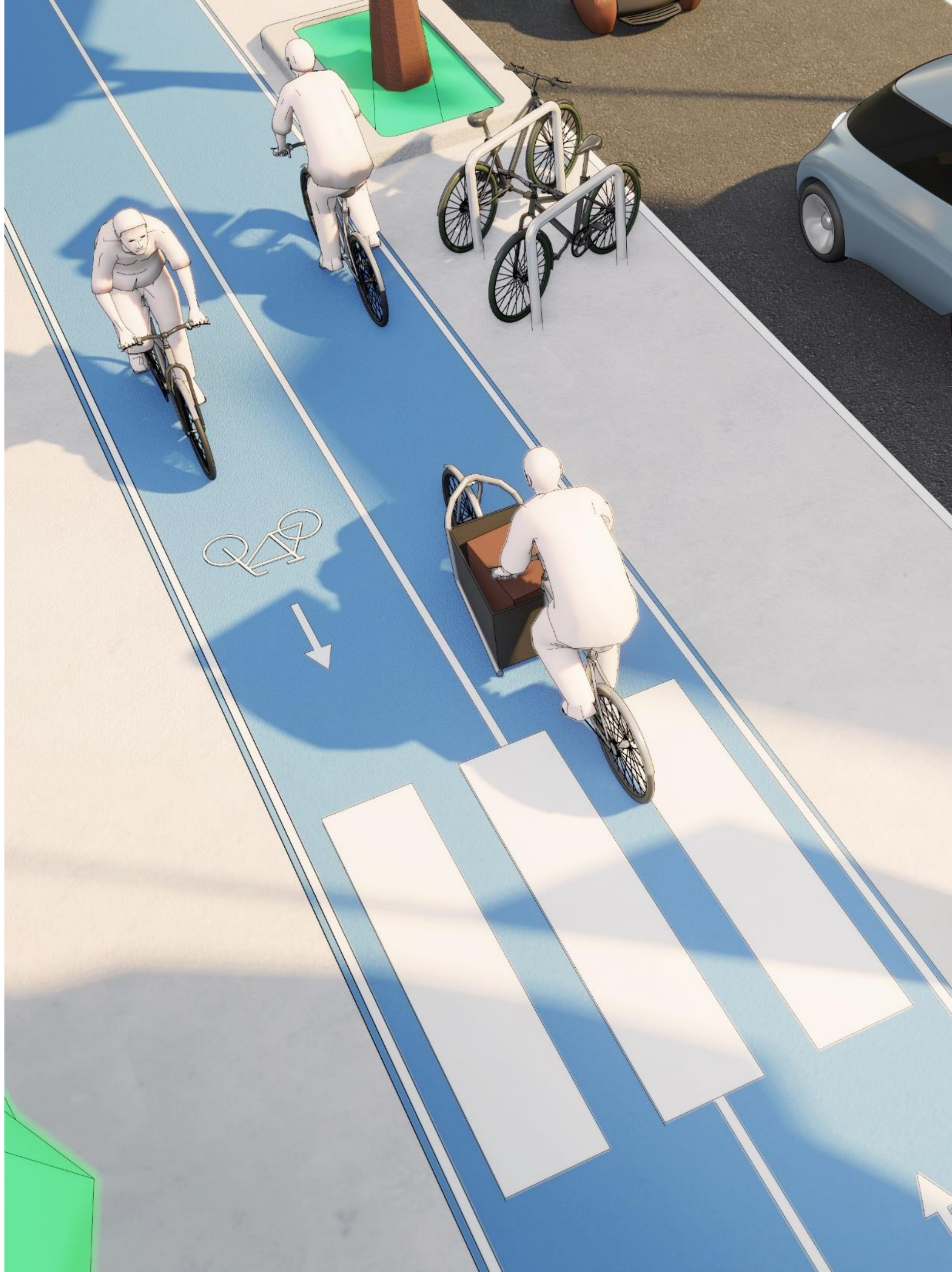
E-scooter | E-bike | E-bike+ | Speed Pedelec | Moped | Motorcycle | Microcar 125 | Microcar 45 | Microcar 90

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.

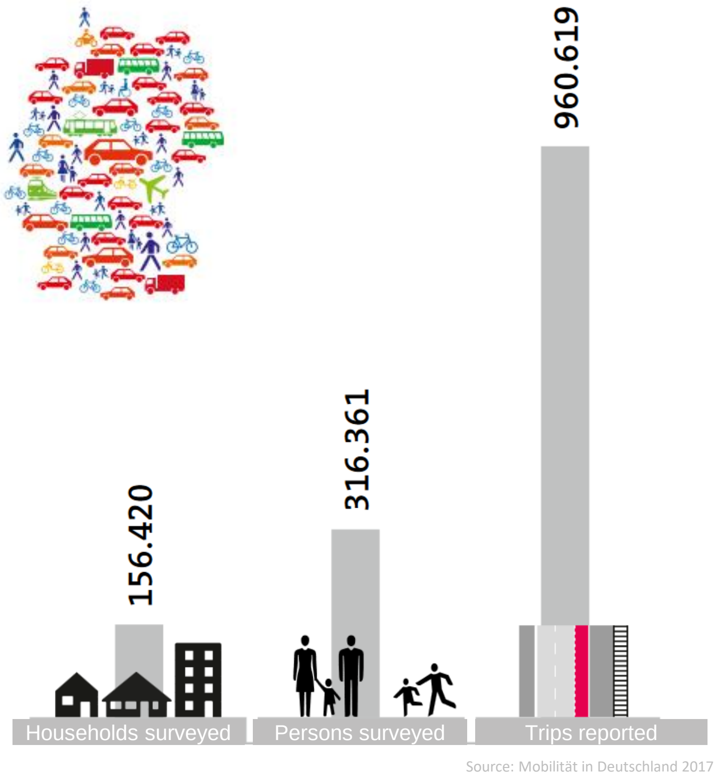
For each category, an exemplary LEV model that is (soon) available on the market serves as basis for definition of technical parameters. These parameters are needed for evaluation of trip substitution potential and emission reduction.

