



MobiliTec Forum

Li-ion Batteries for Electrified Mobility - Quo vadis?

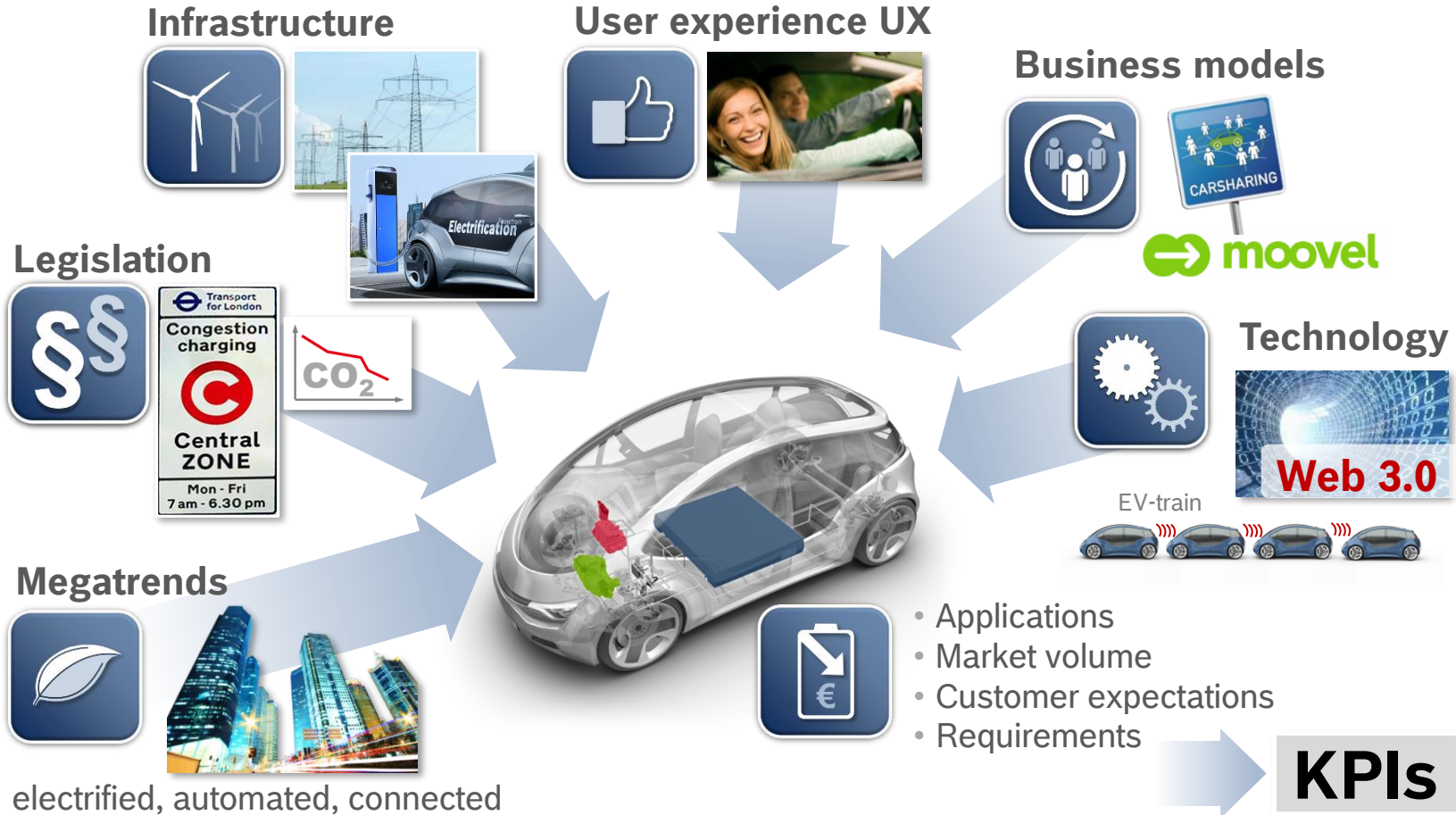
Hannover | 28.04.2016

Alexander Kieper

SW Test and SW Calibration, Calibration Tools

Bosch Battery Systems GmbH

Influence variables on eMobility



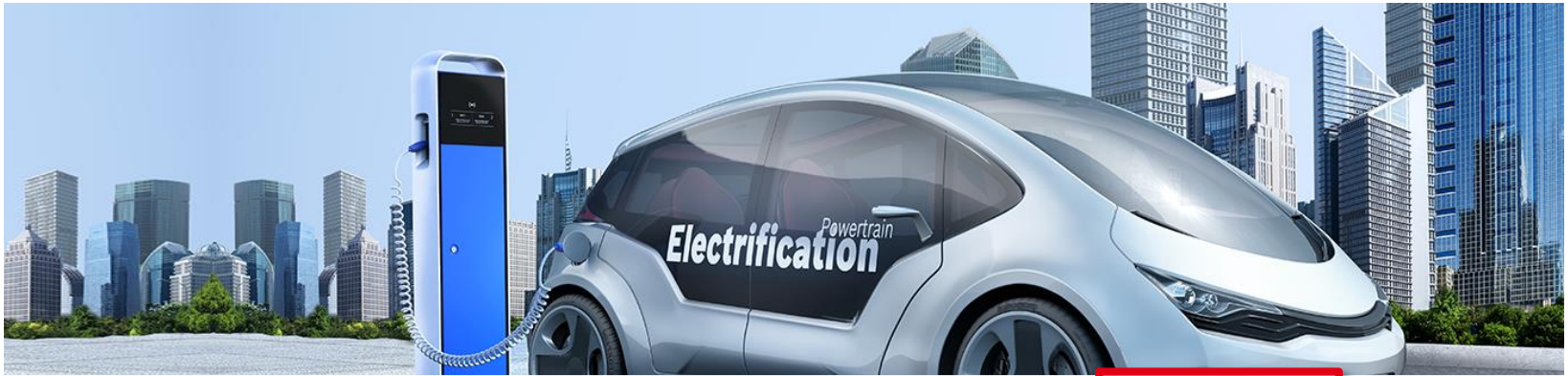
Content

- ▶ Market requirements for batteries 2020ff – the Bosch view
 - ▶ Applications
 - ▶ Market volume
 - ▶ Customer expectations
 - ▶ Battery requirements
 - ▶ KPIs

- ▶ Technologies to reach the targets
 - ▶ Battery cell technologies – until 2020 LIT
 - ▶ From 2020: PLIT

