New Electric Axles and Battery Systems in Battery Electric Vehicles

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Department: ST

Location, Date: Berlin, 2nd April 2024

Classification: Conference Version

INTRODUCTION

- eAx solutions GmbH

ONE TEAM FOR DEVELOPMENT & INDUSTRIALIZATION

System engineering/ HW & SW development/ mechanical engineering/ test/ process technology development/ proven serial production competence

R&D

Industrialization

Support functions

eAxx solutions

GET DRIVE UNIT COMPETENCE INHOUSE…

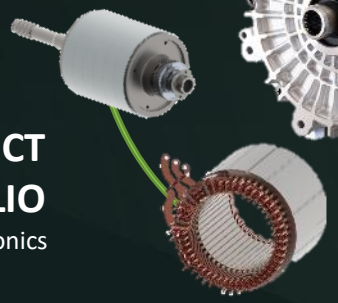
FAST/ LEAN/ INNOVATIVE

TEAM

Holistic engineering & industrialization competence along the e-drive development/ Lean organization & fast decisions

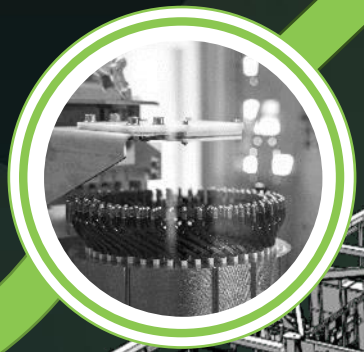
PROCESS & TOOLS

PLM/ ALM/ tool chain/ ISO 26262/ ISO 9001/ ASPICE/ Autosar



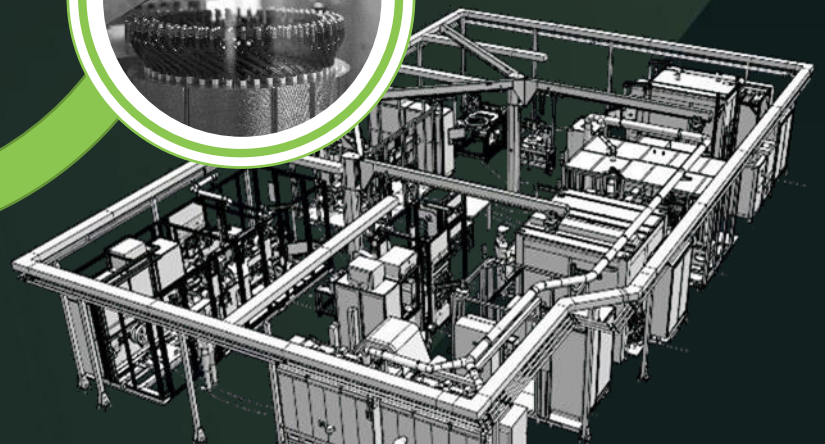
SCALABLE PRODUCT PORTFOLIO

Hairpin Stator/ Rotor/ Gearbox/ Electronics



LOW VOLUME PRODUCTION LINE

Automotive standard/ flexible line concept/ clean room area/ scalable capacity/ MES



…START YOUR PRODUCTION TOMMOROW

ONE TEAM FOR DEVELOPMENT & INDUSTRIALIZATION

eAx production

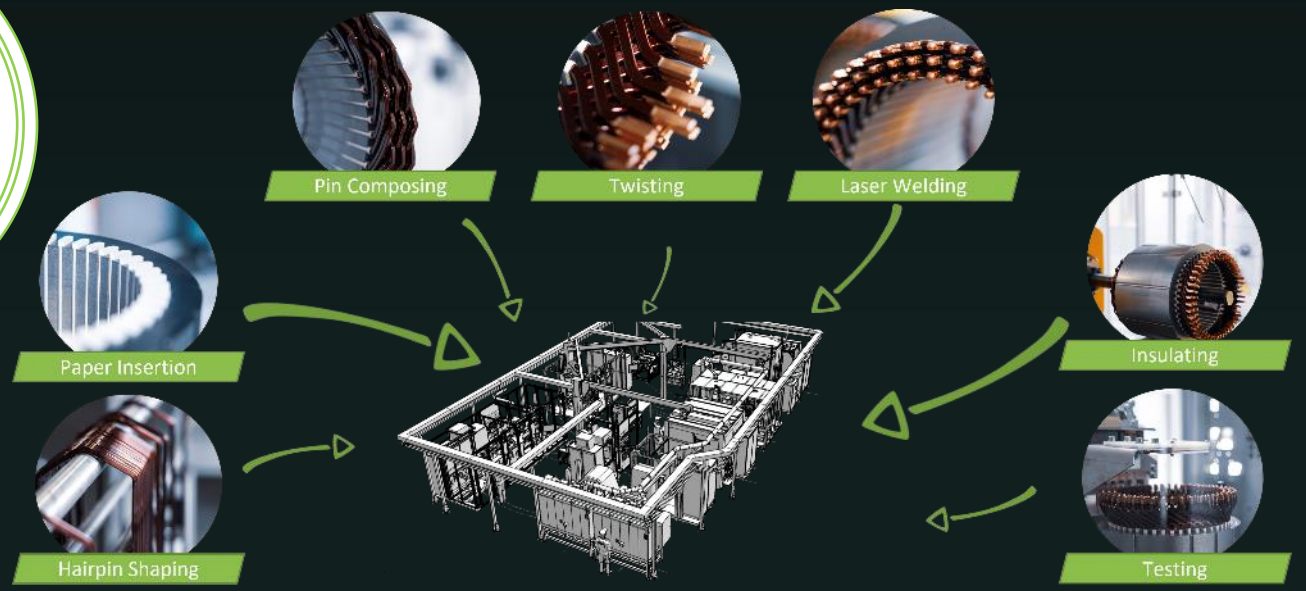
OUR PRODUCTION

Your electric axle made in Berlin

Facts & Benefits

- Capacity: 15.000 pcs/ year
- Lead time for speed sample 1 month (existing variant)
- Real time automotive manufacturing execution system
- Flexible equipment configuration for multiple electrical drive units
- Production processes developed for mass production
- Electronic production according EN ISO 14644

OUR STATOR LINE



Series standard

Our production offers high volume standards, full traceability and automated manufacturing processes.

Flat wire winding

The Hairpin winding line enables scalable build up of stators with different dimensions and winding schemes.