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

Trip Substitution Potential



Data Base to identify the Substitution Potential of current Car Trips



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

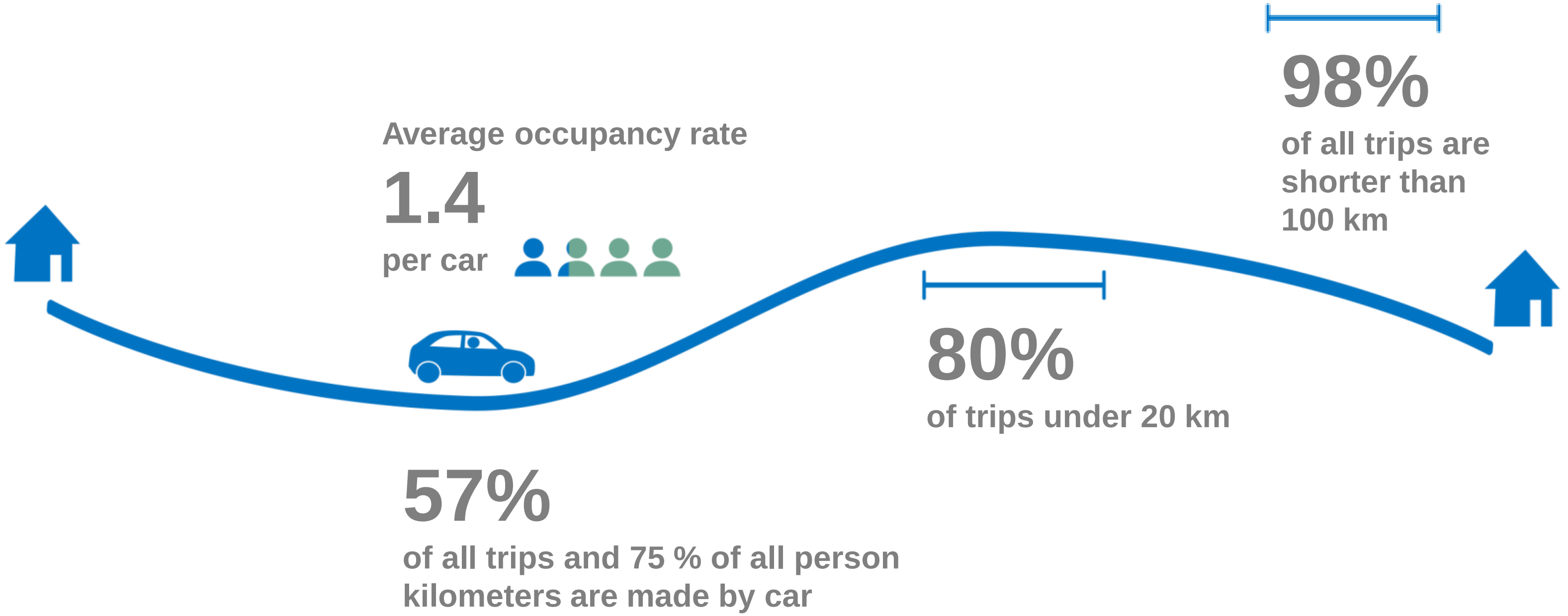
- German national travel survey
- Conducted 2002, 2008 and 2017; planned for 2023

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

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*:



Emissions, mileage & trips

- emissions correlate primarily with mileage, not number of trips
- few long trips cause a relatively high share of emissions, but still:
- 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.

Methodological Approach to identify the Substitution Potential of LEVs

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

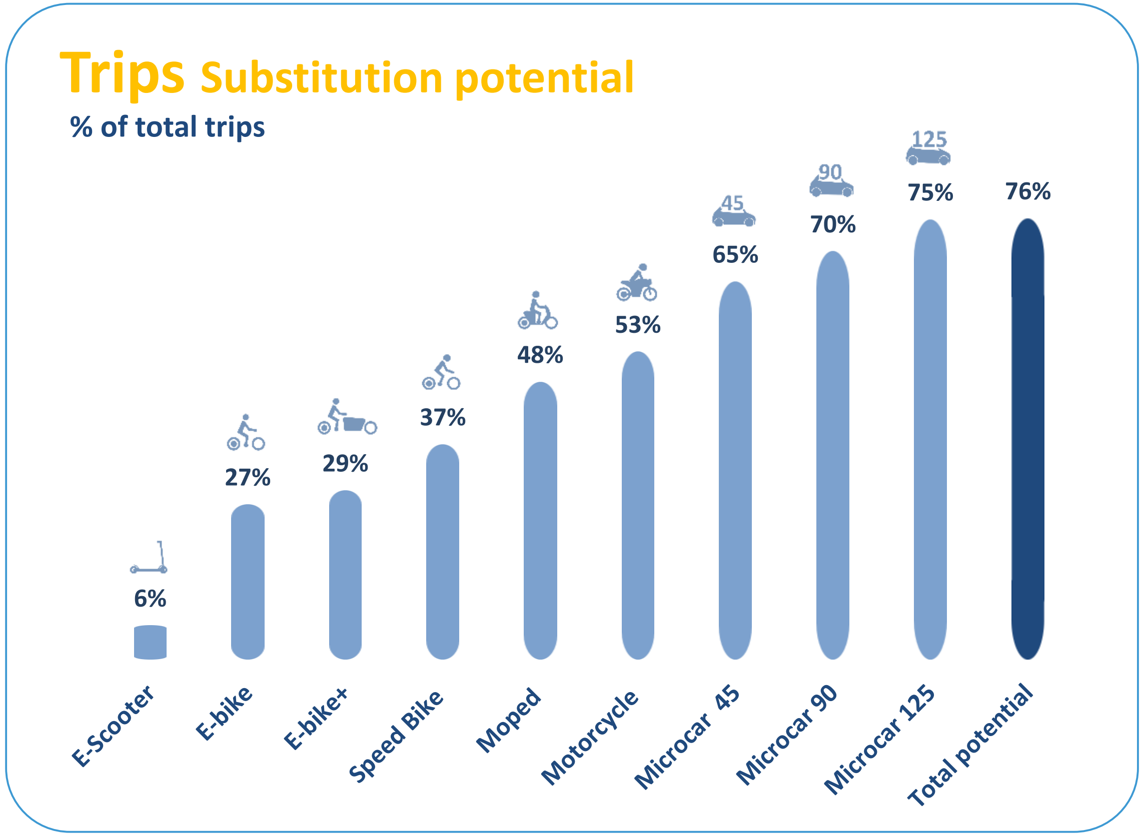
To decide whether each motorised trip could be undertaken using an LEV, trip characteristics are compared with LEV properties*. For example, whether any LEV has enough seats for the group making the trip or whether the trip length is possible. The following shows a worked example.