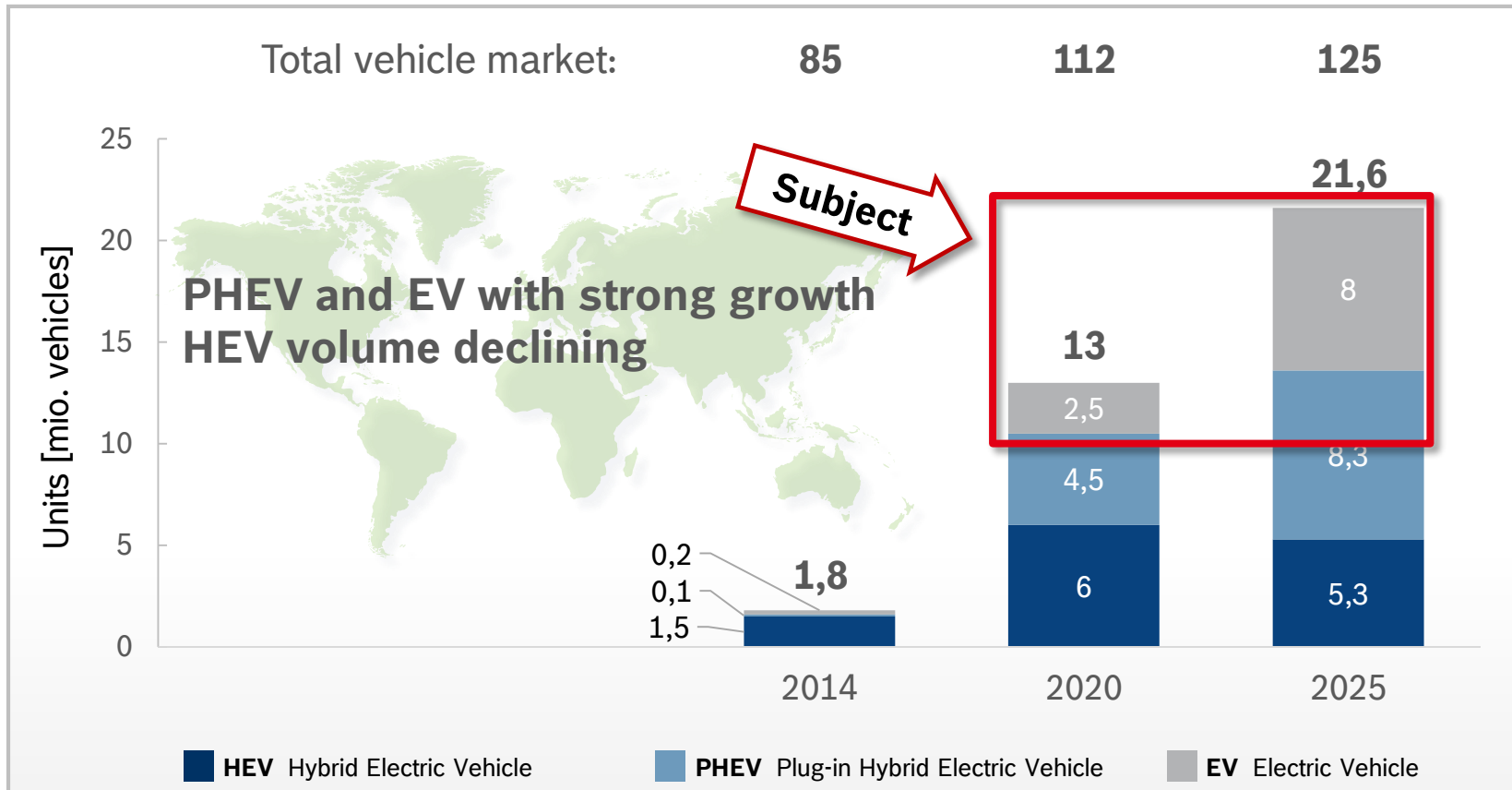
- ▶ Summary and prospect

Applications



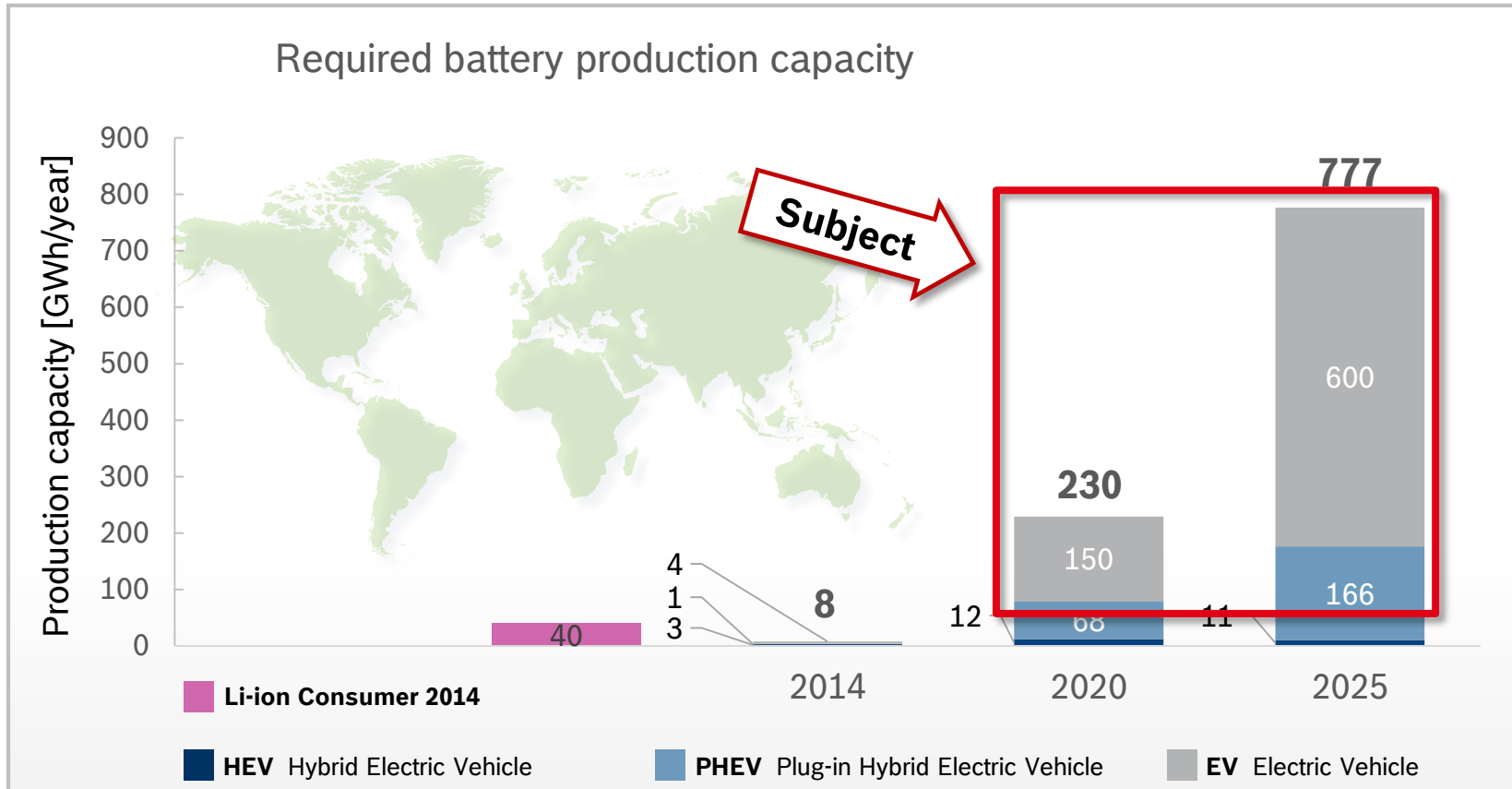
	HEV	PHEV	EV	BRS
Generation 1 (series)	●	●	●	
Generation 2 (in development)	●	Subject →	●	●
Electrical range	→	↔	↑	
Electrical power	→	↔	↗	
Challenges	<ul style="list-style-type: none"> • High power • Low cost 	<ul style="list-style-type: none"> • High performance • Cycle life • Cost down 	<ul style="list-style-type: none"> • High energy density • Cost down 	<ul style="list-style-type: none"> • High power • Low cost
Technology	Li-ion (available)	Li-ion (improved)	Li-ion (improved) → Post Li-ion	Li-ion (available)