Testing

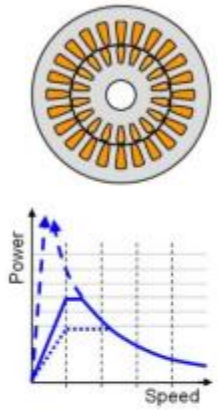
Inline test as well as end of line test technology guarantees high quality of our products.

E- AXLE

- Overview E- Machines
- eAx new 800 V applications
- Transmissions
- Power Electronic

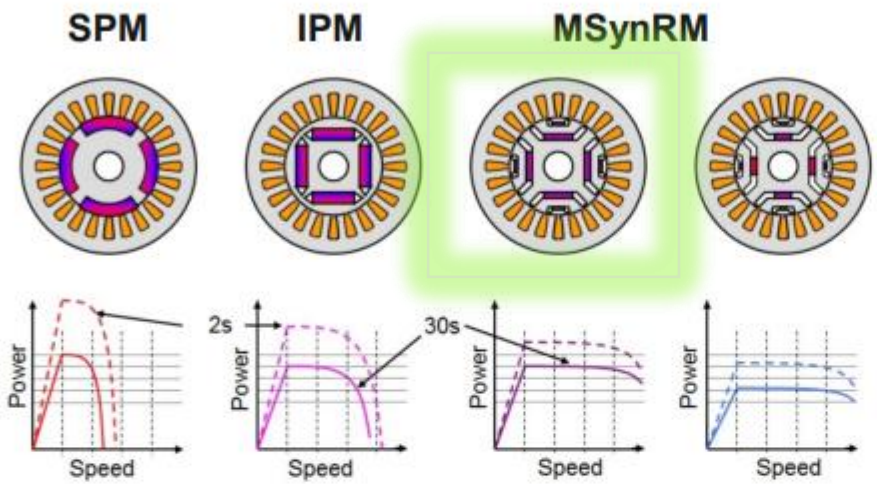
Overview E- Machine Types

ASM
ASynchronous **M**achine



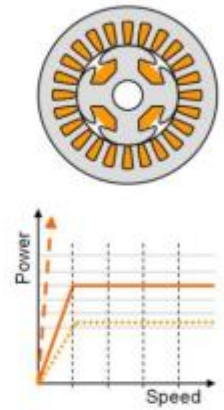
- No constant peak power
- Peak power is not limited by magnetic properties, but by thermal and mechanical issues (arrows)

PSM
Permanent excited **S**ynchronous **M**achine



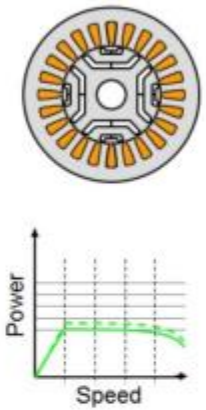
- Peak power is limited by magnetic properties
- SPM cannot work at high speed
- Internal PSM in combination with reluctance torque (MSynRM) provide the best power characteristic
- HMSynRM comparable to MSynRM, but slightly higher

ESM
External excited **S**ynch. **M**achine



- Constant peak power (however, lower than IPM)
- Constant power speed range much higher (>5x) than ASM
- Peak power is not limited by magnetic properties, but by thermal and mechanical issues (arrows)

SynRM
Synchronous **R**eluctance **M**achine



- Constant power over wide speed range
- Low power density

Source: fka Aachen

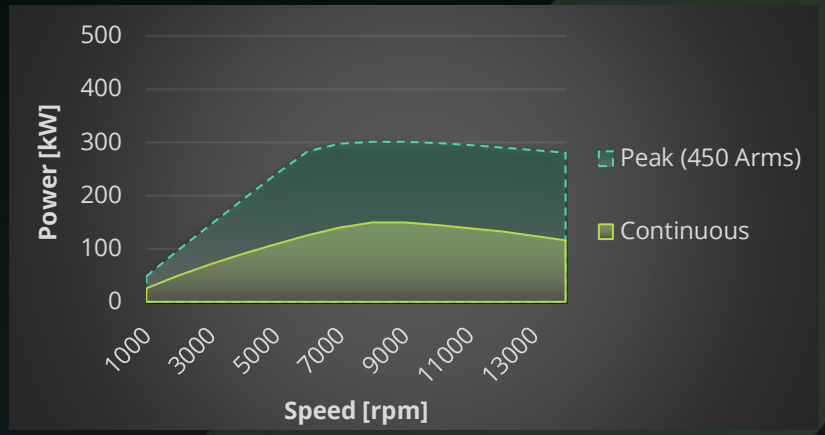
electric motor

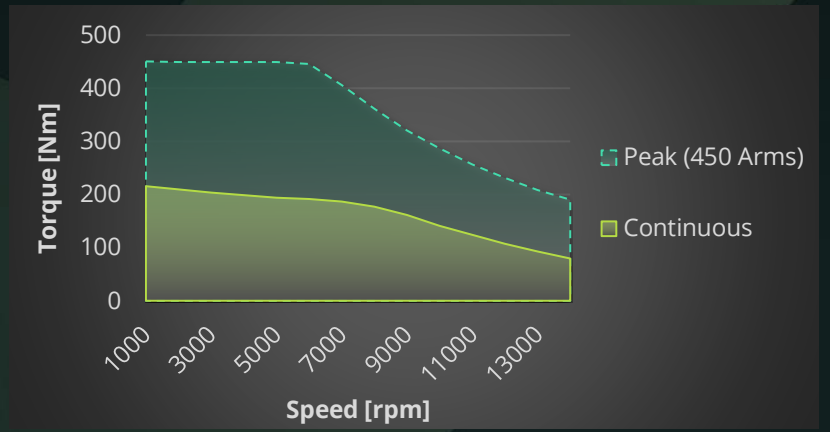
eAx EM220-154-800

Technical Specifications

Peak Performance: (20s)	300 kW, 450 Nm @450 Arms
Cont. Performance:	150 kW, 215 Nm @240 Arms
Max. Operating Speed:	13.000 rpm
Nominal DC Voltage:	700 V
Rotor Active:	PSM
Outer Stator Diam.:	220 mm
Active Length:	154 mm
Cooling:	water jacket, 8 l/min
Weight:	62 kg
HV-Interface:	TE AMP IPT 3pxi
Gearbox Interface:	8x M10 in ø275 mm, male centering ø82 mm or customized adapter plate
Shaft Spline:	DIN5480-N26x1.25x19x9H or customized
Lifetime:	10.000 h
Dimensions (LHW):	348 x 370,5 x 305
Interlock:	Optional
Temperature range:	-25 ... 65°C