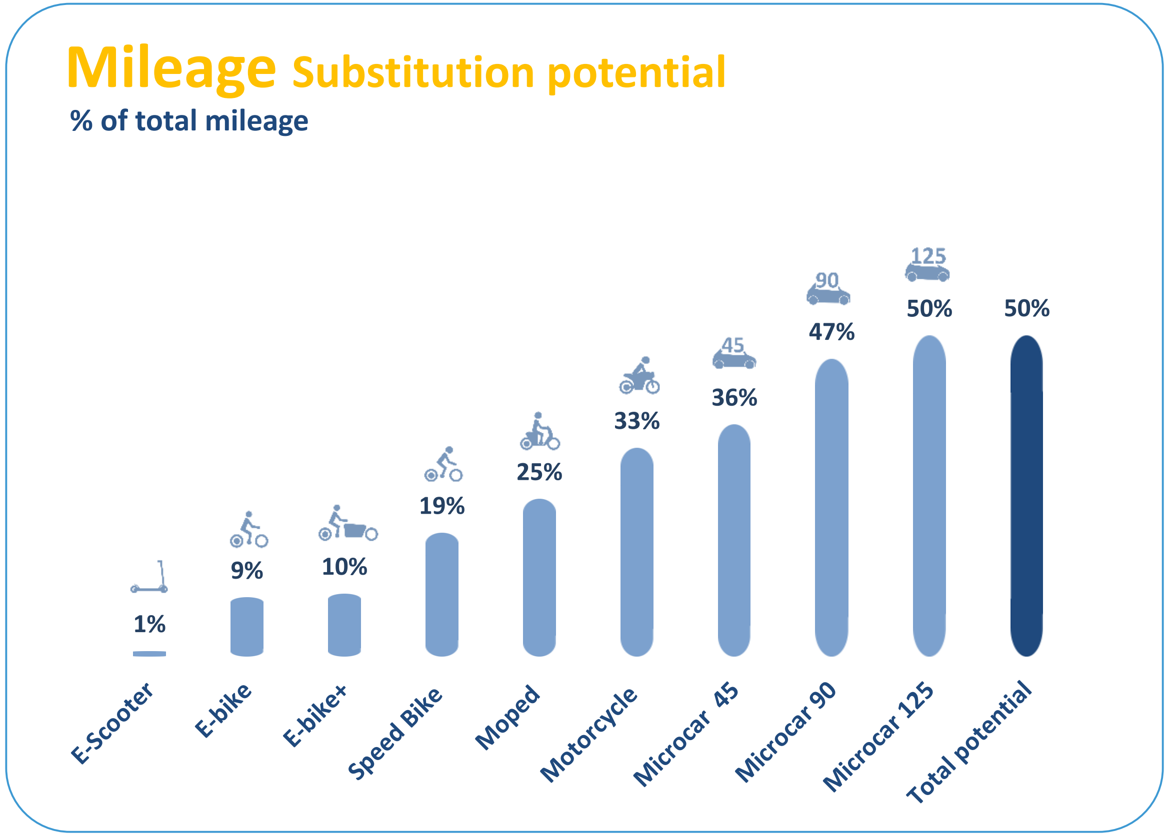
Criteria	**Exemplary trip** reported in the large-scale National Mobility Survey in Germany (MID 2017)	**Scenario E-bike+** E-bike+ is used here to explain our methodological approach. Same procedure with all selected vehicles.	check
Trip length	8 km (one-way)	Up to 15 km (single trip), up to 30 km round 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.