Market volume

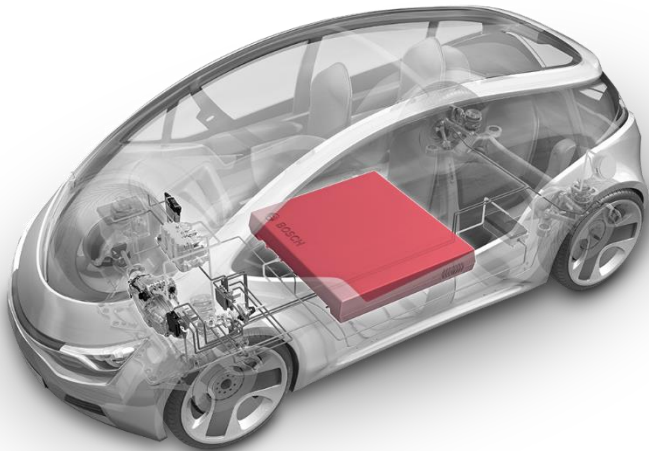


Vehicle sales PC incl. LCV<6t: Estimation Bosch

Consequences on production capacity



Customer expectations towards an EV



Customer expectations	Battery requirements
Driving range ≥ 350 km	≥ 50 kWh 200Wh/kg...400Wh/kg
Good performance	150kW...250kW → P/E ratio 3...5
Fast charging	250km with 15min charge time
No battery exchange during vehicle life	80% capacity & performance @ 300Tkm, > 10years
Reasonable safety	Safety level equal or higher than in vehicle with ICE
Affordable	Market price target battery: 6.000EUR