Performance





electric motor

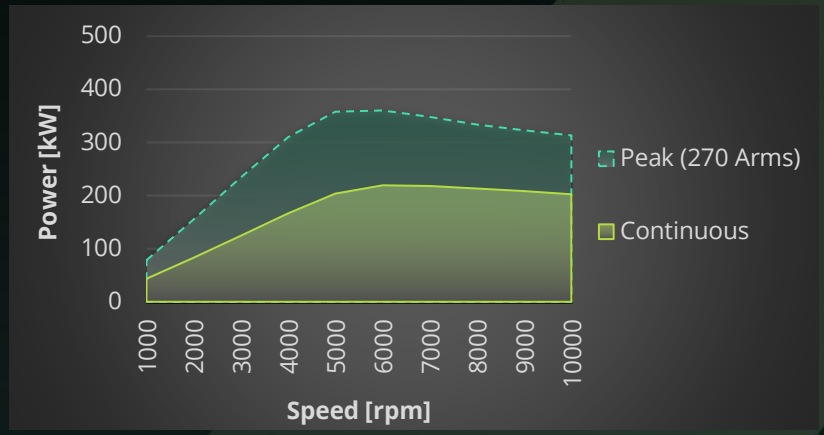
eAx EM220-205-800

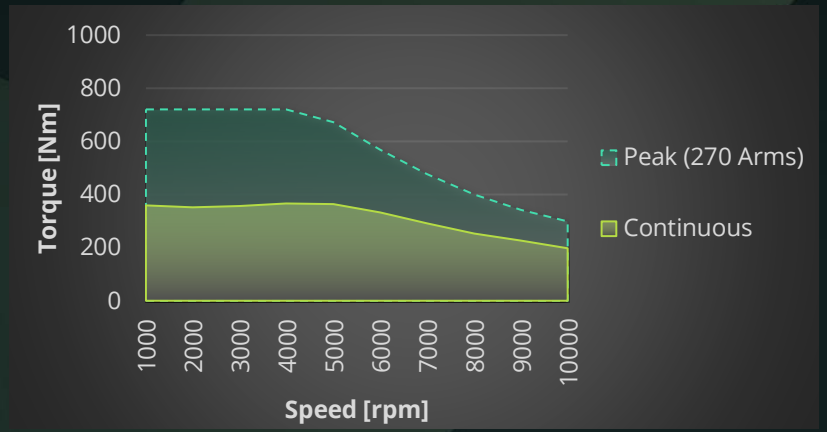
eAx solutions

Technical Specifications

Peak Performance: (20s)	360 kW, 720 Nm @550 Arms
Cont. Performance:	220 kW, 360 Nm @330 Arms
Max. Operating Speed:	10.000 rpm
Nominal DC Voltage:	750 V
Rotor Active:	PSM
Outer Stator Diam.:	220 mm
Active Length:	205 mm
Cooling:	water jacket, 8 l/min
Weight:	74 kg
HV-Interface:	TE AMP IPT 3pxi
Gearbox Interface:	8x M10 in ø275 mm, male centering ø82 mm or customized adapter plate
Shaft Spline:	DIN5480-N26x1.25x19x9H or customized
Lifetime:	10.000 h
Dimensions (LHW):	399 x 370,5 x 305
Interlock:	Optional
Temperature range:	-25 ... 65°C

Performance





ePTO *)

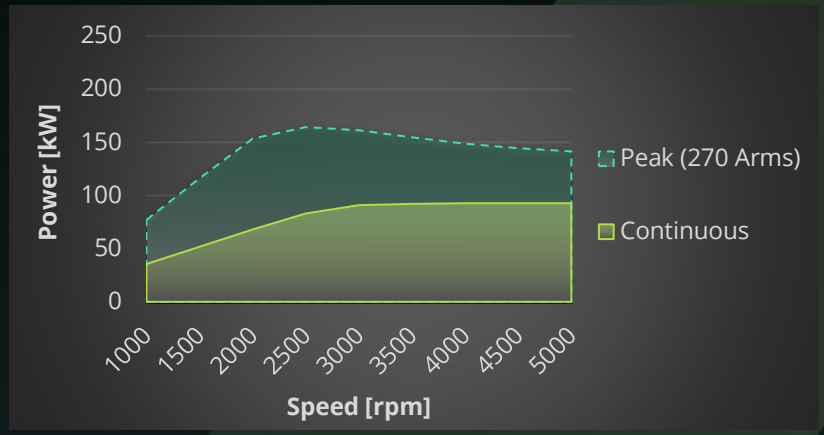
eAx EM220-205-800

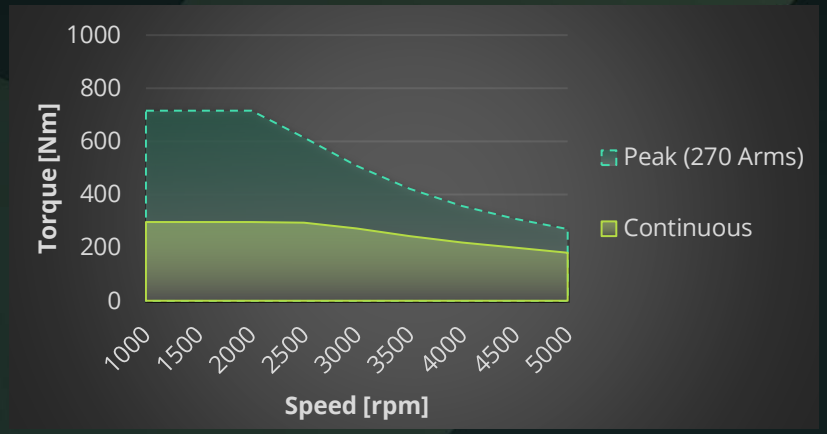
eAx solutions

Technical Specifications

Peak Performance: (20s)	160 kW, 710 Nm @270 Arms
Cont. Performance:	90 kW, 300 Nm @135 Arms
Max. Operating Speed:	5.000 rpm
Nominal DC Voltage:	700 V
Rotor Active:	PSM
Outer Stator Diam.:	220 mm
Active Length:	205 mm
Cooling:	water jacket, 8 l/min
Weight:	74 kg
HV-Interface:	TE AMP IPT 3pxi
Gearbox Interface:	8x M10 in ø275 mm, male centering ø82 mm or customized adapter plate
Shaft Spline:	DIN5480-N26x1.25x19x9H or customized
Lifetime:	10.000 h
Dimensions (LHW):	399 x 370,5 x 305
Interlock:	Optional
Temperature range:	-25 ... 65°C

Performance





*) electric Power Take Off (auxiliary drive)