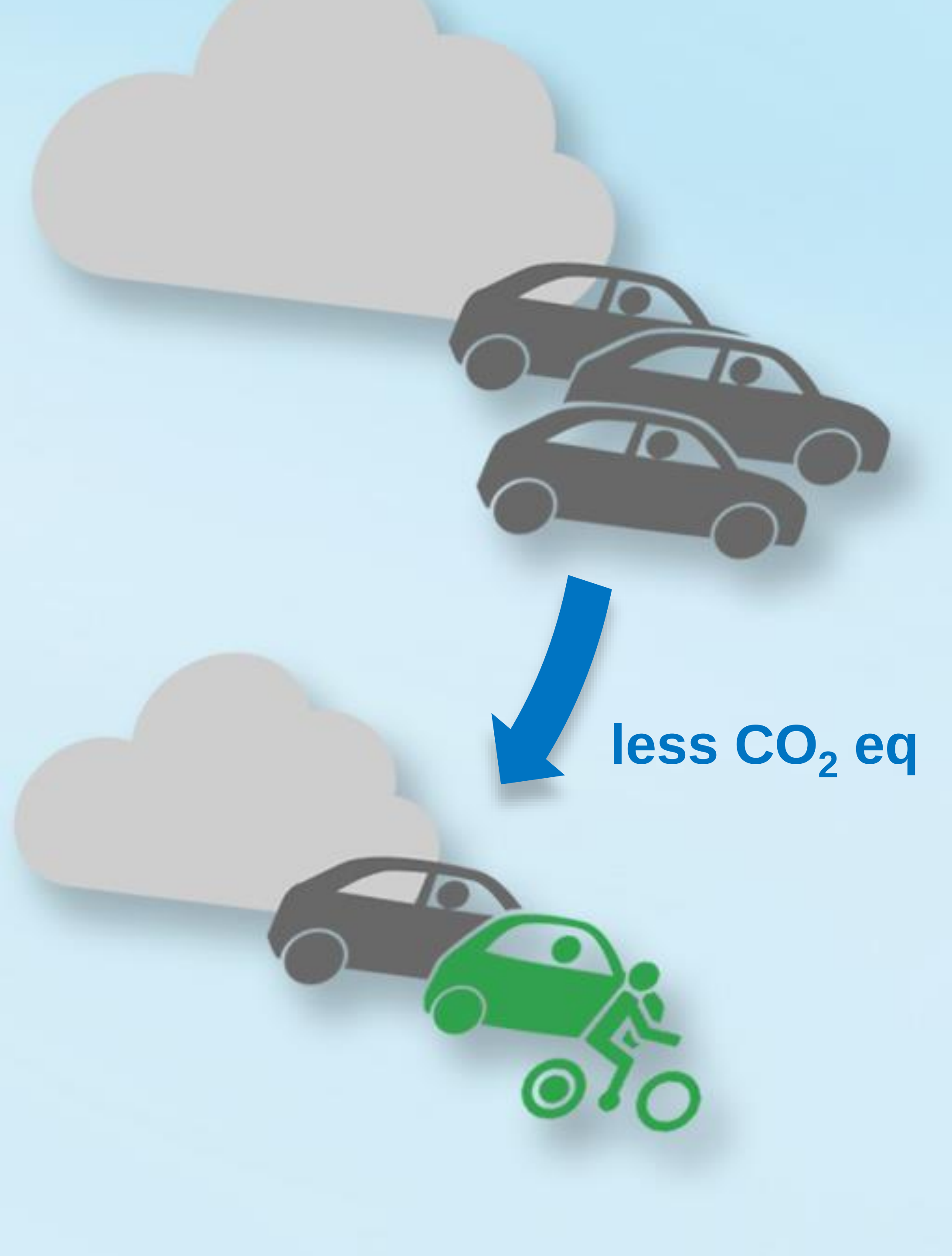




Read: For example, a Microcar 125 vehicle (max. speed 125 km/h) could in theory be used to undertake 75 % of motorised trips. In effect therefore, given it has broadly the greatest capabilities of all LEVs, this almost equals the maximum absolute substitution potential.

