

DEVELOPMENT OF BATTERY DEMAND AND PRODUCTION FOR SPECIALTY APPLICATIONS

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**Track 2: EV Technology
for Specialty Vehicles**

Outline

1

Global Battery Demand 2015/2016 and Outlook

2

Global Battery Production 2015/2016 and Outlook to 2025

3

Technology Development and Cost reduction Potentials

4

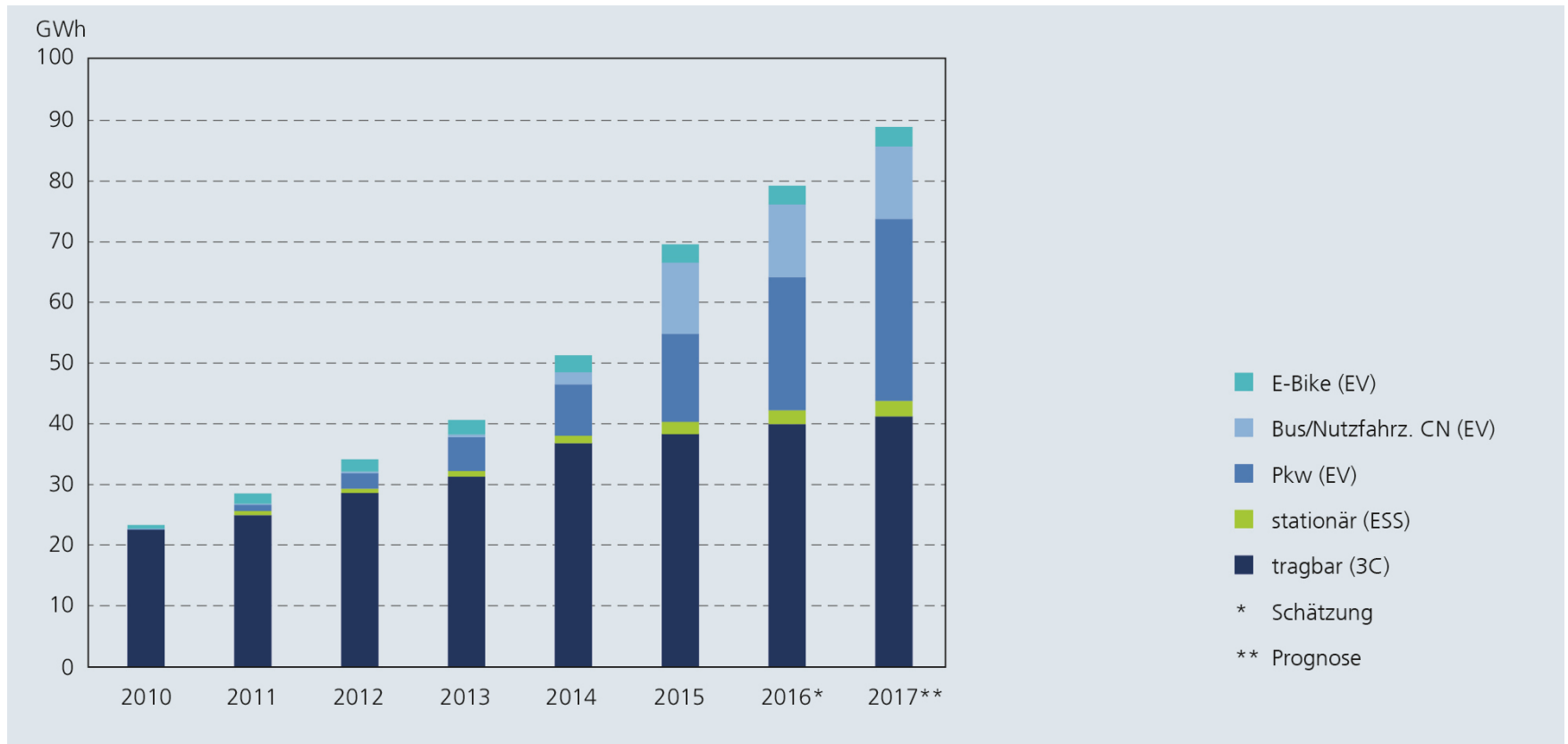
Batteries for Specialty Applications

5

Summary and Conclusions

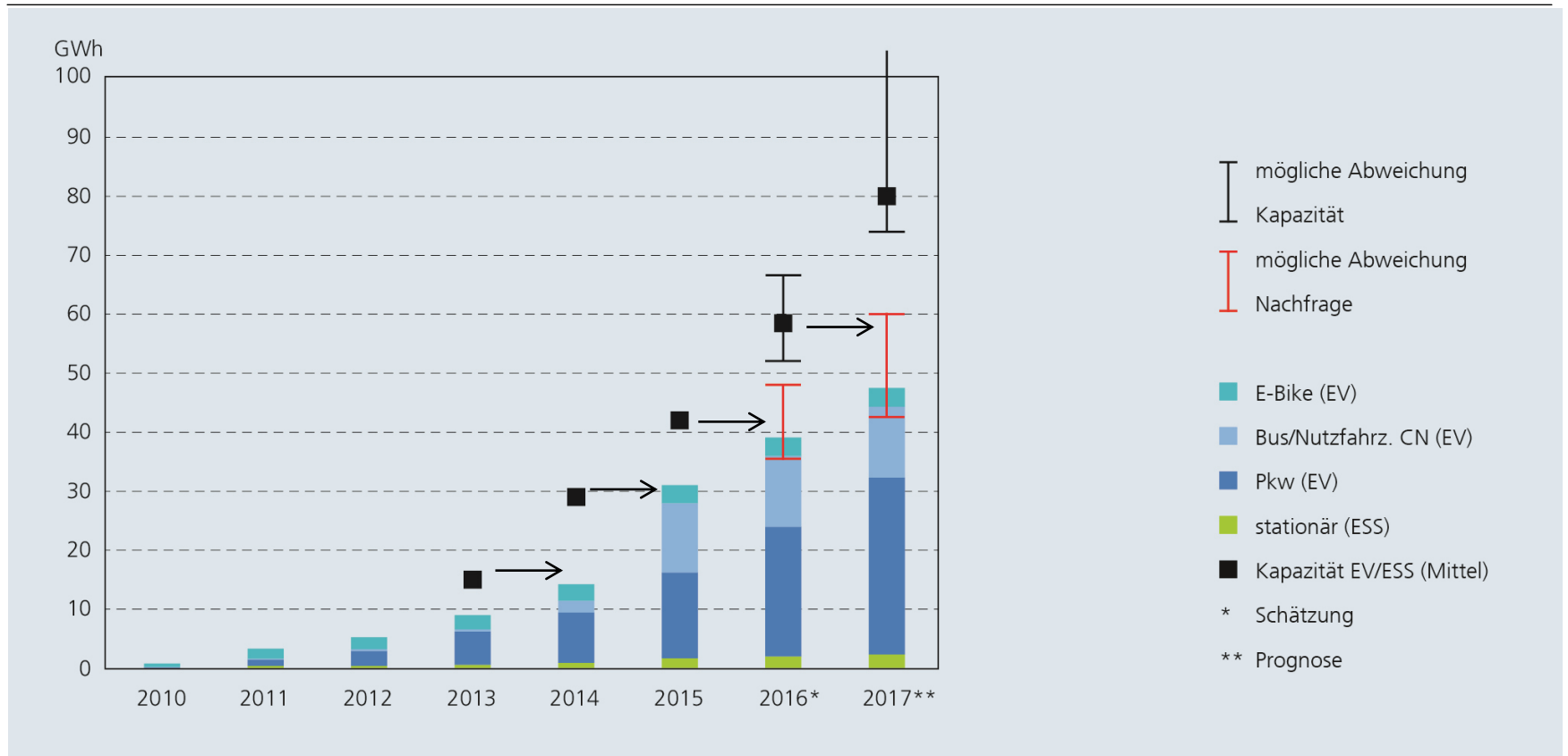
Global LIB Demand in GWh and Dynamics

Growth: 3C ~8-10%, ESS >30%, PKW/Passenger Cars ~40%, Commercial Vehicles*, ebikes 5-10%



Source: Thielmann, A.; Friedrichsen, N.; Hettesheimer, T.; Hummen, T.; Sauer, A.; Schneider, C.; Wietschel, M. (2016): Energiespeicher-Monitoring 2016. Deutschland auf dem Weg zum Leitmarkt und Leitanbieter? Karlsruhe: Fraunhofer ISI.