KPIs: status 2015, market targets 2020 - 2025

Energy Density

Cost

Lifetime

Performance

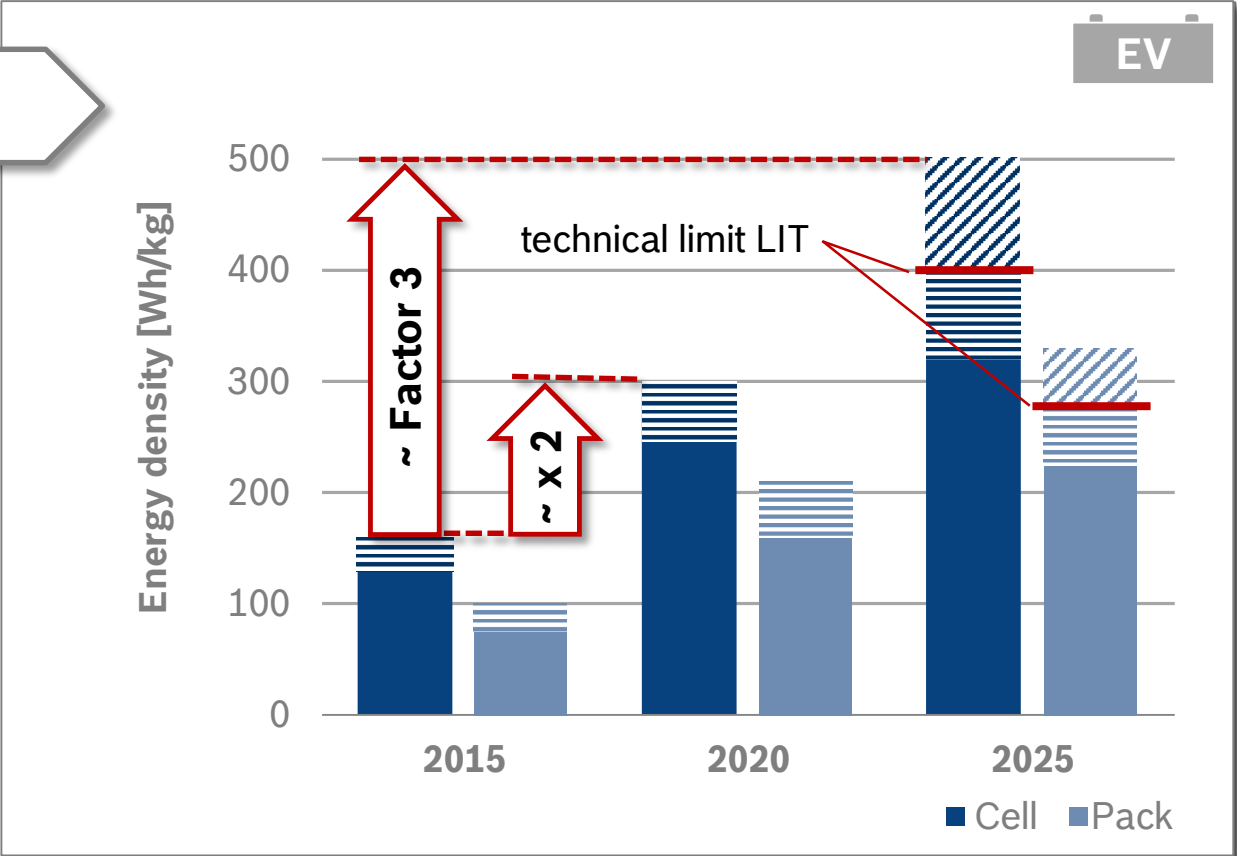
Quality

Safety



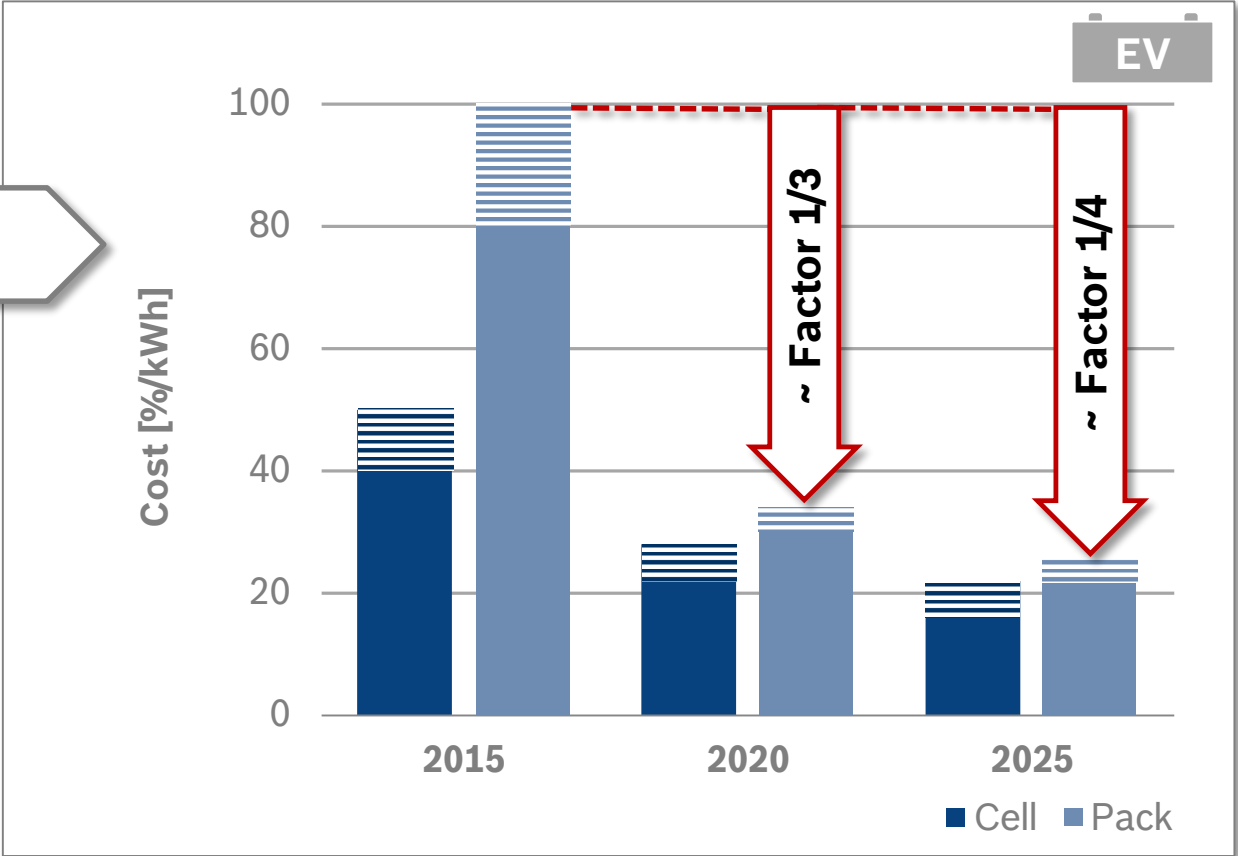
KPIs: status 2015, market targets 2020 - 2025

Energy Density



KPIs: status 2015, market targets 2020 - 2025

Cost