Transmission - Trends

Without

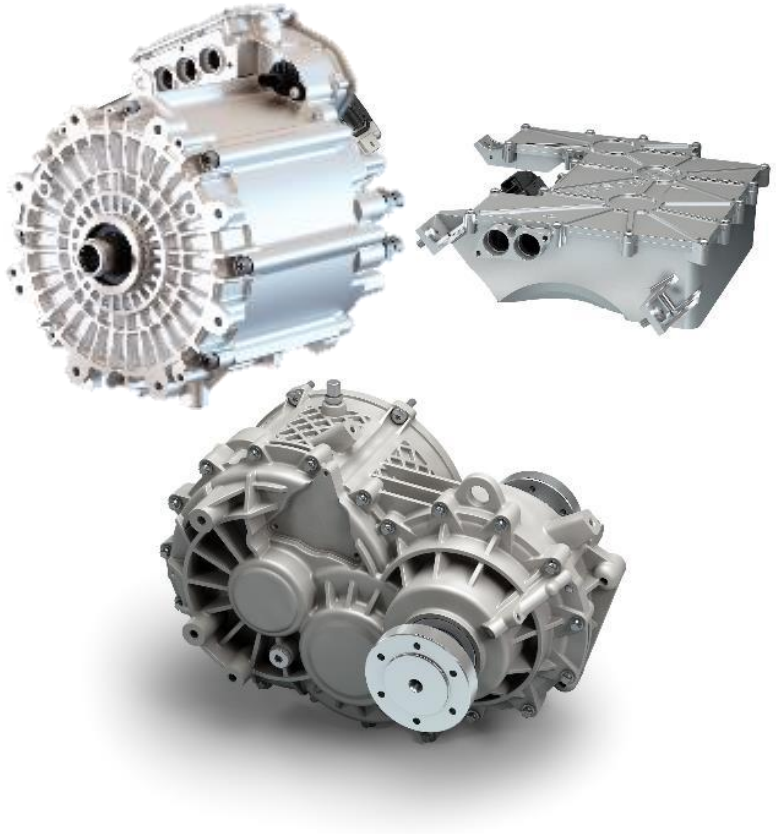
- In- wheel hub motor, axial flow machines = special applications

Single speed gearbox

- today's standard - 3 in 1 solution: highly integrated
- Trend: Use of high power at higher speeds

Multiple speed gearbox

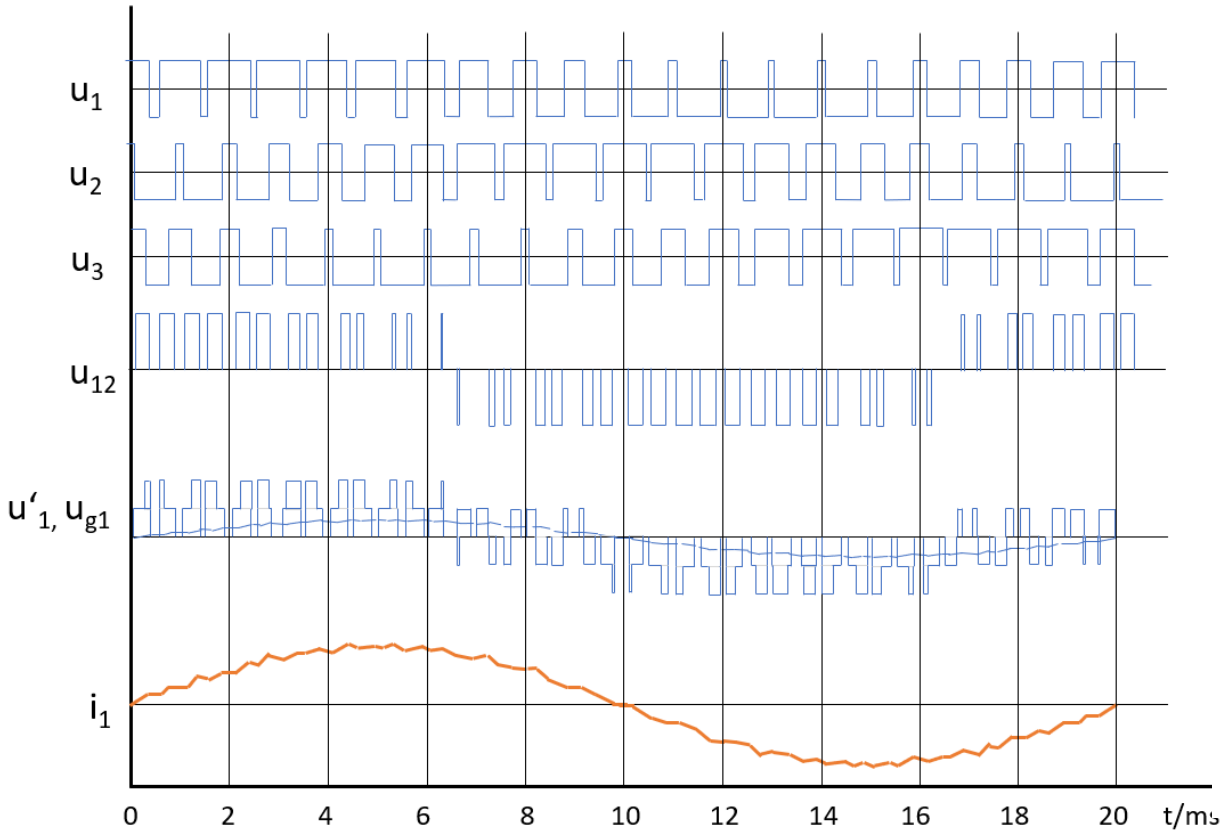
- Standard two-speed gearbox for high-performance cars
- Trend: three-speed gearbox for CV
- Target: low priced solutions for uninterrupted transmission