Global LIB Demand vs. Cell production capacity for EV and ESS applications



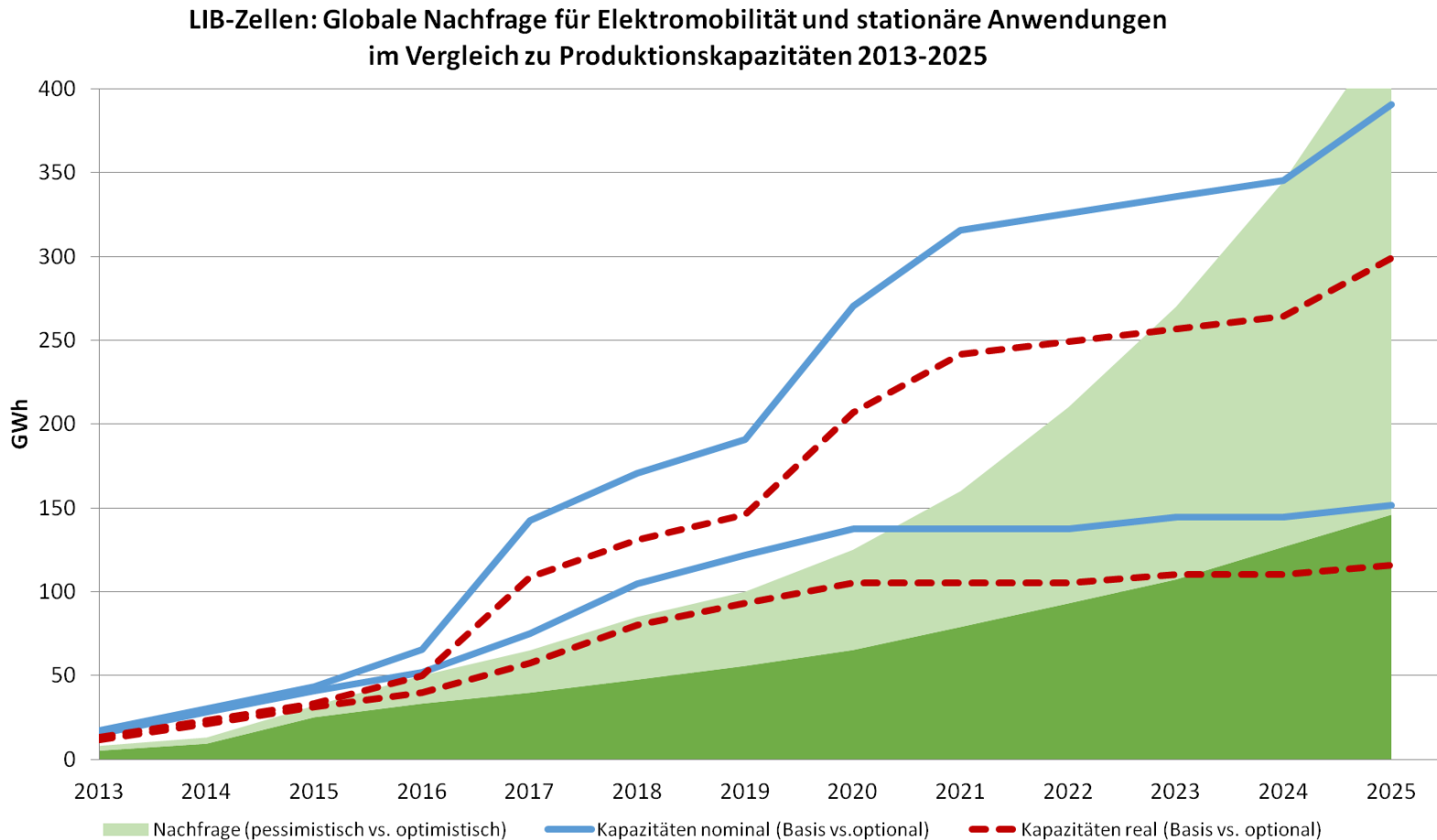
Includes 18650 cells (e.g. Tesla, Ebikes, partially ESS and vehicles in CN) as well as large format prismatic, pouch cells with similar share (2015/2016).

Capacity of a given year fits to the demand of the following year (no over capacities!)

Thielmann, A.; Friedrichsen, N.; Hettesheimer, T.; Hummen, T.; Sauer, A.; Schneider, C.; Wietschel, M. (2016): Energiespeicher-Monitoring 2016.

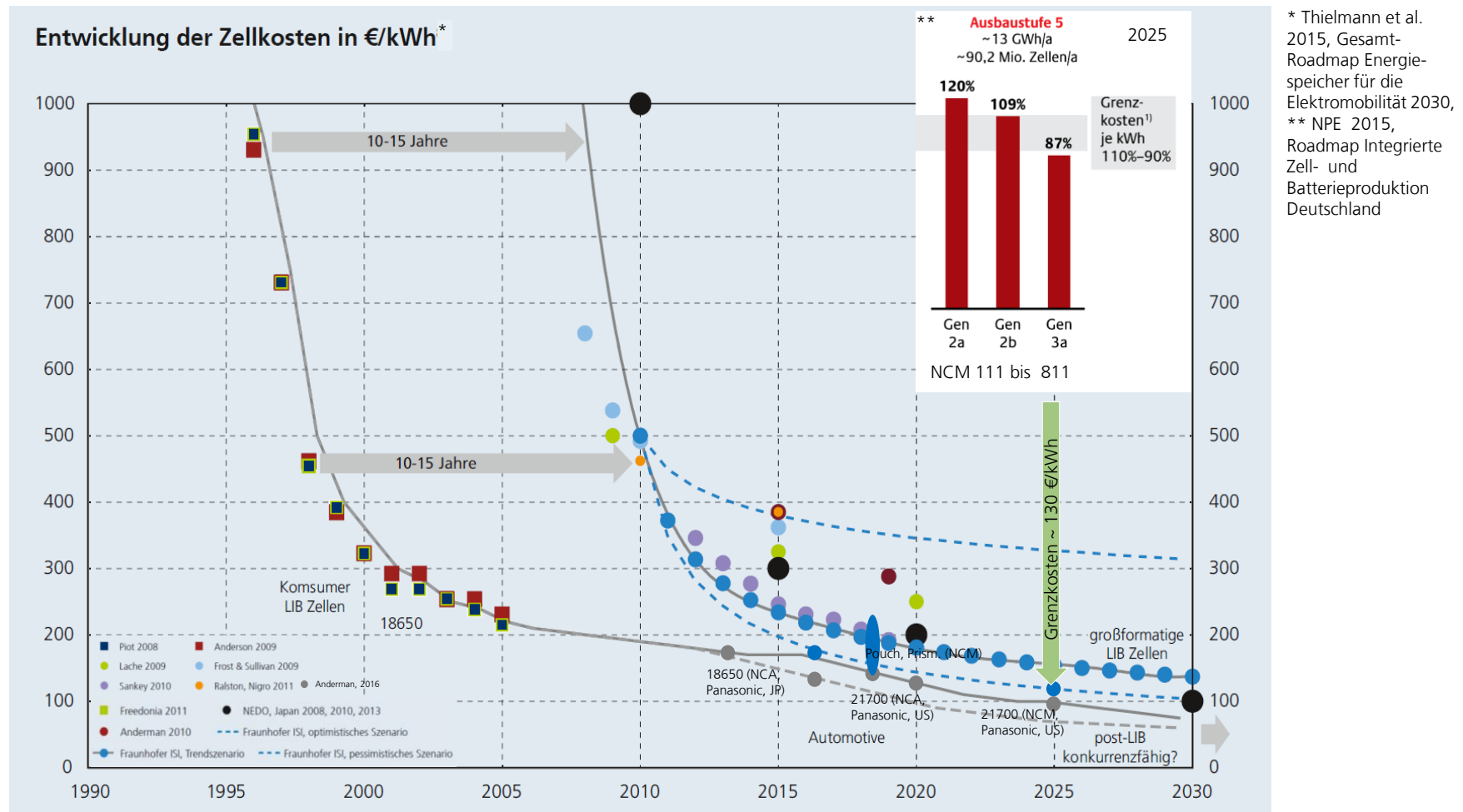
Deutschland auf dem Weg zum Leitmarkt und Leitanbieter? Karlsruhe: Fraunhofer ISI.