Content

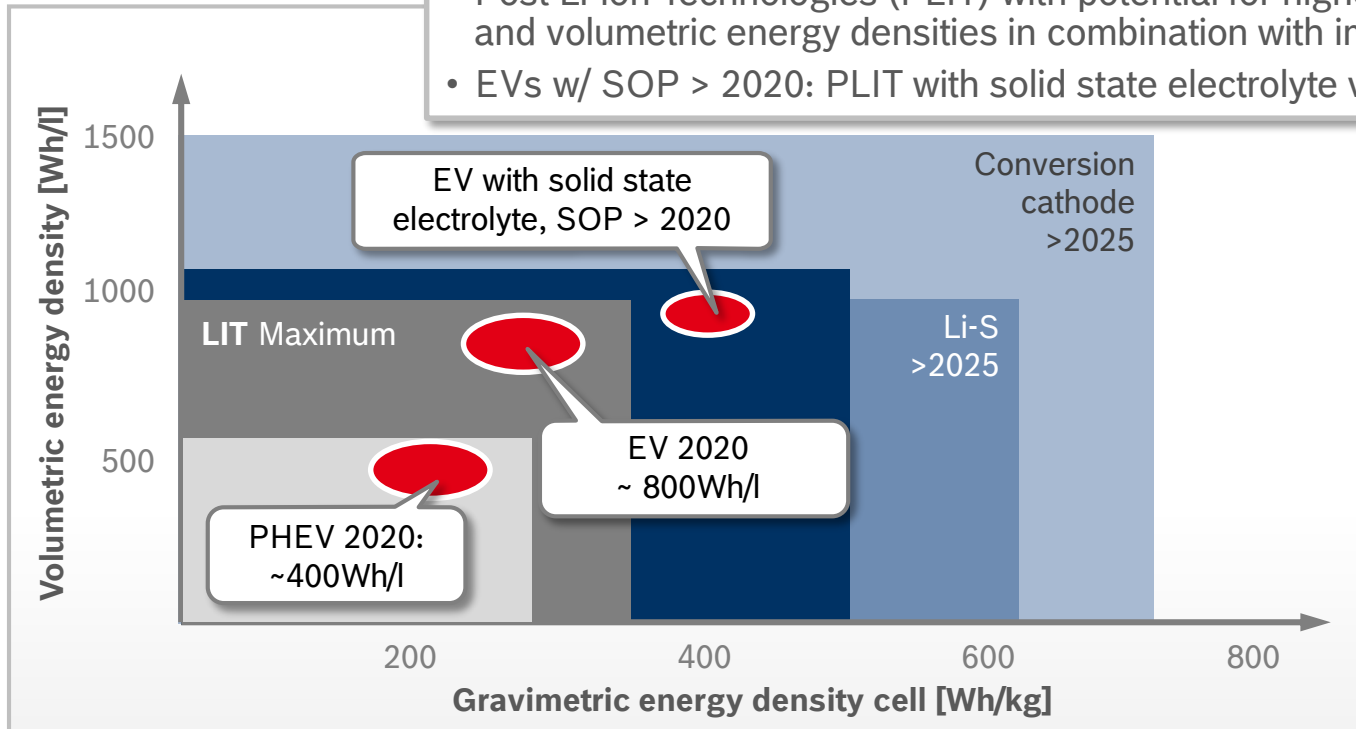
- ▶ Market requirements for batteries 2020ff – the Bosch view
 - ▶ Applications
 - ▶ Market volume
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- ▶ Technologies to reach the targets
 - ▶ Battery cell technologies – until 2020 LIT
 - ▶ From 2020: PLIT