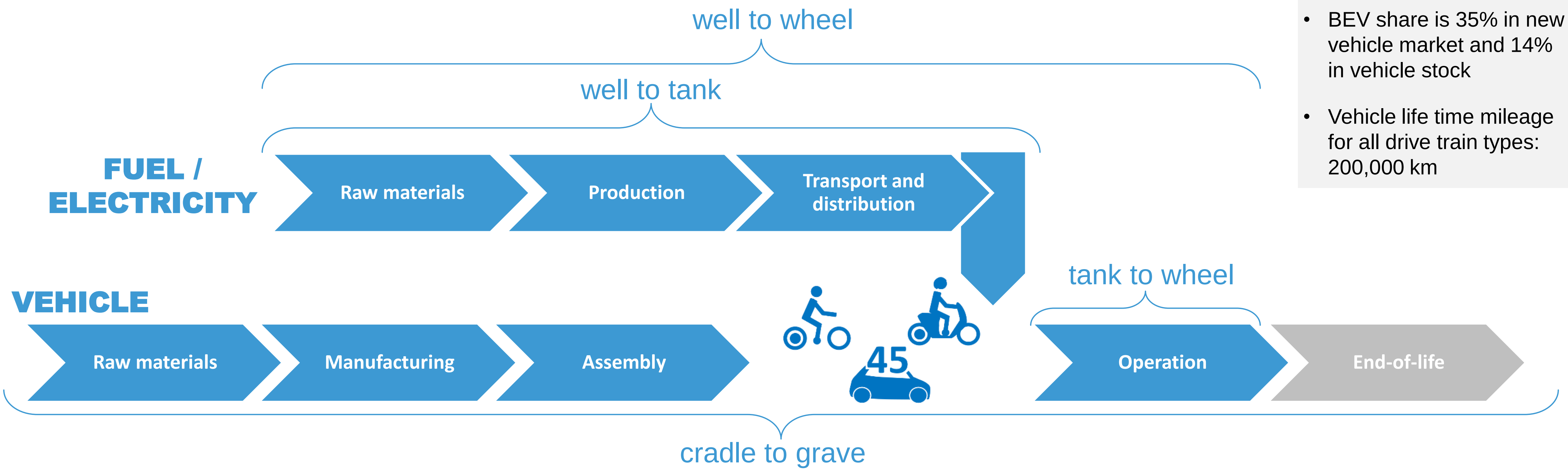
DLR

Emission Reduction Potential



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



Passenger Cars

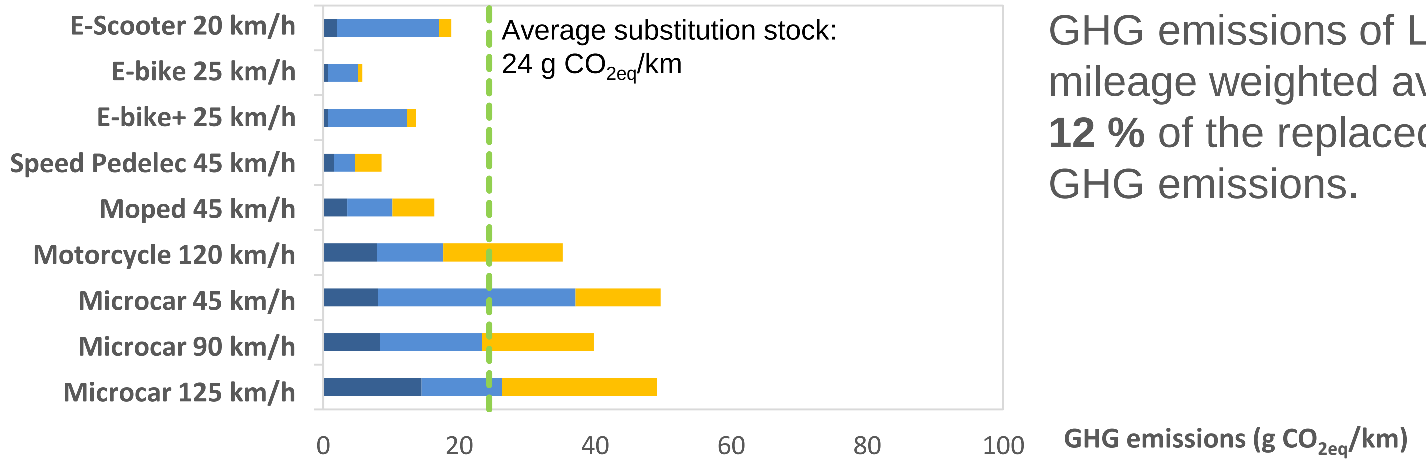
- Passenger car market: Trend scenario for 2030*
- ICE vehicles still dominate vehicle stock
- BEV share is 35% in new vehicle market and 14% in vehicle stock
- Vehicle life time mileage for all drive train types: 200,000 km

* Kopernikus-Projekt Ariadne 2021

DLR

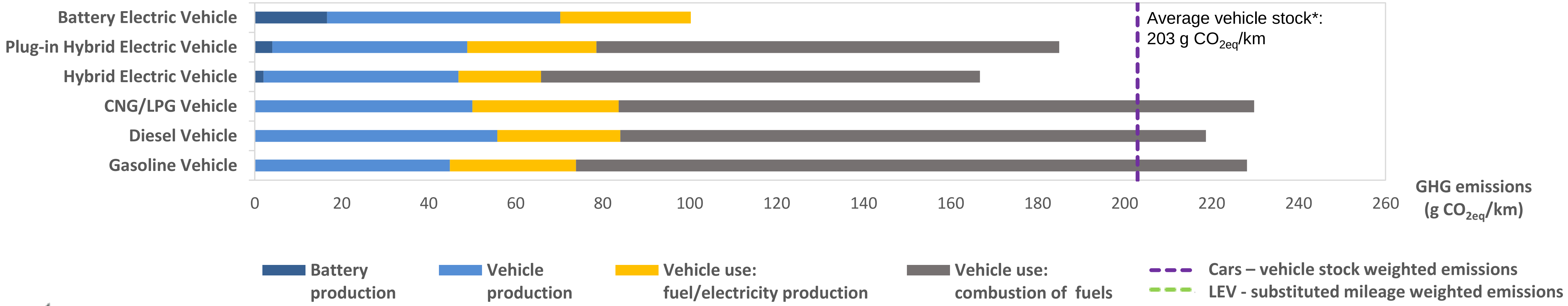
Results: Life Cycle Emissions per Kilometer

LEVs



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

Passenger cars



* Kopernikus-Projekt Ariadne 2021

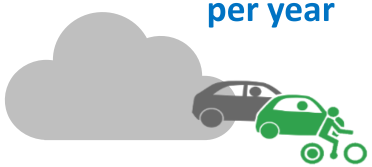
Results: Greenhouse Gas Emission Reduction Potential by LEV Substitution

CO_{2eq} emissions before LEV substitution

130 million tonnes per year

CO_{2eq} emissions after LEV substitution

73 million tonnes per year



44% Emission reduction potential contributed by

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

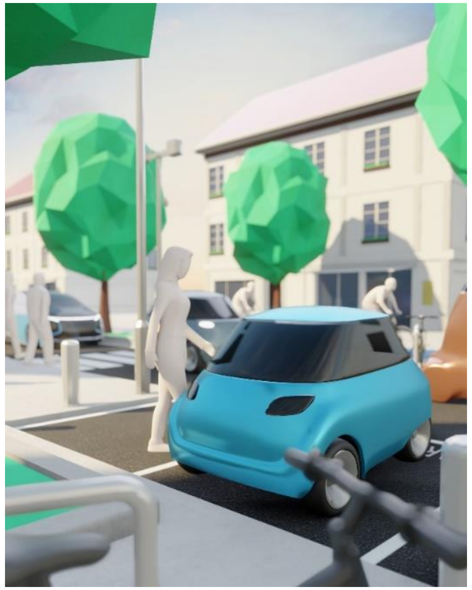
In absolute numbers:

- 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

Summary and Discussion

- **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:** 75 % trip substitution potential might seem high first glance, but considering that 80 % of the trips are less than 20 km, the result is plausible.
- **Variation of input parameters:** discover various scenarios with an interactive **online-tool**
- **Realisation of potential:** achieving even part of this potential will require fundamental changes to encourage a switch away from long-standing mobility habits, including push and pull measures.
- **LEVs and other paths to sustainable mobility:** many approaches must work together, LEVs as one building block in the approach:

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.