LIB Scenarios for Demand (green) vs. Capacities (blue) & Production (red) – scale up & drop costs



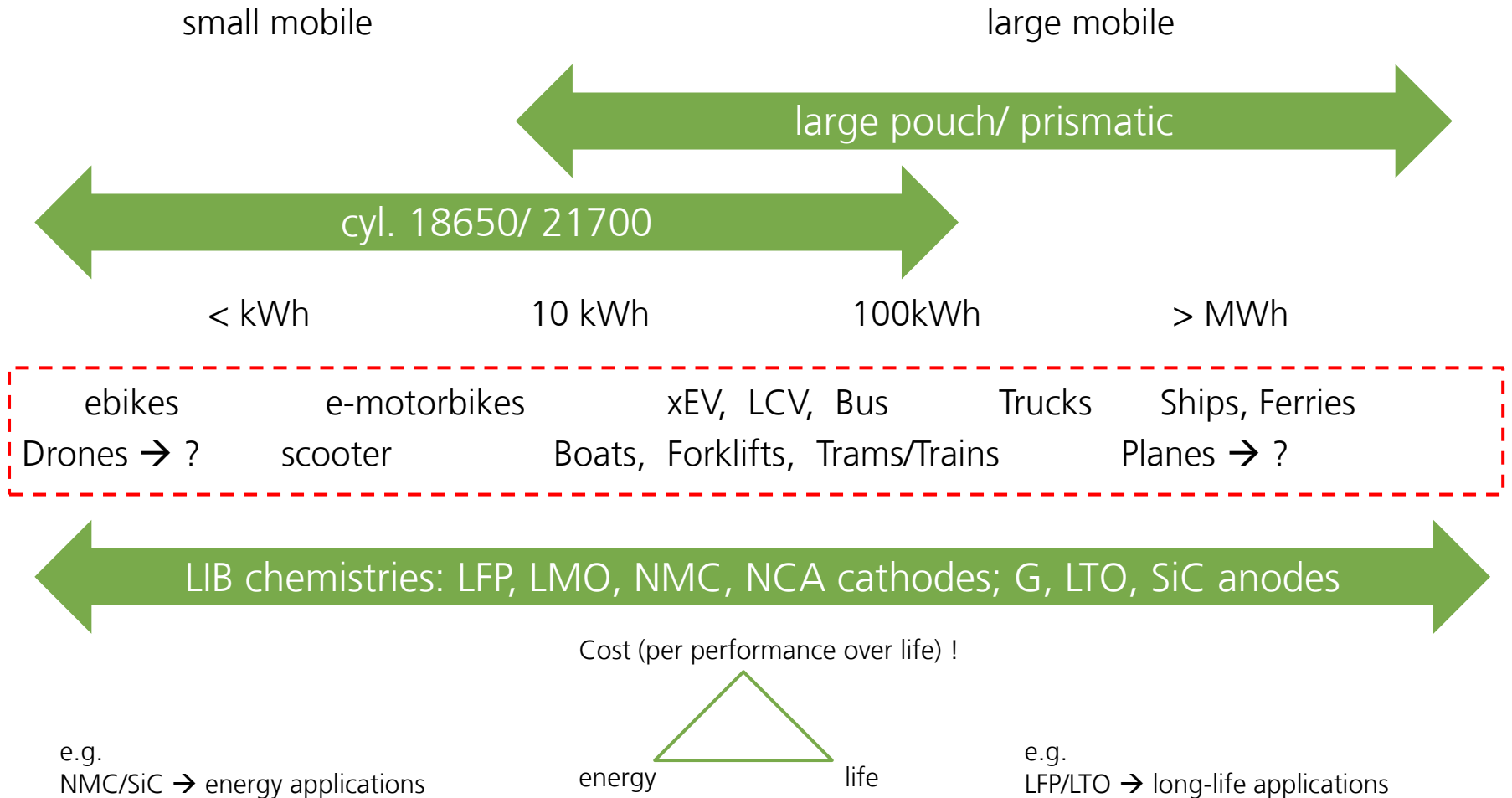
Michaelis, S.; Maiser, E.; Kampker, A.; Heimes, H.; Lienemann, C.; Wessel, S.; Thielmann, A.; Sauer, A.; Hettesheimer, T. (2016): VDMA Batterieproduktion, Roadmap Batterie-Produktionsmittel 2030, Update 2016. Frankfurt: VDMA Verlag GmbH.

Cost reduction potential for large format LIB due to scaling, technol. developm., engineering, ...



* Thielmann et al. 2015, Gesamt-Roadmap Energiespeicher für die Elektromobilität 2030,
** NPE 2015, Roadmap Integrierte Zell- und Batterieproduktion Deutschland

Suitable formats and cell chemistries across applications and battery sizes

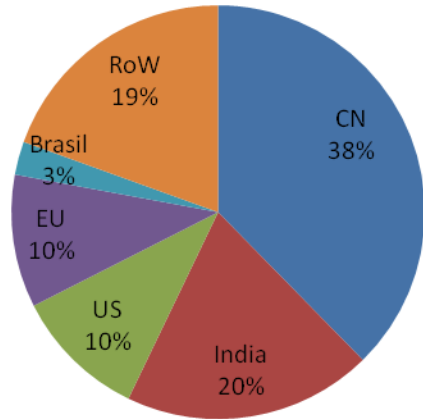


E-bikes – today ~200 Mio ebike stock (Pb/LIB)

Pb-substitution in CN; EU LIB-bike markets maturing; ~5% LIB-bike share

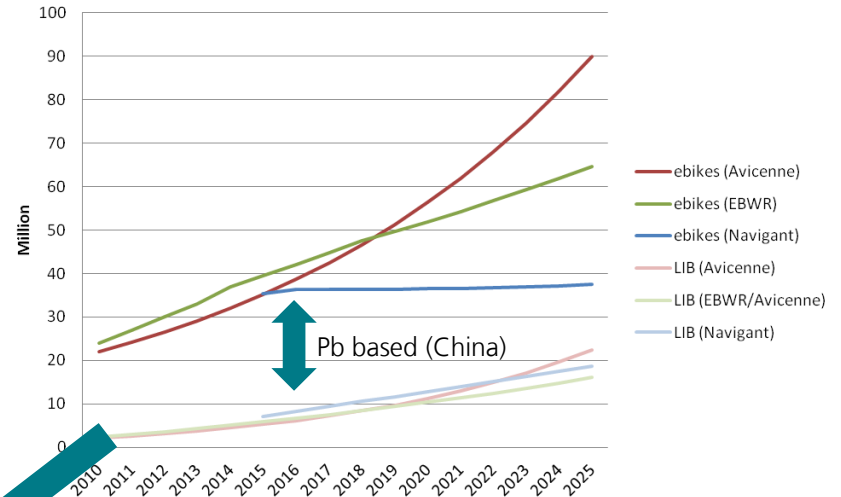
Global annual Bike Market (2010-2015)

~130-150 Mio bikes

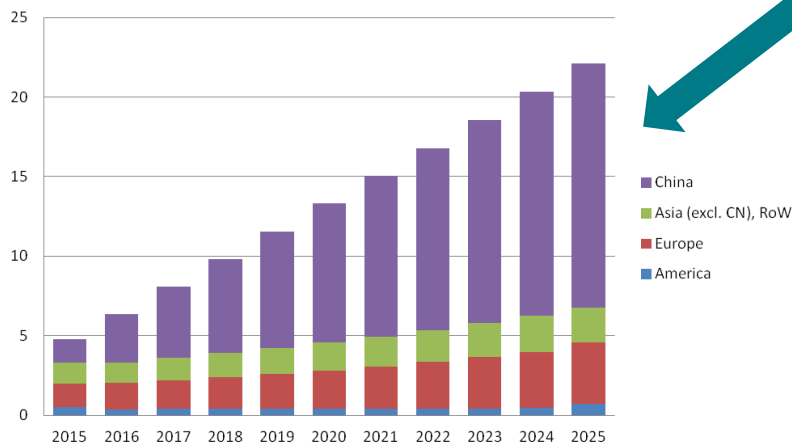


Bike stock
2010/2011
~1600 Mio.