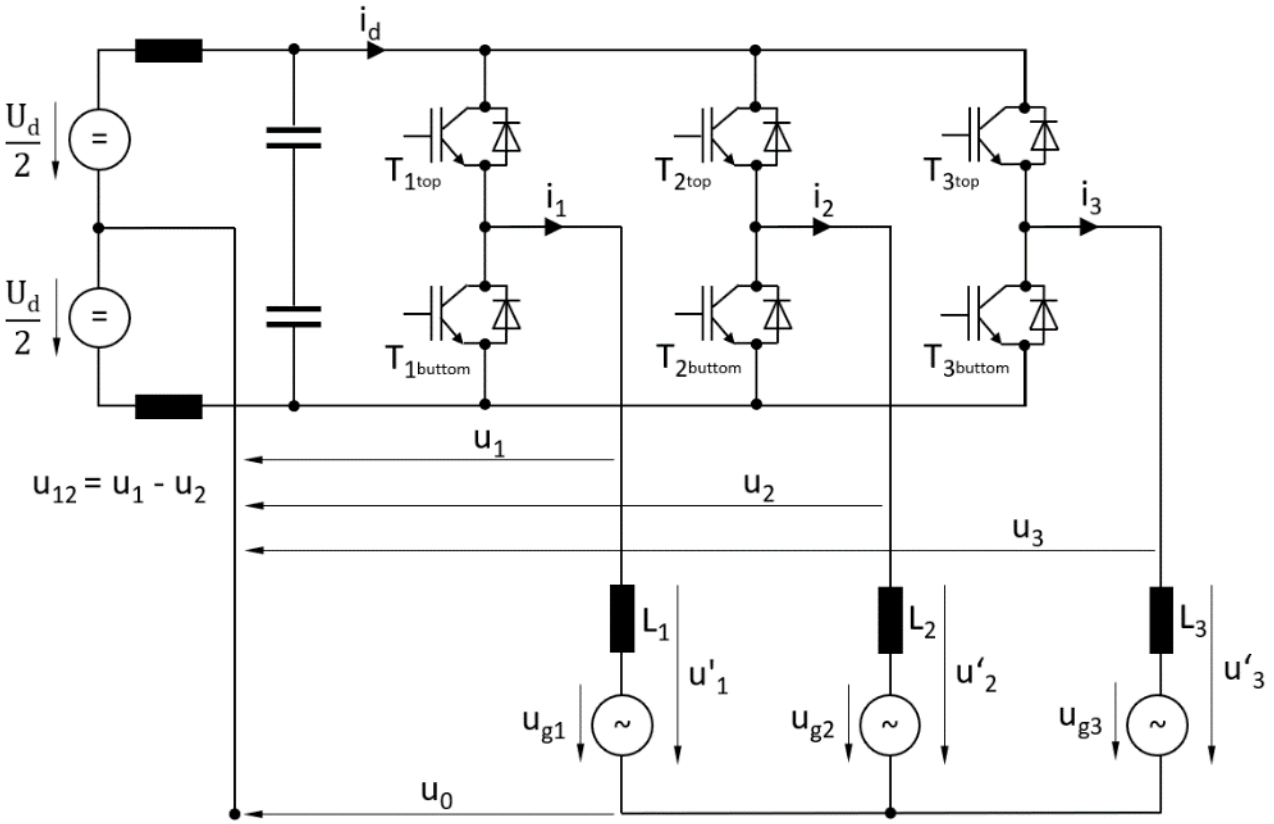
Source: Robert Bosch GmbH Medien-ID #1161644

Power Electronic - Trends

PSM (**P**ermanent excited **S**ynchronous **M**achine)



Six-pulse bridge circuit with IGBT semiconductor



Graphics: eAx solutions GmbH

Power Semiconductor - Trends

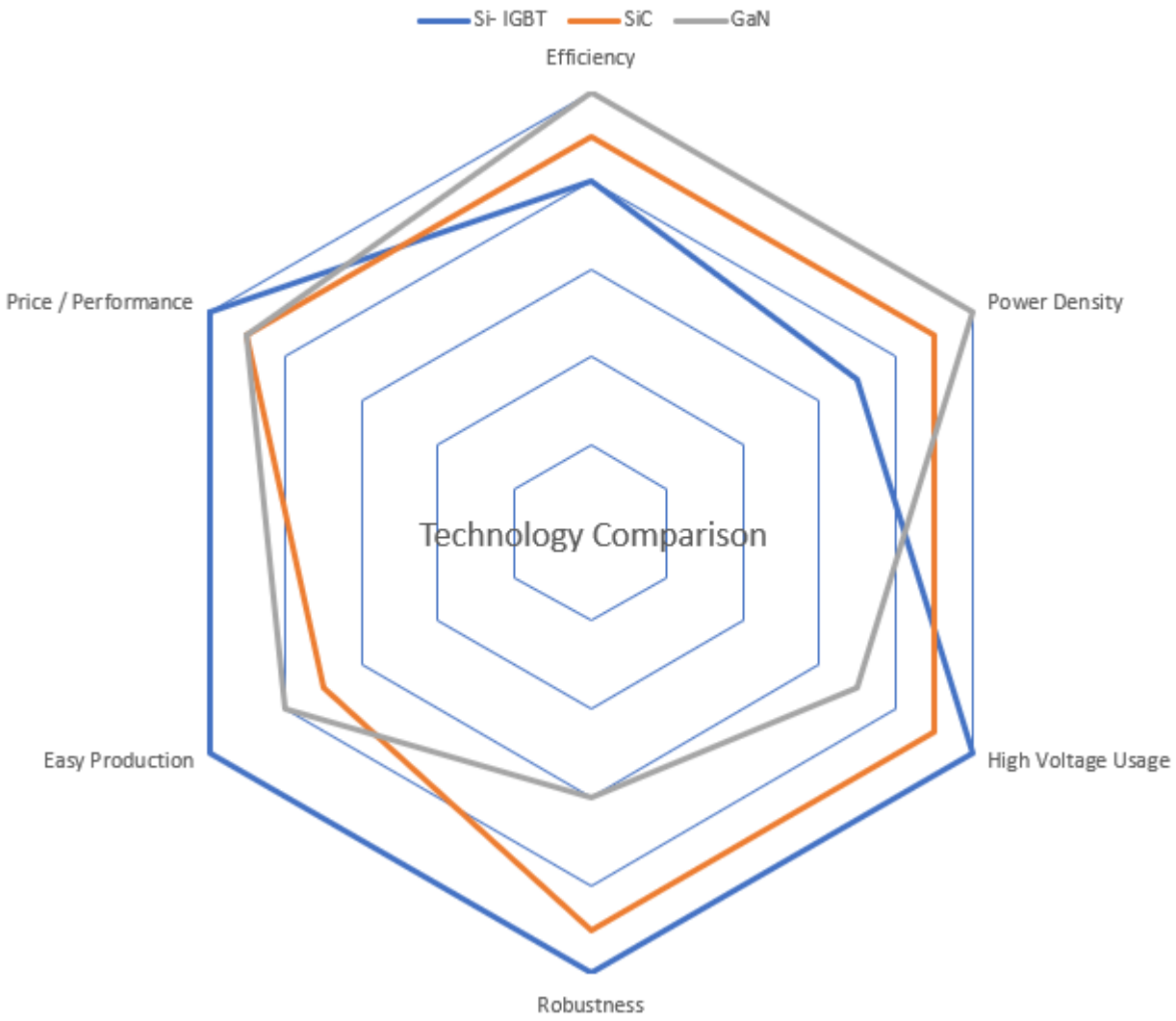
Si IGBT
- Best price / performance ratio
- Mature, stable, well established
- For both 450 / 900 V batteries