- ▶ Summary and prospect

Battery cell technologies

- Market until 2020 dominated by Li-ion Technology (LIT)
- Energy density in 2020 already close to the technical limit of LIT
- Post Li-ion Technologies (PLIT) with potential for higher gravimetric and volumetric energy densities in combination with improved safety
- EVs w/ SOP > 2020: PLIT with solid state electrolyte very promising

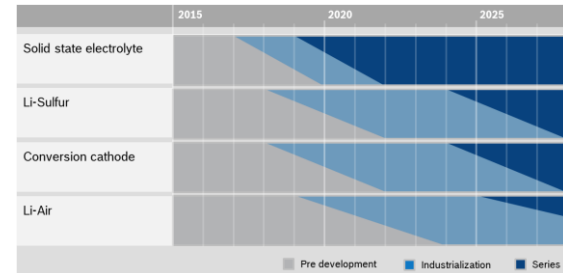


■ LIT: Li-ion Technology ■ PLIT: Post Li-ion Technology

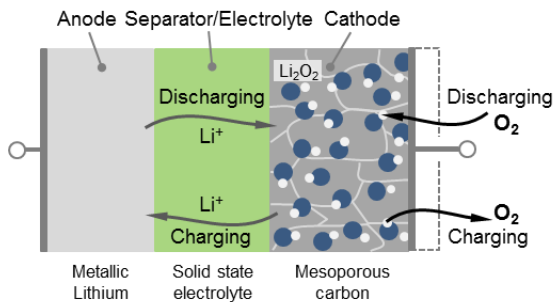
Terminology

LIT? PLIT

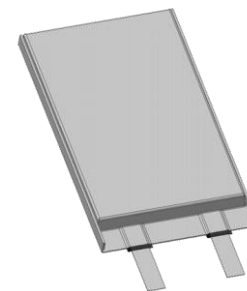
Roadmap



Examples



Solid State Cell

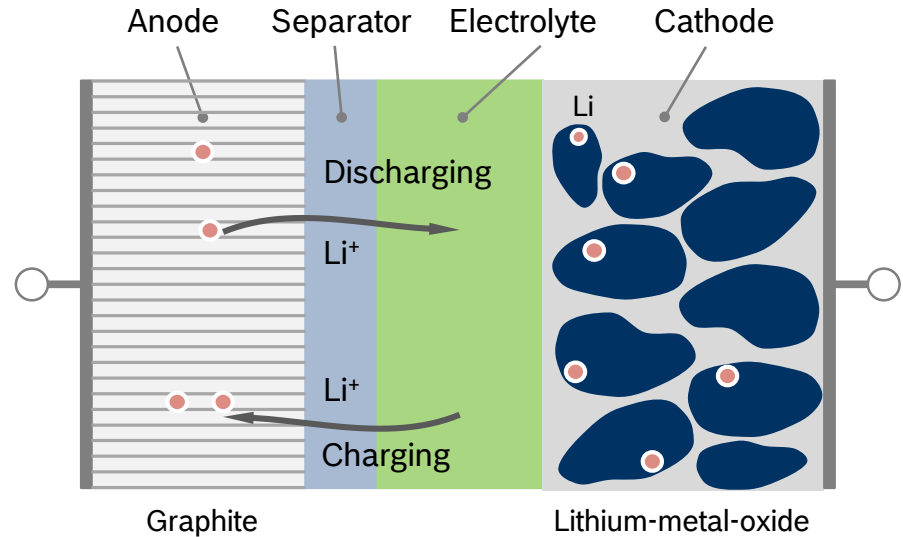


PLIT cell technologies

Terminology

▶ Li-ion Technology (LIT)