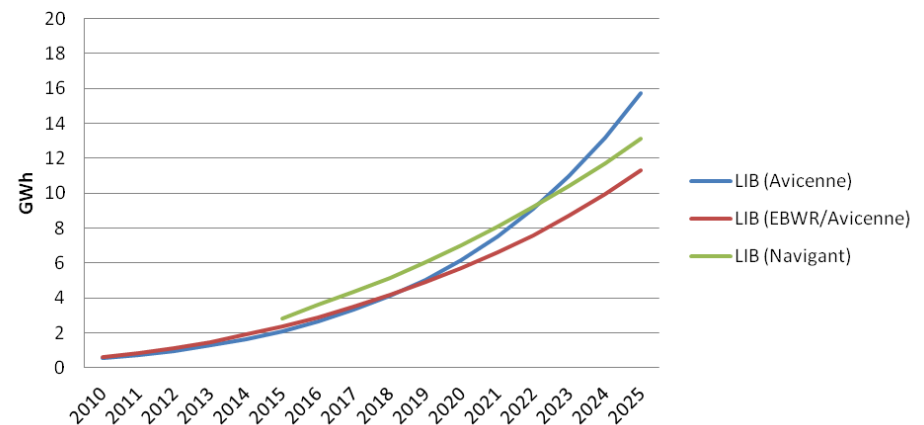
Global ebike sales forecasts



LIB based ebike sales forecast by region (in Million)

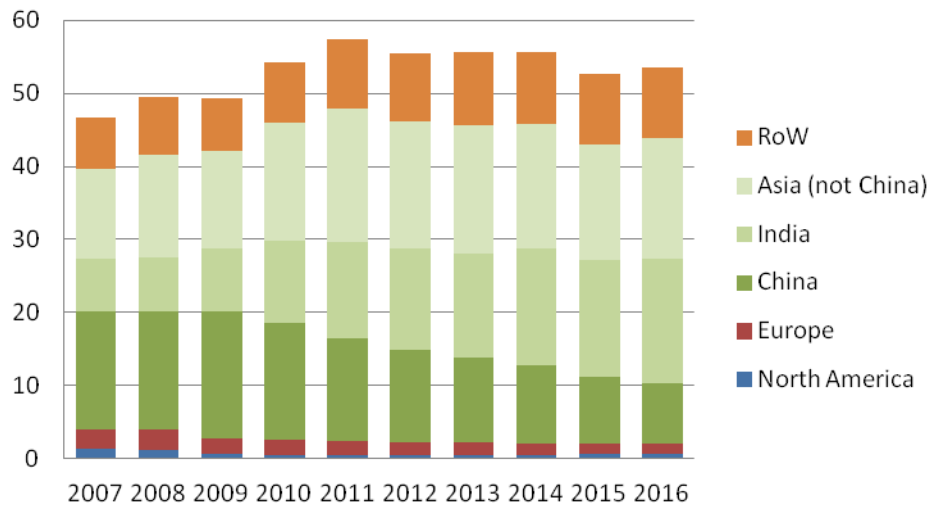


Global LIB cell demand forecast for ebikes



E-scooter/ e-motorbikes – strong market growth expected (LIB), currently ~1% share

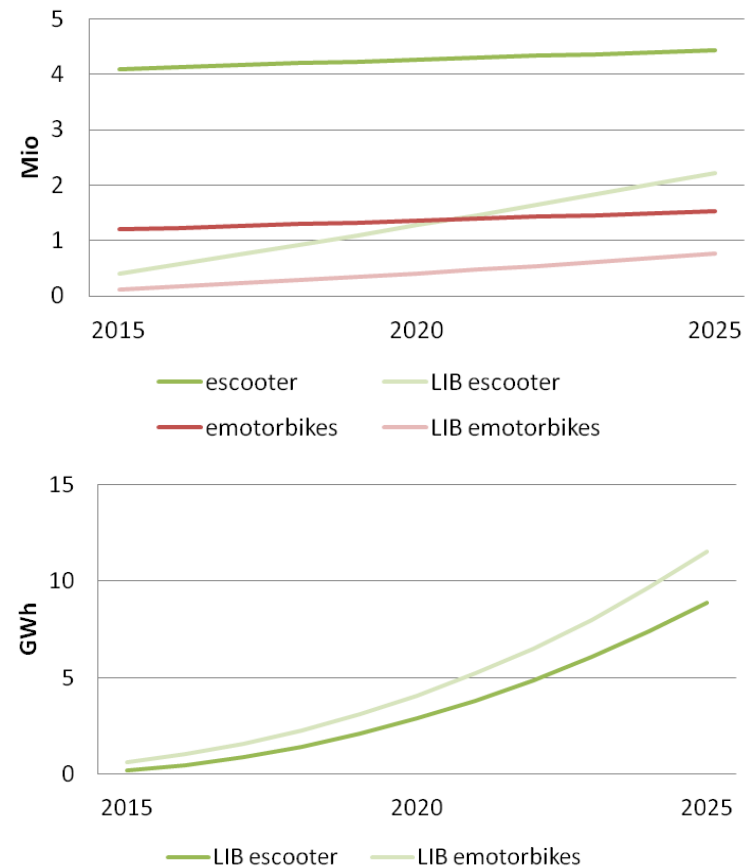
Global motorcycle demand (in Mio)



Source: Marklines and Yamaha

Escooter and emotorbike sales currently mainly in China (Pb based), other regions expected to increase demand in the next 10 years (increasing sales in Europe, e.g. 5.451 in France 2016)

Global escooter/emotorbike demand

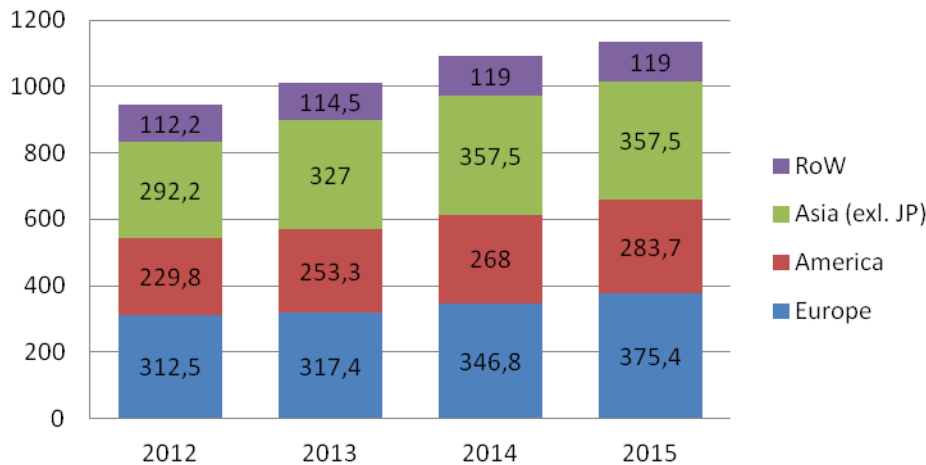


Escooter/emotorbike forecasts from Navigant 2015: <https://www.navigantresearch.com/research/electric-motorcycles-and-scooters>

LIB penetration estimated similar to ebikes (from Pb to LIB), escooter <1-4 kWh, emotorbikes 5-15 kWh

Industrial (Forklifts): > 1 Mio annual forklift sales – LIB-based forklift market ~1% in 2015

Global Forklift sales (in Tsd units)



The CAGR of the global forklift market has been 4-8% in the last years

The share of E-Forklifts is estimated globally at >10% (i.e. >100.000/ year), estimated Pb:LIB ratio 9:1, i.e. ~10.000 LIB based forklifts with 20-25 kWh

LIB market for E-forklifts in 2015 estimated at ~ 0,2-0,25 GWh

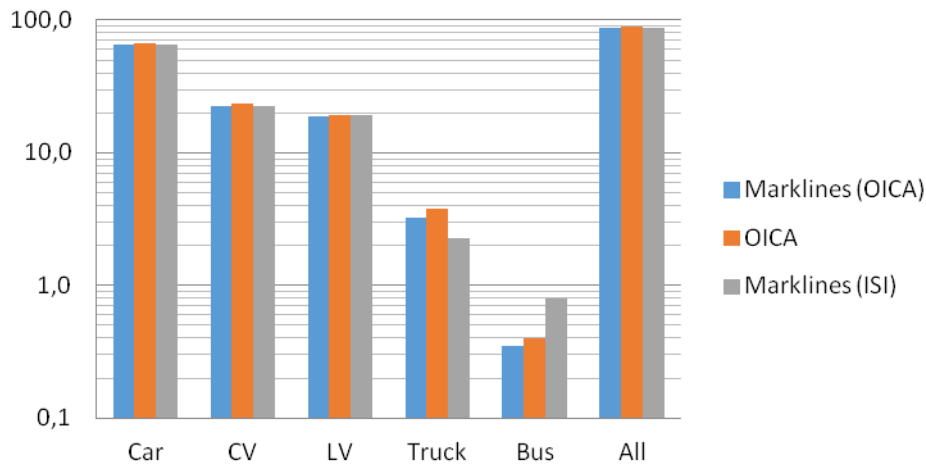
Source: National Warehouse Equipment, 2015 Year in Review | Annual Forklift Industry Report | www.nationalwarehouse.com

Potential LIB cell demand 2025: >2-3 GWh (at least tenfold increase)

Potential longterm demand: > 20-30 GWh

Global Vehicles – Passenger Cars (BEV/PHEV) provide largest market potential for LIB

Vehicle Sales in Mio. (2015)



Global car/vehicle sales in 2015 have been on the level of 87-89 Mio.