SiC
- High performance, robustness
- High reliability especially with high temperature and in harsh environments
- Smaller system size

vGaN (vertical) → Outlook
- Highest efficiency at highest frequency
- Smaller system size

https://www.yesvgan.eu

Wide Band Gap Power at Silicon Cost

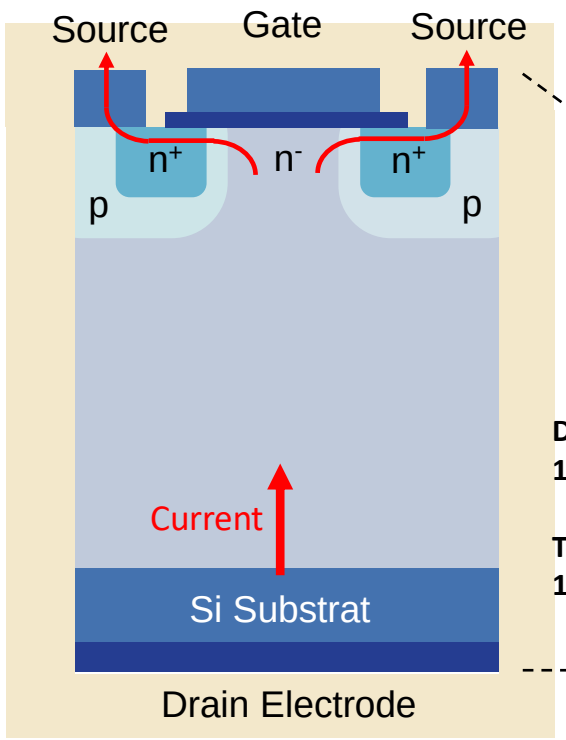


Source: Bosch, eAx

Si- MOSFET vs SiC vs GaN

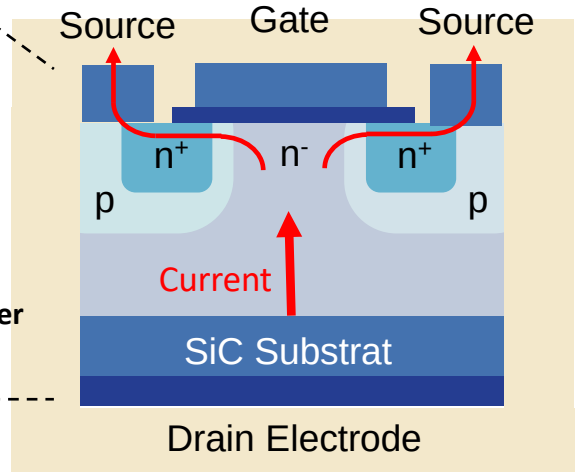
Si- MOSFET | **SiC- MOSFET** | **vGaN- HEMT*)**

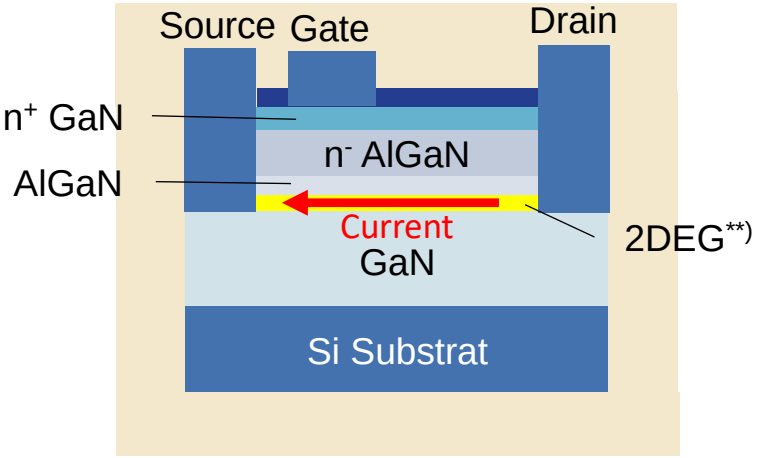
Dielectric Strength 0,3 MV / cm → 2,8 MV / cm



Design:
1/10 thinner

Temp. Resistant
1/300 … 1/1.000 lower





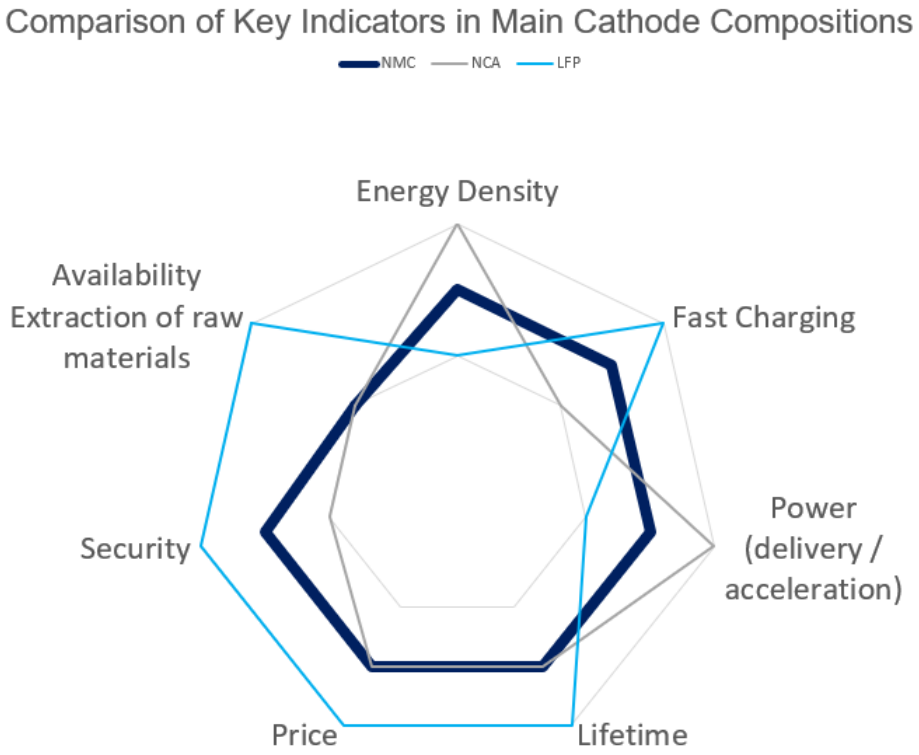
High Speed Switching ~ 100 kHz → ~ 10 MHz