Need for research:

- What specific changes are necessary to realise a significant proportion of LEVs' emissions-reduction potential?
- 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?

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.

German Aerospace Center for LEVA-EU

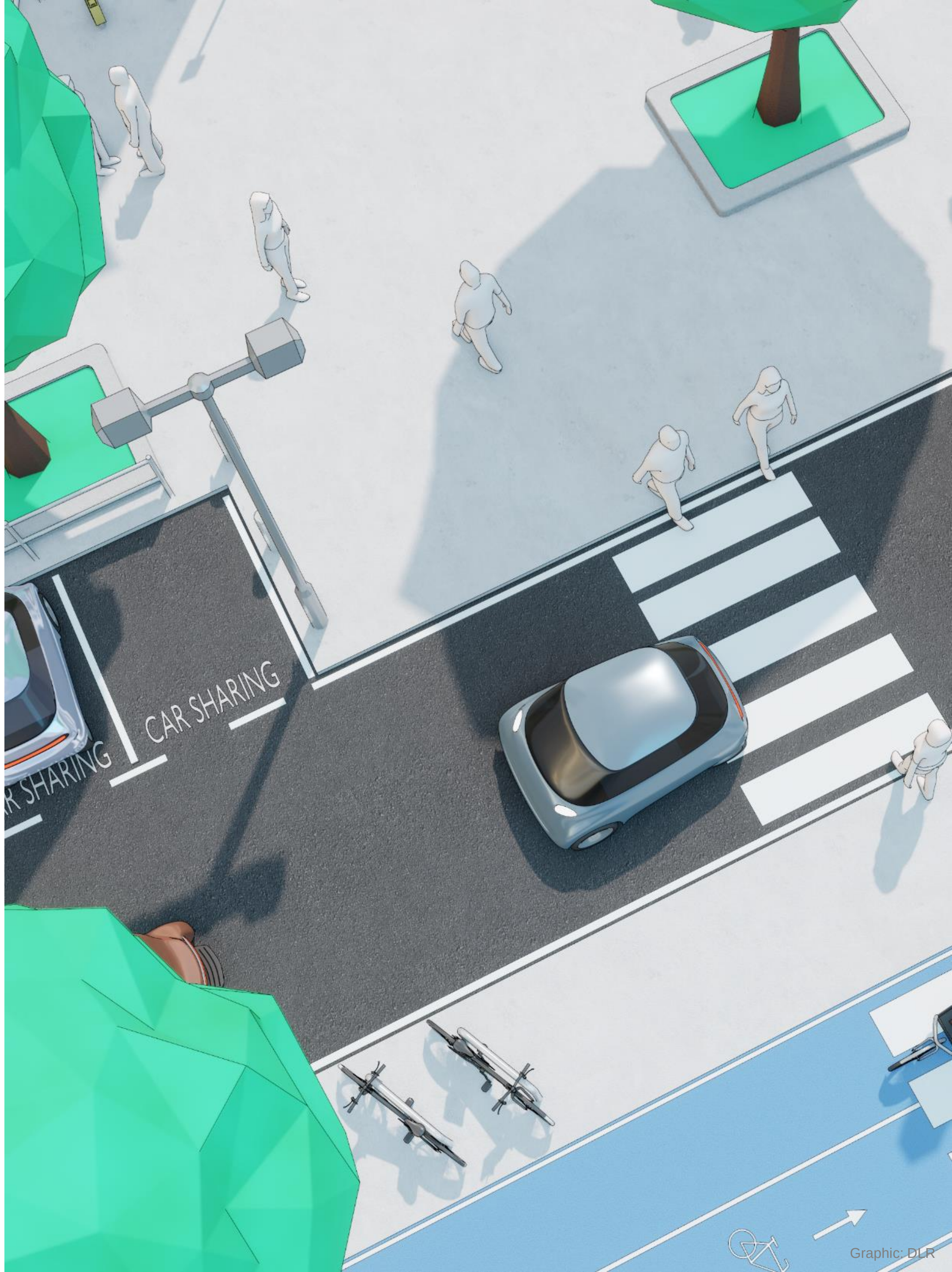
Authors:
Mascha Brost, Simone Ehrenberger, Isheeka Dasgupta, Robert Hahn
DLR Institute of Vehicle Concepts
Laura Gebhardt, Robert Seiffert
DLR Institute of Transport Research

Cite as: Brost, M.; Gebhardt, L.; Ehrenberger, S.; Dasgupta, I.; Hahn, R.; Seiffert, R. (2021): The Potential of Light Electric Vehicles for Climate Protection Through Substituting for Passenger Car Trips – Germany as a case study. Projectreport.

Sponsors:

Superpedestrian

PODBIKE



Graphic: DLR

BACKUP

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 CO2 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]

DLR

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 motorized 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

Consideration of LEV Properties 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)

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

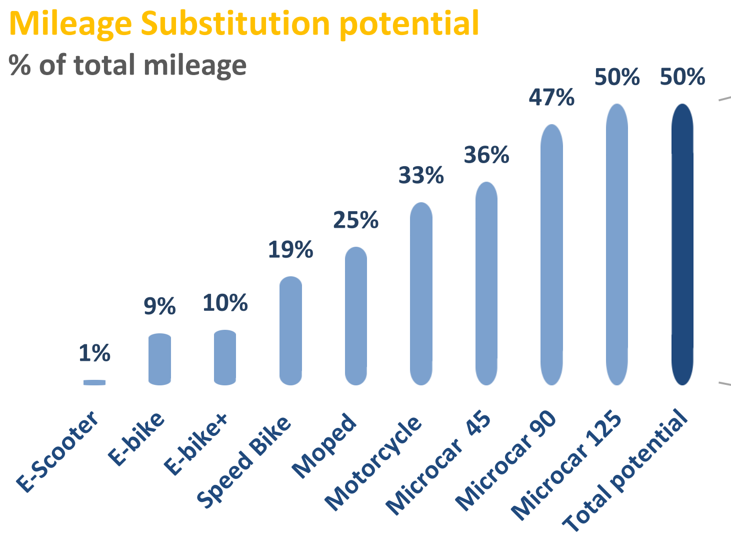
The parameters shown represent only a selection of the criteria specified in the regulation. The regulation is available via:
Regulation (EU) No 168/2013 on the approval and market surveillance of two- or three-wheel vehicles and quadricycles