- Passenger cars 65-66 Mio.
- Commercial vehicles 22-23 Mio. thereof
 - Light com. Veh. ~18,7-19,2 Mio
 - Trucks 2,3-3,8 Mio
 - Buses 0,4-0,8 Mio

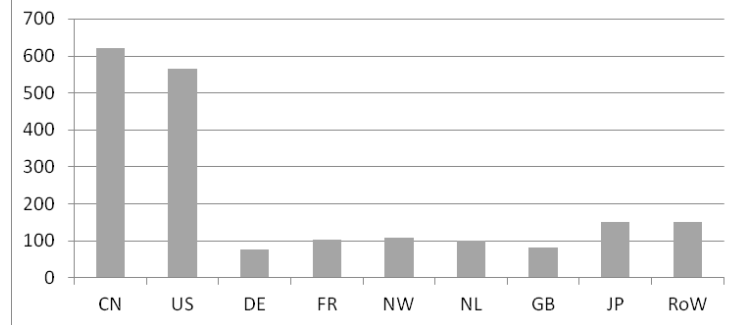
Strong dependence on typisation (References: OICA, Marklines with different vehicle typisations)

BEV/PHEV sales 2016 0,7-0,8 Mio (→ ~1% share)

LIB demand 2015 ~14 GWh, 2016 ~ 20 GWh

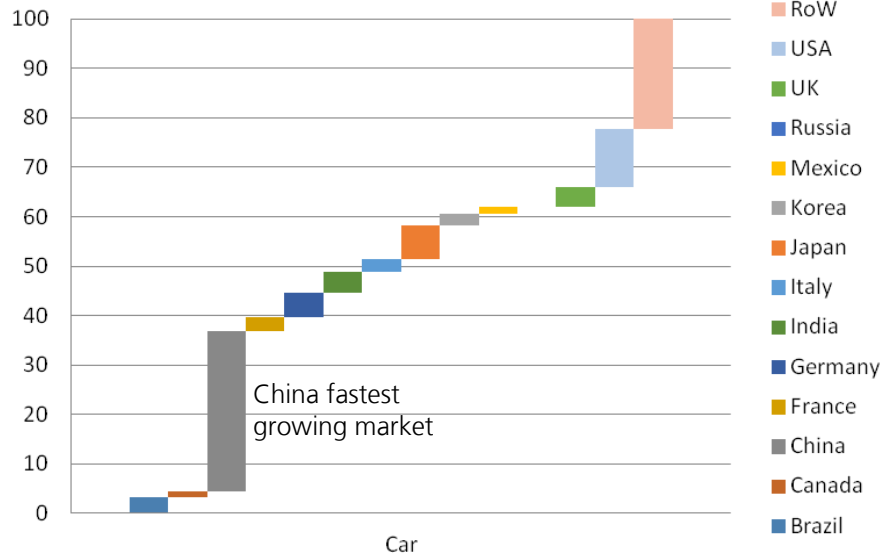
LIB demand 2025 forecasts range: 100-400 GWh

Cumulative BEV/PHEV sales until 2016 (~2 Mio)



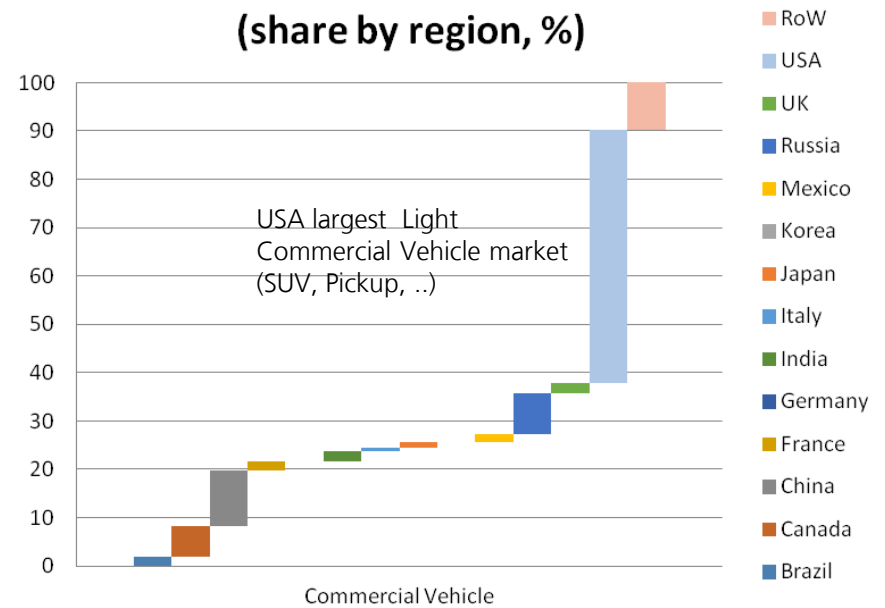
Commercial Vehicles provide next highest market potential after Passenger Cars

**Global Passenger car sales in 2015
(share by region, %)**



Source: Marklines and OICA, Sales: 65-66 Mio

**Global Commercial Vehicle Sales 2015
(share by region, %)**

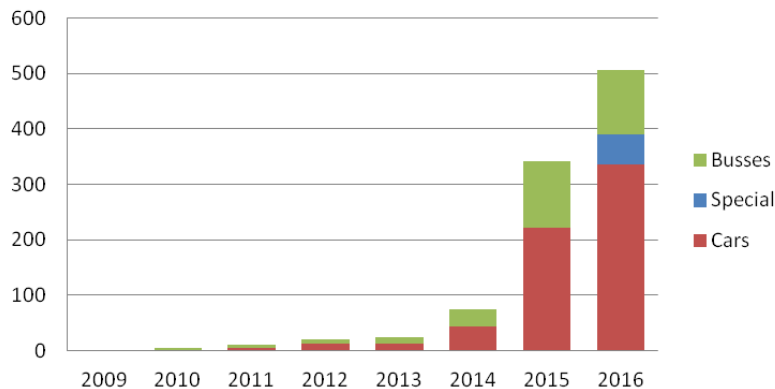


Source: Marklines and OICA, Sales: ~19 Mio

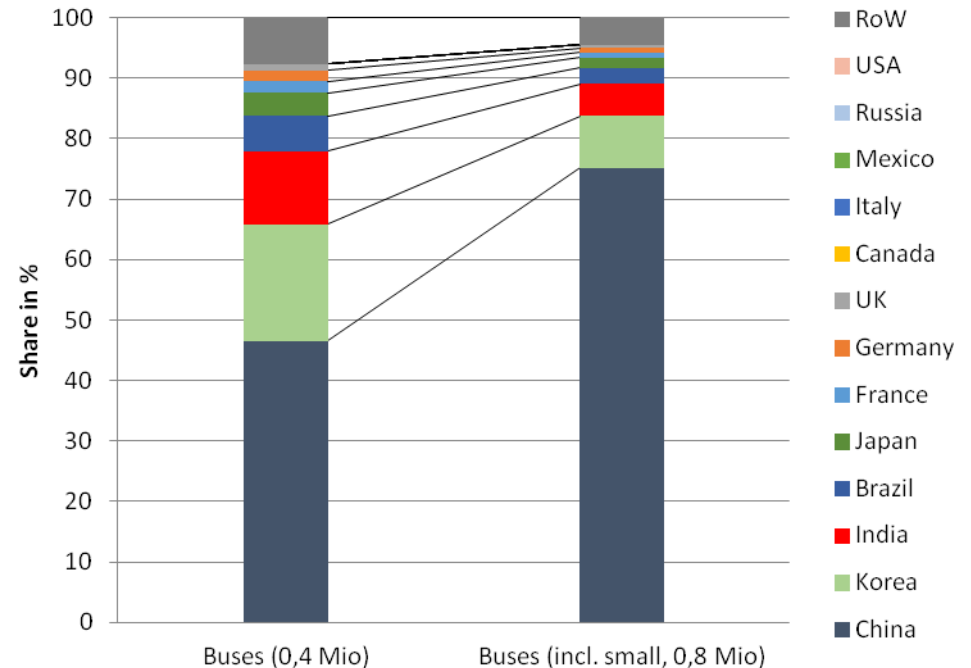
Buses – China is the lead market for E-Buses, other world regions at ~1% share (E-B. vs. B.)