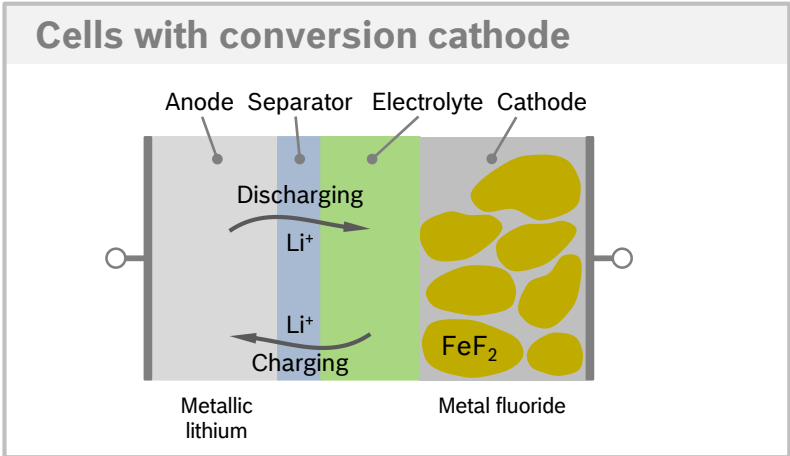
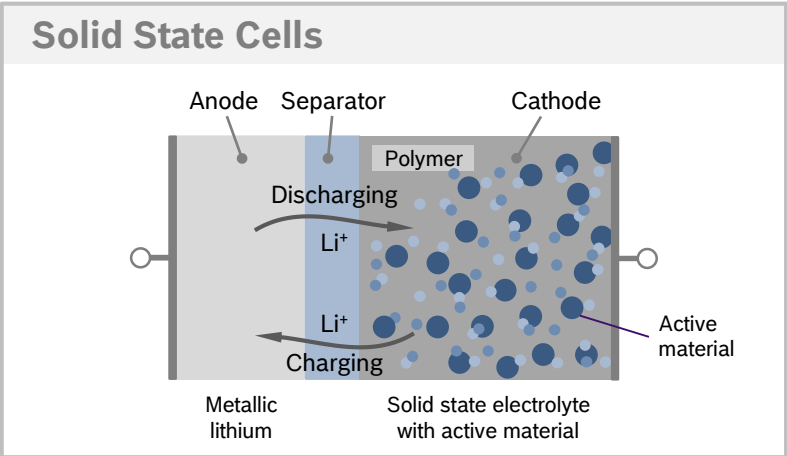
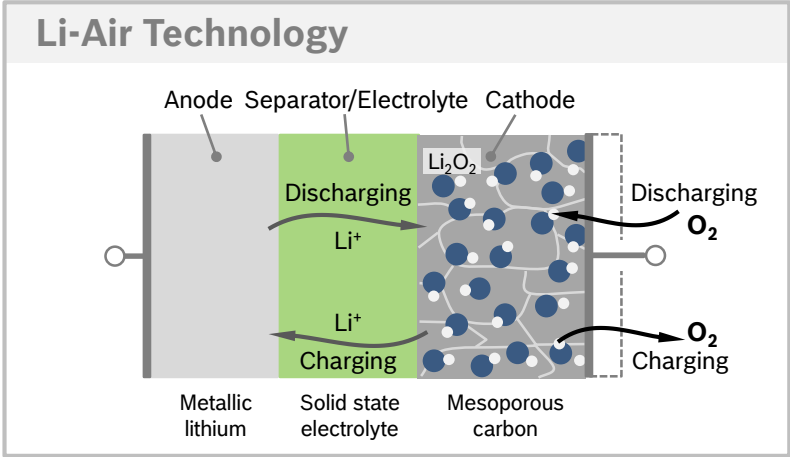
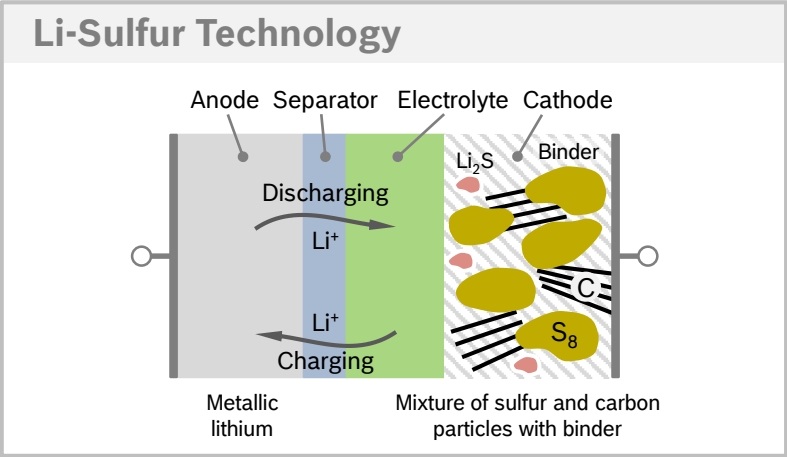
- ▶ Lithium in both electrodes mainly intercalated
- ▶ Structure of electrodes hardly changed due to intercalation
- ▶ Li-ions migrate free via (liquid) electrolyte



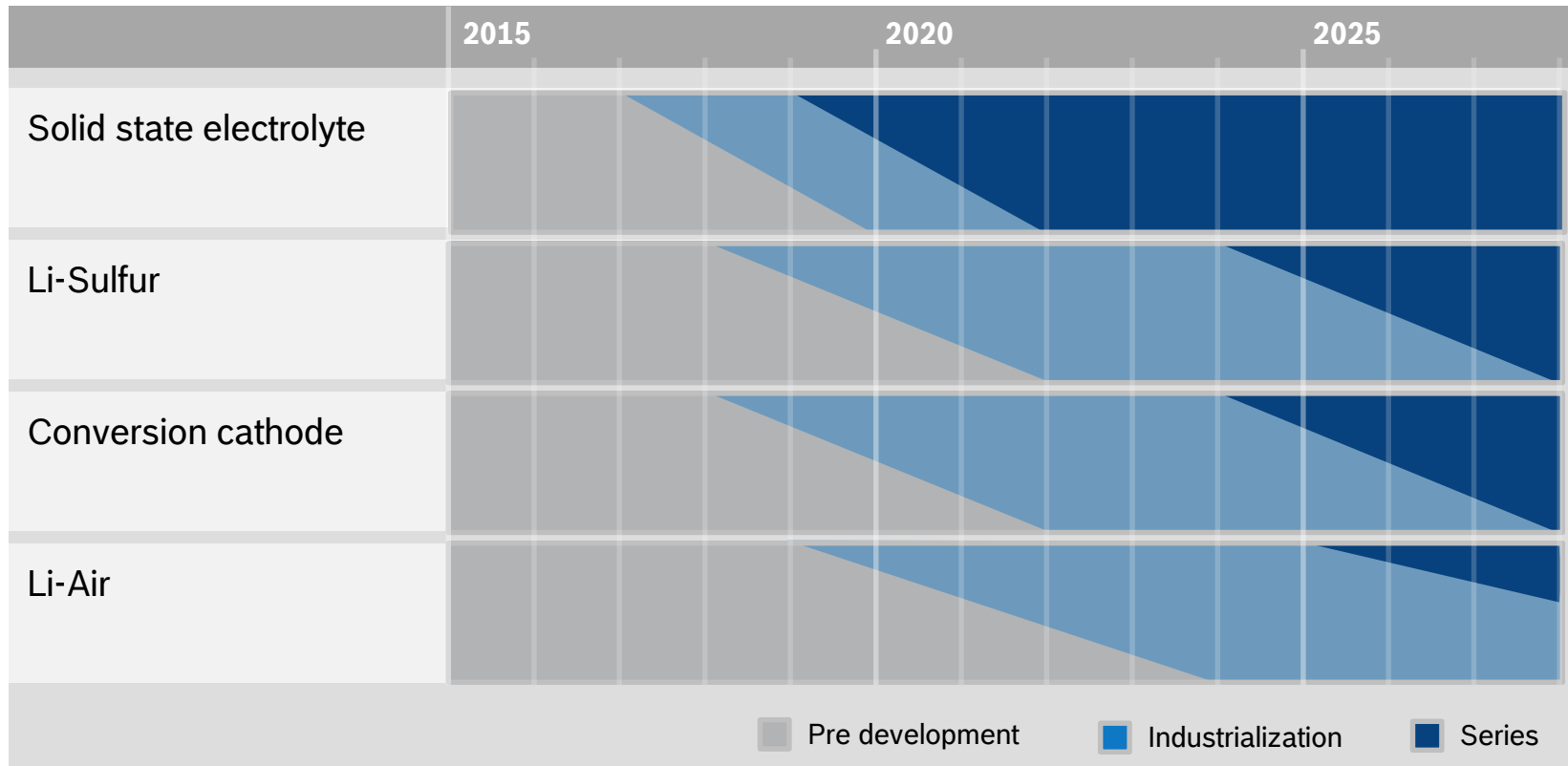
▶ Post Li-ion Technology (PLIT)