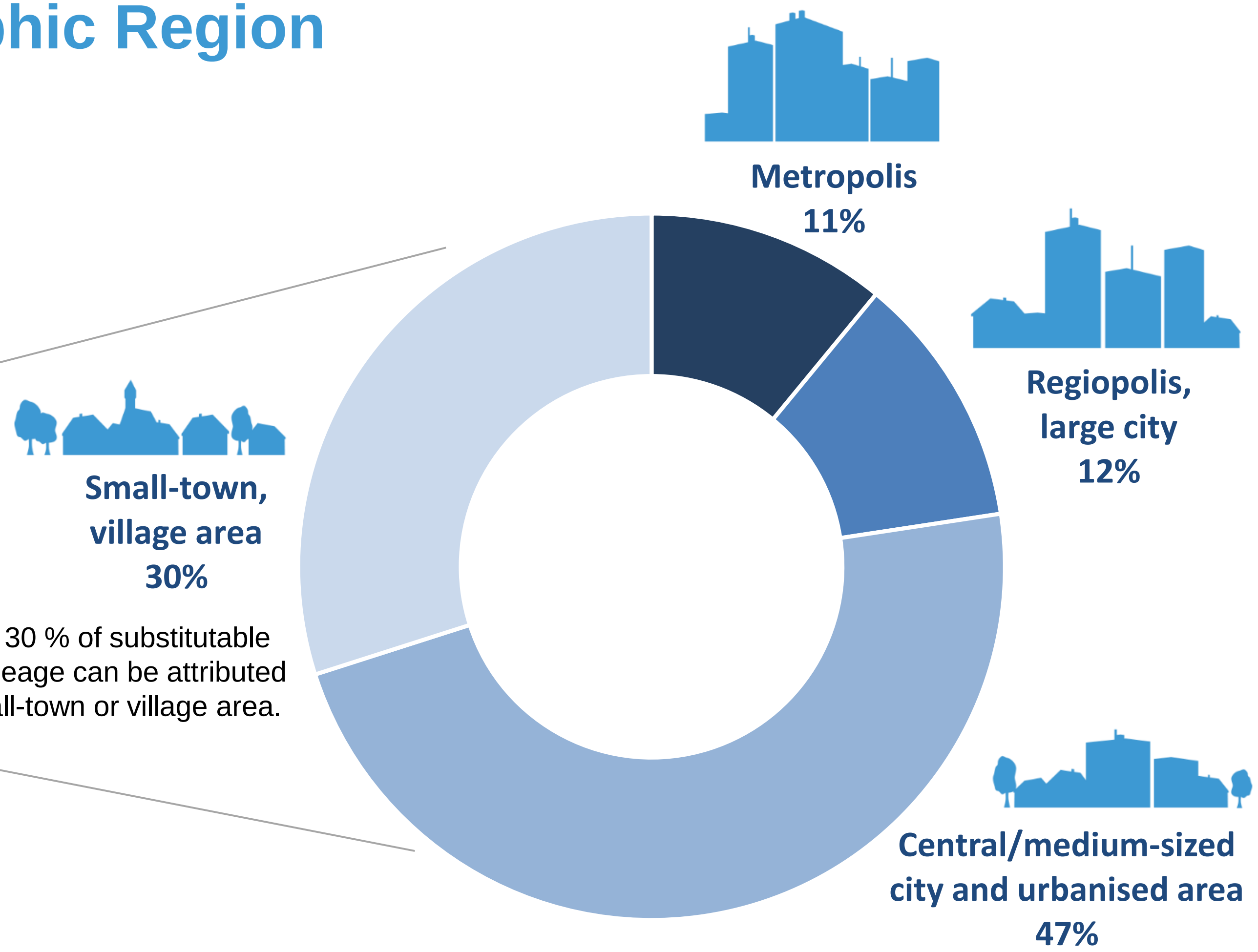
* BP: passenger transport, BU: utility purposes **mass in running order without propulsion batteries

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.