- China is globally the largest market for Buses (50-75% of the 0,4-0,8 Mio annual sales).
- EV Bus sales in China on the level of 100-120 Tsd. since 2015 (Yutong, BYD among leading manufacturers).
- Cumulative EV Bus sales until end of 2016 on the level of 300 Tsd. (only a few Tsd. outside China). Full electrification of bus fleets in China to be expected in the next 5-10 years.

EV sales in China (in Tsd)



Global Bus sales in 2015 by region

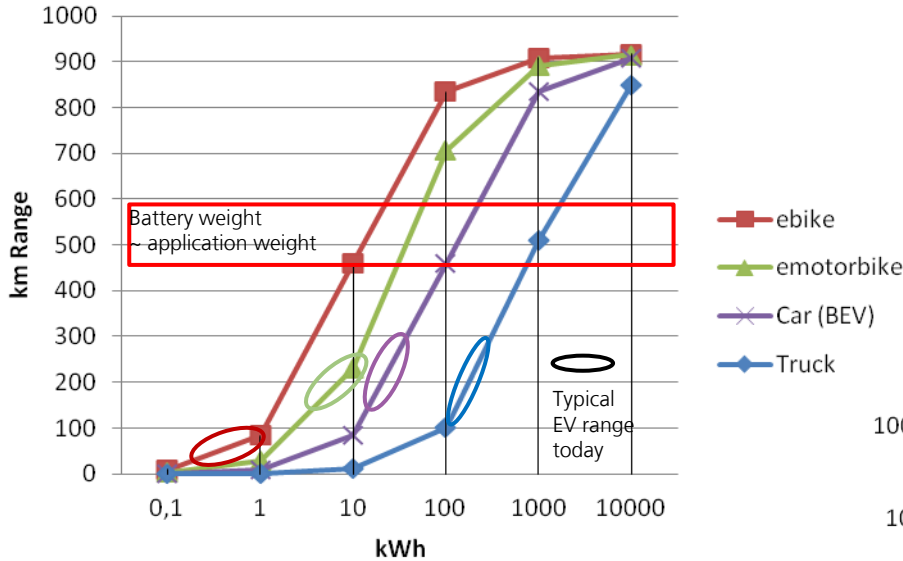


Source: Marklines and OICA

- LIB Demand in 2015 ~ 10 GWh
- LIB Demand to 2025 > 20 GWh
- longterm potential estimated > 100 GWh

Range and Energy use of EV-Applications

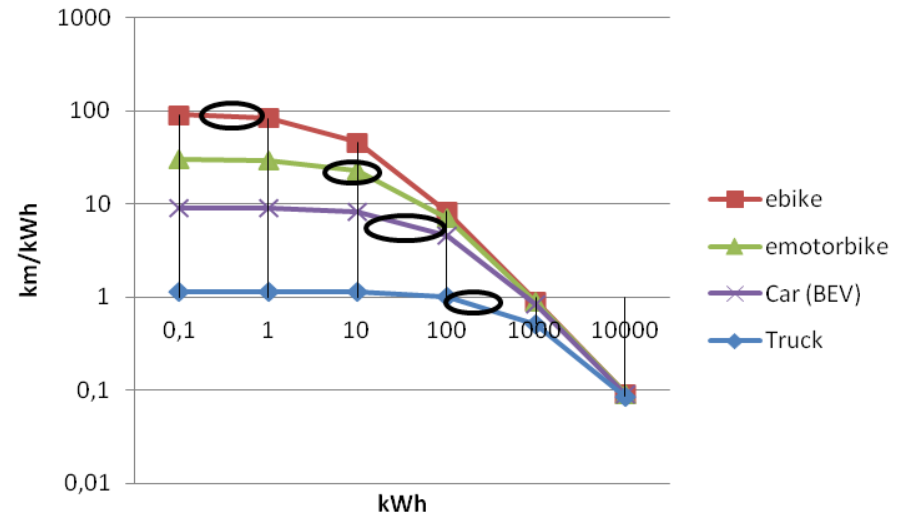
Battery development will help to improve range and diffusion of larger EV applications



Simplified Calculation:

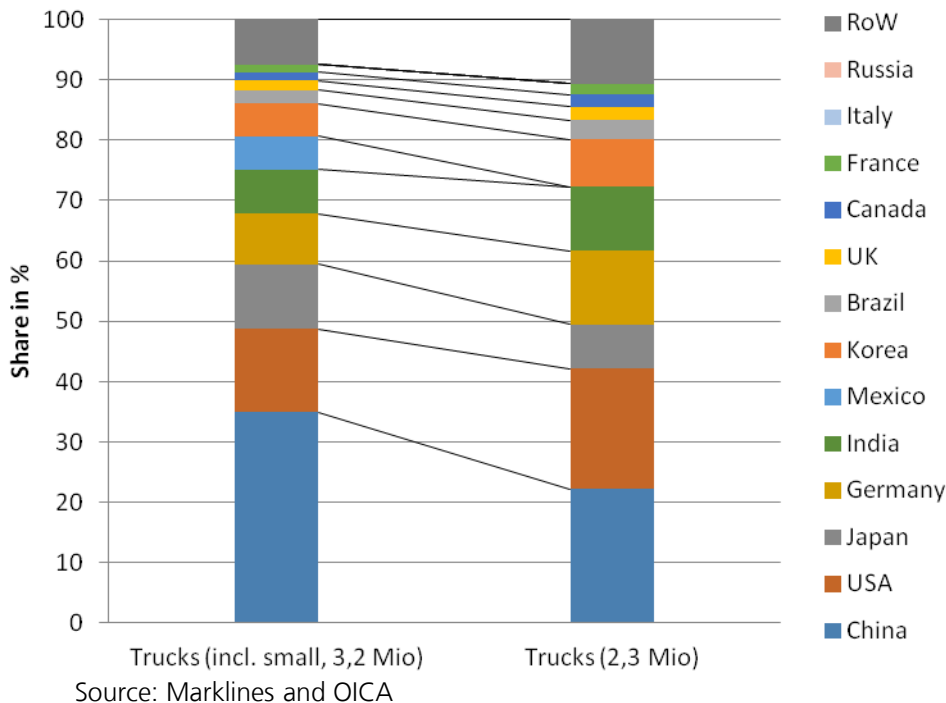
- Only rolling friction (F_r), no air resistance (low velocity), no declination (plain/ city)
- Battery on System level ~ 100 Wh/kg (for cyl. cells higher Wh/kg)

Vehicle mass:
 100 kg ebike (incl. driver)
 300 kg emotorbike
 1000 kg car
 8t truck



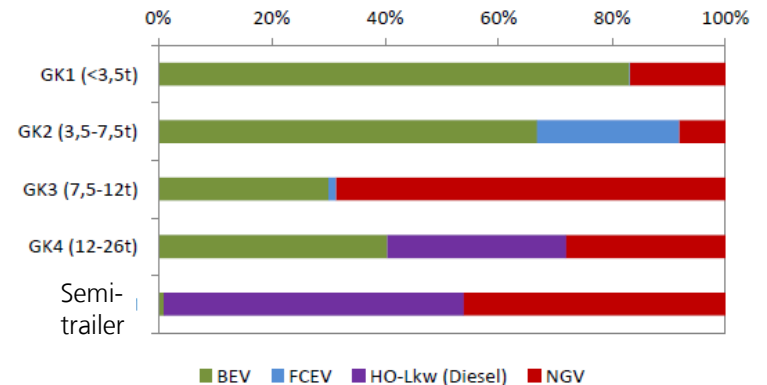
Trucks – battery (cost) development open door for E-Truck diffusion

Global Truck sales in 2015 by region



Estimates : 250.000 or 10% of Trucks to be electrified until 2030 (~10% of Trucks are for distribution traffic/ city/ short range)

Share of alternative Vehicle concepts (Basisszenario for Germany 2030)



Gnann et al. 2016: „Brennstoffzellen-Lkw: kritische Entwicklungshemmnisse, Forschungsbedarf und Marktpotential“, BMVI Study from Fraunhofer ISI, Fraunhofer IML, PTV Transport Consult GmbH.

Potential LIB demand 10-100 GWh (2020-2030), longterm potential ~ 1TWh

Railway – catenary-free trams and e-trains for non electrified routes

- Large parts of railway routes are not electrified (e.g. ~50% in Germany) and diesel engines are the current solution.
 - Also, in cities catenary-free trams are developed to overcome relatively short gaps in existing electrification infrastructure.
 - Technology (on-board energy) alternatives:
 - battery (NiMH): e.g. Saft batteries in catenary-free tram in Nice since 2012 (limited range and long charging)
 - battery (LIB): e.g. PRIMOVE catenary-free tram in Nanjing since 2015 (from Bombardier)
 - supercapacitor (stop-go, fast charging)
 - hydrogen fuel cell + LIB hybrid system: e.g. plans from Alstom (scheduled 2018)
- Battery sizes ~ 100 kWh
- Demand starts from MWh level
 - 2020-2030 ~ GWh LIB demand could be exceeded

From consumer Drones to airplanes – space for emerging applications!