- ▶ At least one electrode not intercalating lithium
- ▶ Acronym PLIT often used as synonym for Li-Sulfur and Li-Air technologies
- ▶ Cells with metallic Lithium anode are counted among PLIT

PLIT cell technologies, examples



PLIT cell technologies, roadmaps






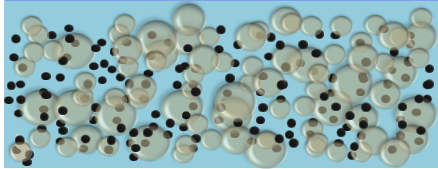
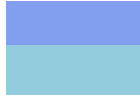
First PLIT cell SOPs expected with solid state electrolyte technology

Solid state cells, status Bosch

- ▶ Bosch acquired Californian battery technology company **Seeo**
- ▶ Engineering prototype cells available

Seeo DryLyte™ Technology

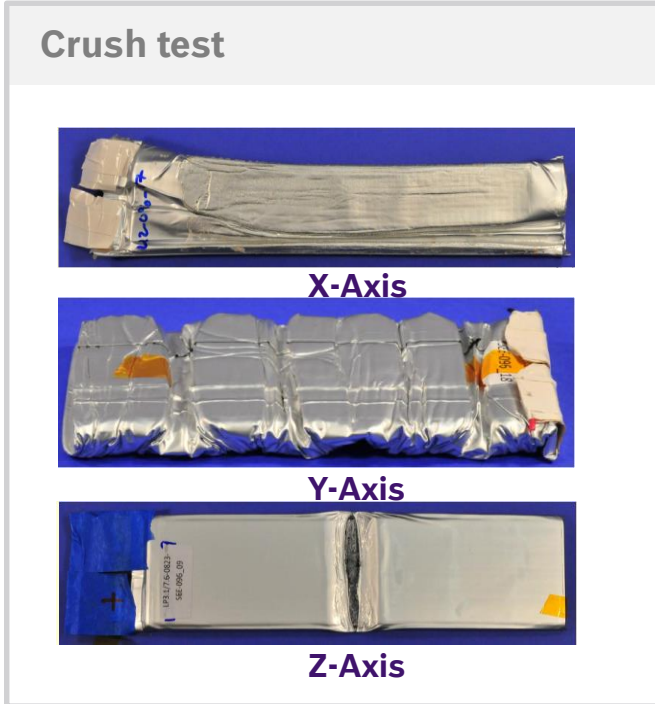


Anode	Lithium Foil	
Separator	Dry Solid	
Cathode	Dry Solid Polymer Composite	
Electrolyte	Dry Solid	

Technology very promising: Lifetime > 1000 cycles reached with LFP cathode, operating temperature 80..100°C

Solid state cells, Safety

► Safety test results (LFP cathode, Li metal anode)



Test	Result
Crush	No smoke or flames
Penetration test	No smoke or flames
Short circuit test	No smoke or flames
Thermal shock	No smoke or flames
Over-discharge	No smoke or flames
Overcharge	No smoke or flames
Thermal stability	Stable up to 180°C

Intrinsic safety of Seo technology is a big advantage

Summary and prospect

- ▶ Li-ion technology will dominate the market until 2020
- ▶ Li-ion technology technical feasible for EV and PHEV
- ▶ Technical limit of automotive Li-ion expected @ ~350..400Wh/kg
- ▶ Post Li-ion with potential to further increase energy density and to reduce cost
- ▶ Solid state cells for EV expected to be ready for series past 2020

**PLIT with high chance
for game changer**



**VIELEN
DANK**