Methodology: Emissions Modelling

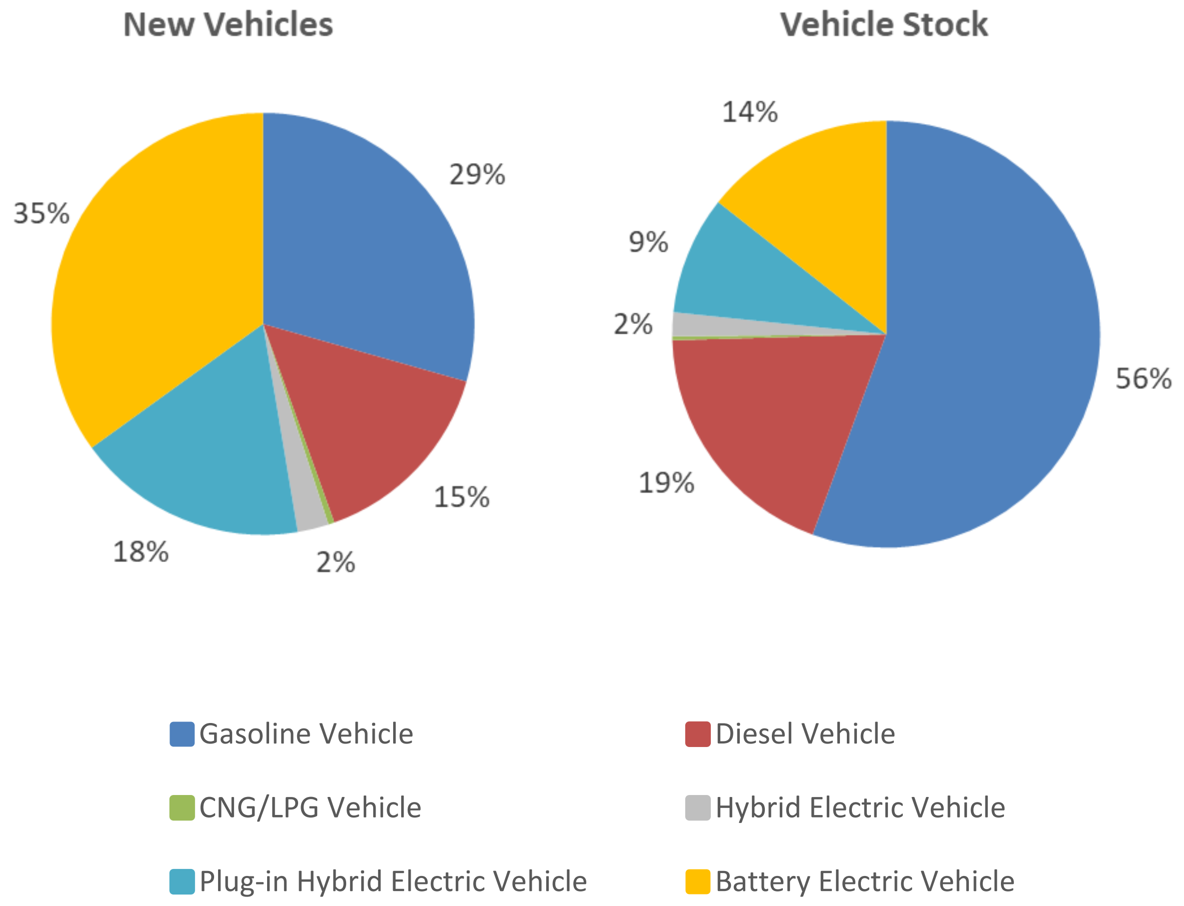
LEVs

- 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

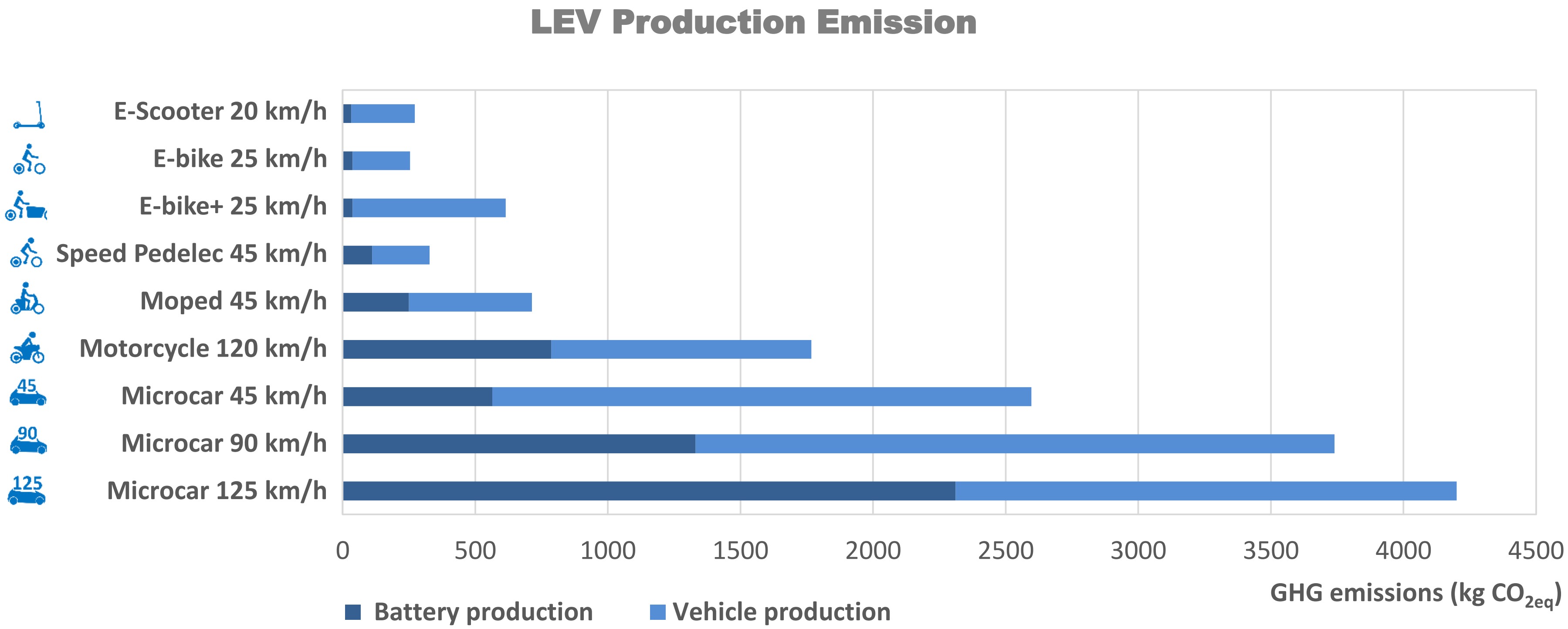
- Passenger car market: Trend scenario for 2030*
- ICE vehicles still dominate vehicle stock
- BEV share is 35% in new vehicle market and 14% in vehicle stock
- Vehicle life time mileage for all drive train types: 200,000 km



* 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