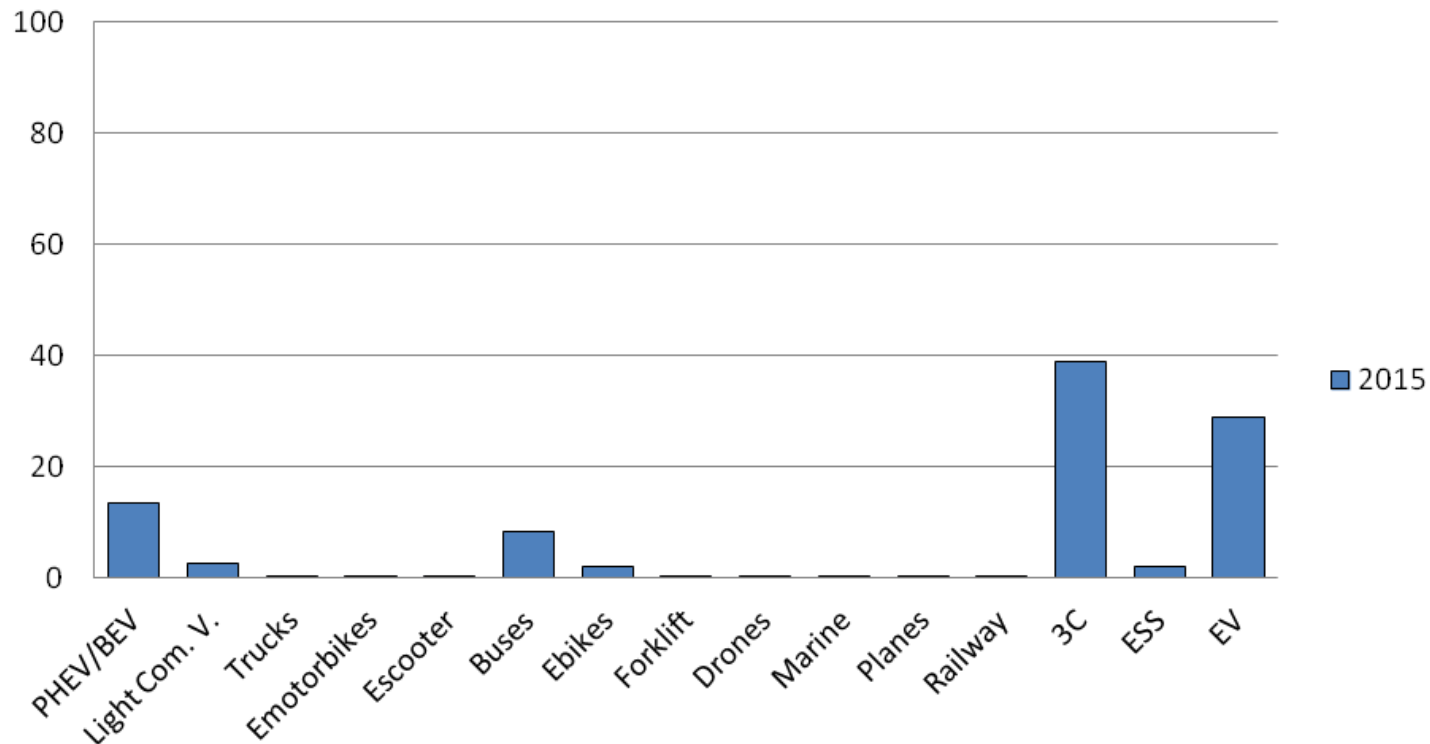
- **Consumer drone or Unmanned Aerial Vehicles (UAV)** sales to increase from 6.4 Mio units in 2015 to 67.7 Mio units in 2021 (Tractica 2016: <https://www.tractica.com/research/consumer-drones/>). Drones have typically 50-100 Wh LIB.
 - LIB Demand for drones to rise to several GWh beyond 2020
- **Human-carrying drones** (10-20 kWh) for few minutes flight have been presented in 2016 (Chinese drone manufacturer Ehang)
- **Small planes** (e.g. hybrid system by Siemens) and other lightweight-flight concepts (e.g. solar impulse) have been demonstrated (<100kWh LIB on board)
- Vision to electrify **larger airplanes** with 100 passengers beyond 2030 (e.g. hybrid systems or short flights „city hopper“).
- For the next 20 years (until 2035) it is estimated that ~35Tsd new airplanes will be produced (< 2000 per year). Larger planes would need ~1MWh LIB on board (→ 1-2 GWh market potential). However, for large/ long-distance airtransport battery technology is not suitable.

Marine – from small (recreational) boats to large ships, ferries and underwater vehicles

- The estimated global (new recreational/leisure) **boat market** is 800.000 (2015) with 14% growth compared to 2014. This includes boats with inboard, outboard motor, inflatable boats, sailboats.
 - The annual production/ order of electric outboard motors is expected to increase from 60.000 to 150.000 from 2014 to 2023 (IdTechEX 2014). Still Pb batteries in Marine applications.
 - Battery sizes for electric boats reach from kWh level to >50 kWh (e.g. Torqueedo DEEP Blue with up to 52 kWh).
 - First **electric ferry** (called Ampere, Norway) in service since 2015 (~1 MWh LIB capacity, combined)
 - Large **ships (luxury, superyachts), submarines**, etc. need several 100 to 1000 kWh batteries.
-
- combined LIB demand 2015 estimated at some 100 MWh
 - combined LIB demand until 2025 estimated on GWh level
 - global longterm potential estimated at 10 GWh level

LIB Cell Demand 2015: Emobility starts to be the leading application by GWh Demand

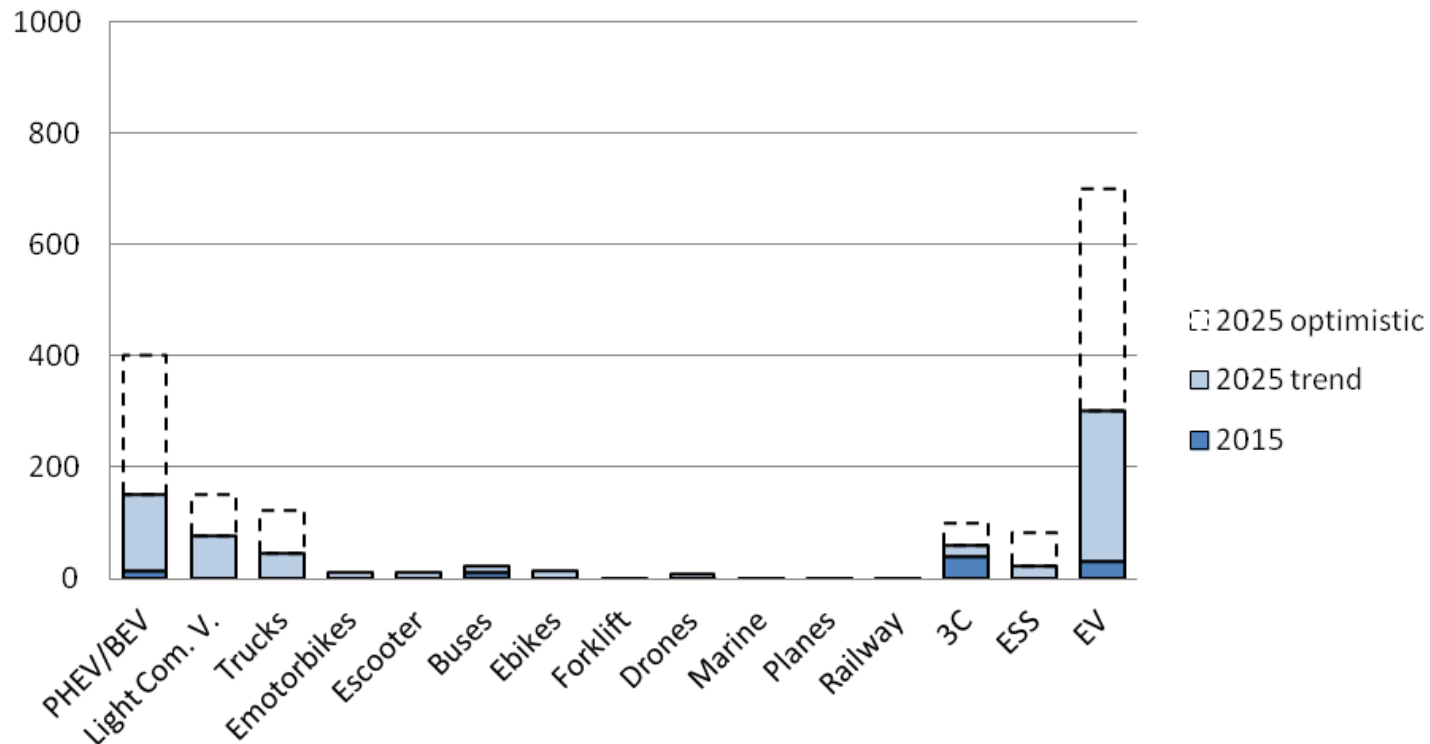
Global LIB Demand and Future Potential Demand by Applications and Segments (GWh)