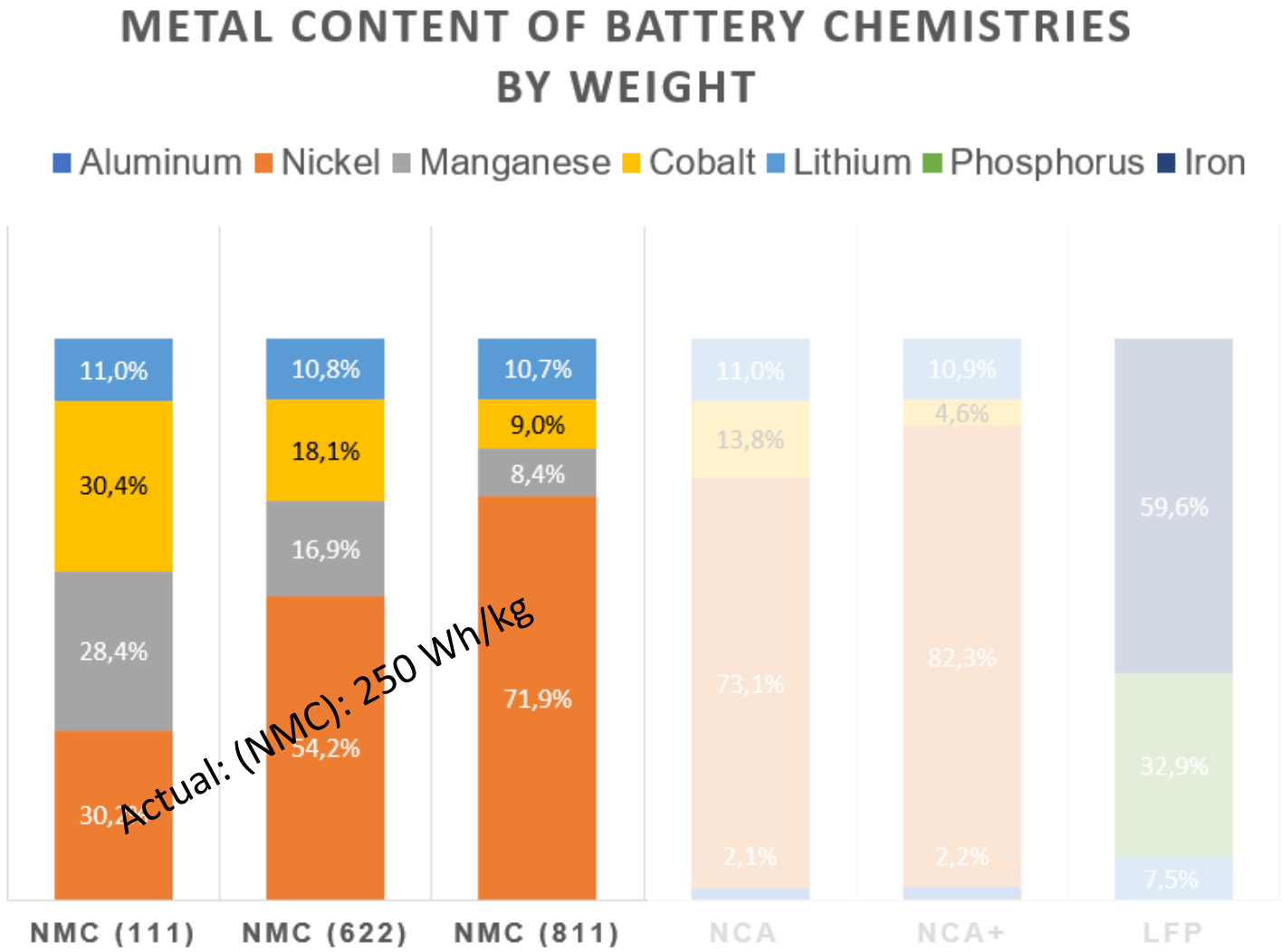
*) HEMT = High Electron Mobility Transistor **) 2D Electron Gas Grafik: eAx solutions GmbH

ENERGY STORAGE

- Overview Cathode Concepts
- Comparison

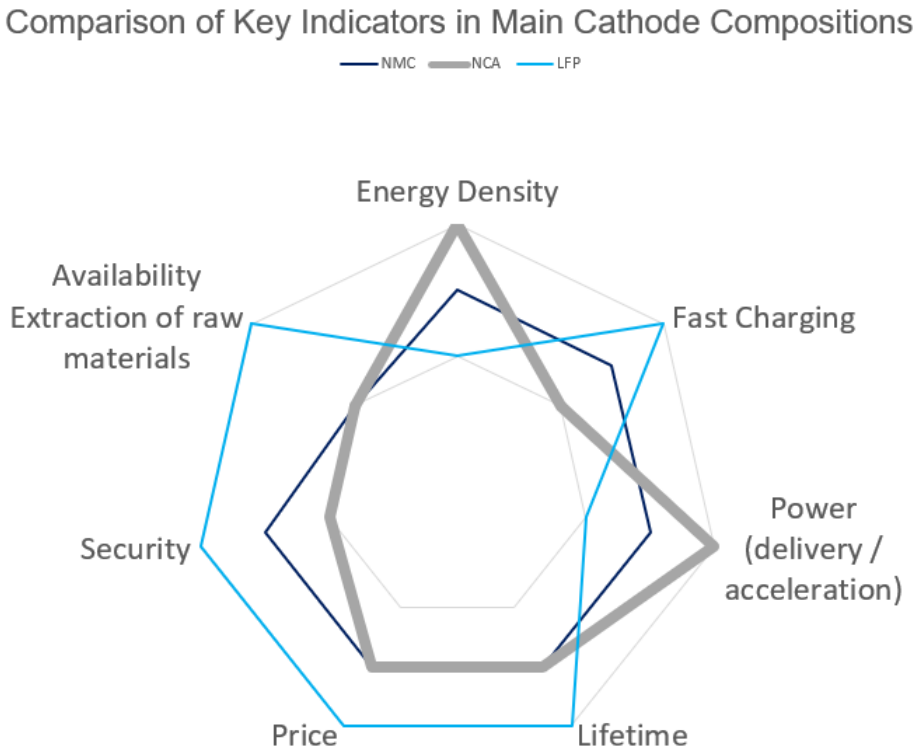
Cathode- Material NMC = Nickel Mangan Cobalt Oxid