LIB Cell Demand 2025: transition to TWh era

Electric Vehicles absolutely dominate demand

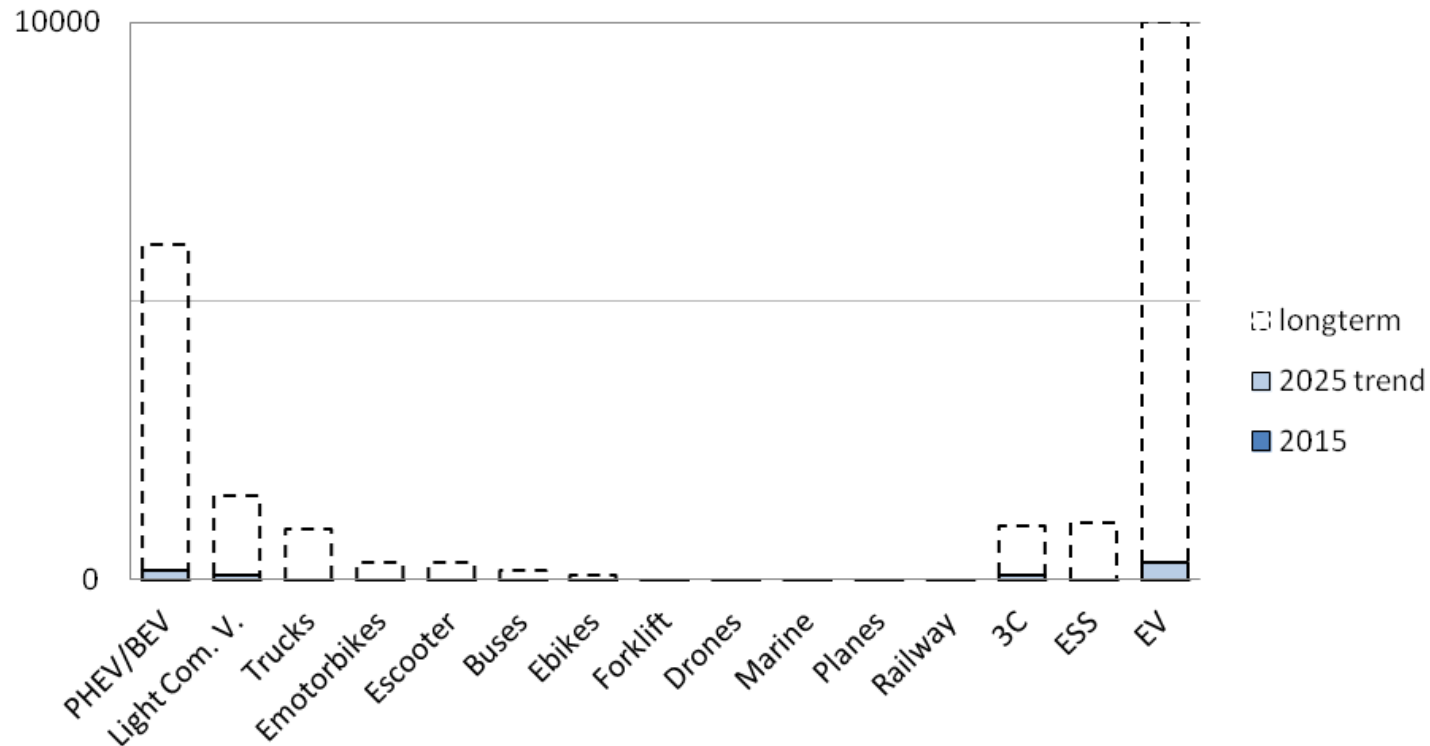
Global LIB Demand and Future Potential Demand by Applications and Segments (GWh)



Forecasts to 2025 and beyond to be understood as rough estimate of potential market dimension

LIB Cell Demand 2030-2050: „ubiquitous battery era“ - longterm potential > 10 TWh

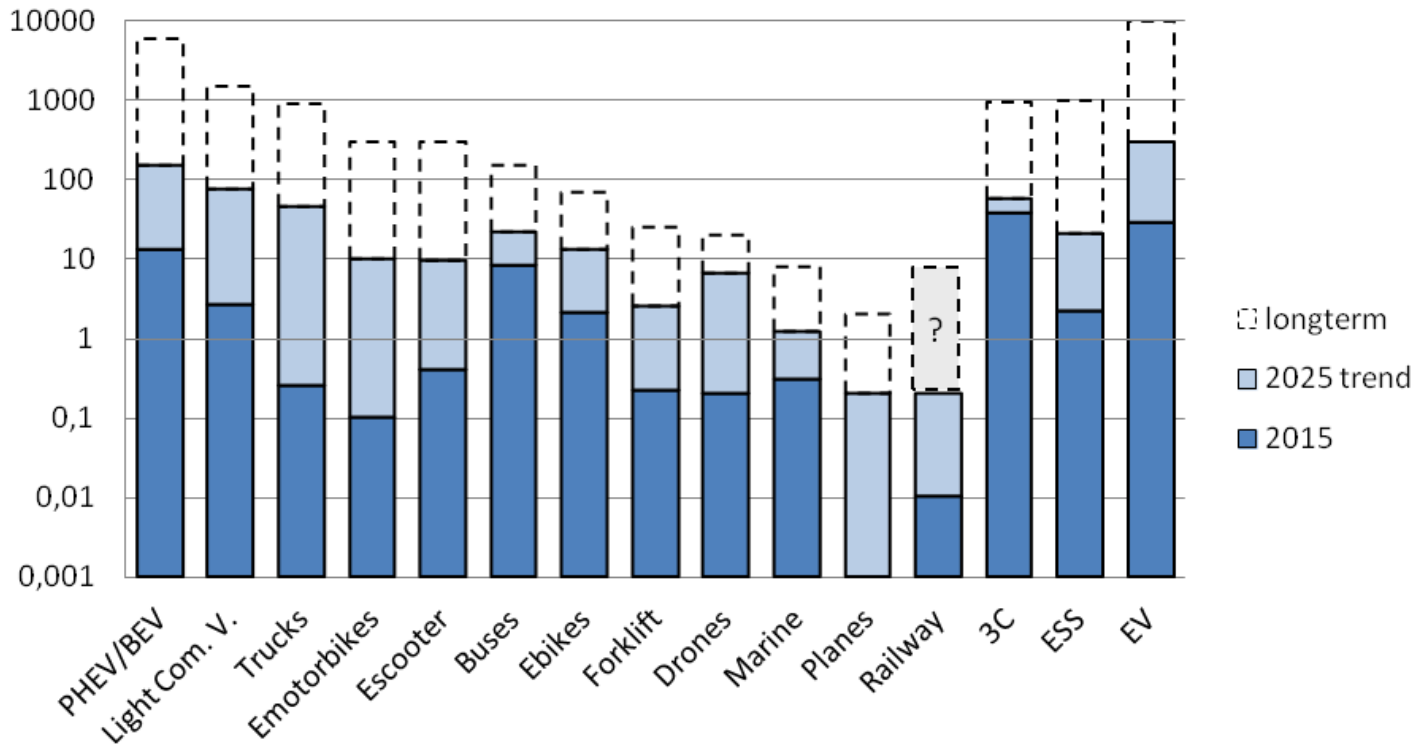
Global LIB Demand and Future Potential Demand by Applications and Segments (GWh)



Forecasts to 2025 and beyond to be understood as rough estimate of potential market dimension

Battery demand for most specialty applic. growth ten-fold in the next years – but at different levels

Global LIB Demand and Future Potential Demand by Applications and Segments (GWh)



Forecasts to 2025 and beyond to be understood as rough estimate of potential market dimension

Many Thanks

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