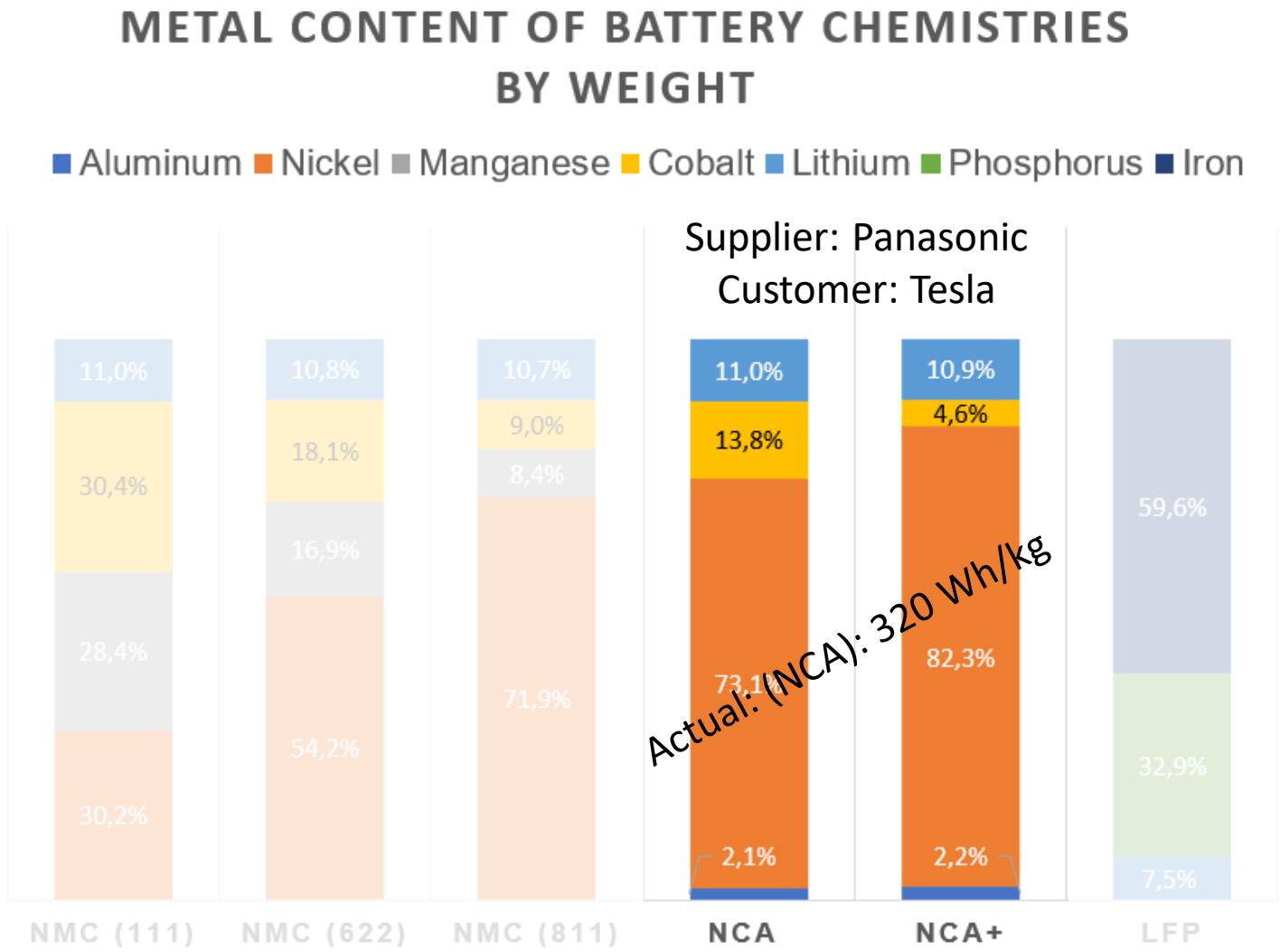


Source: Prof. M. Fichtner / HIU, BloombergNEF

Cathode- Material NCA = Nickel Cobalt Aluminium

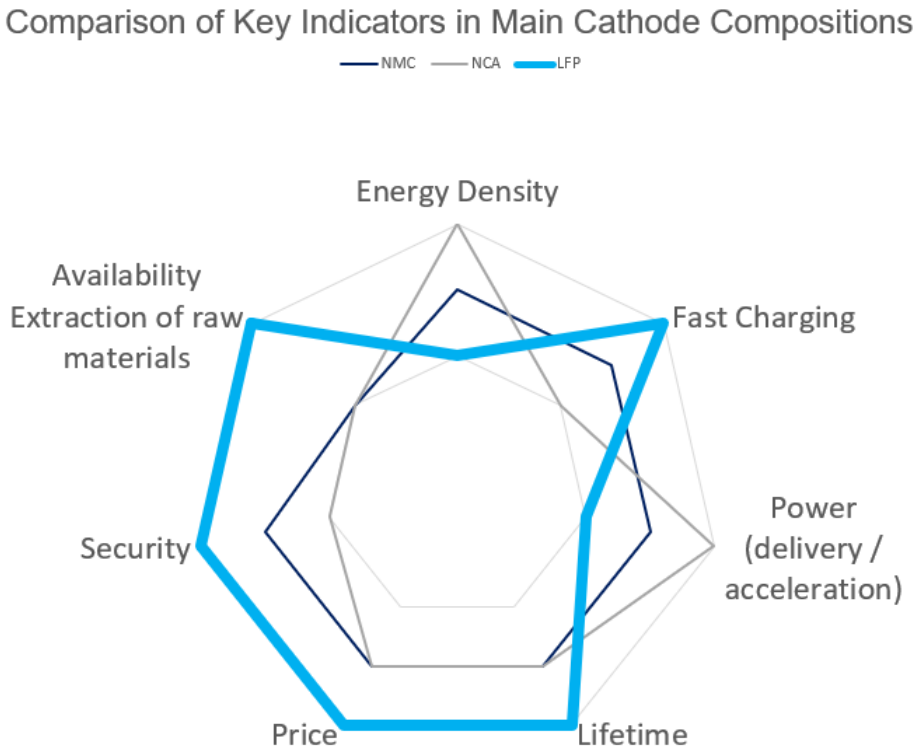


High storage capacity and energy density

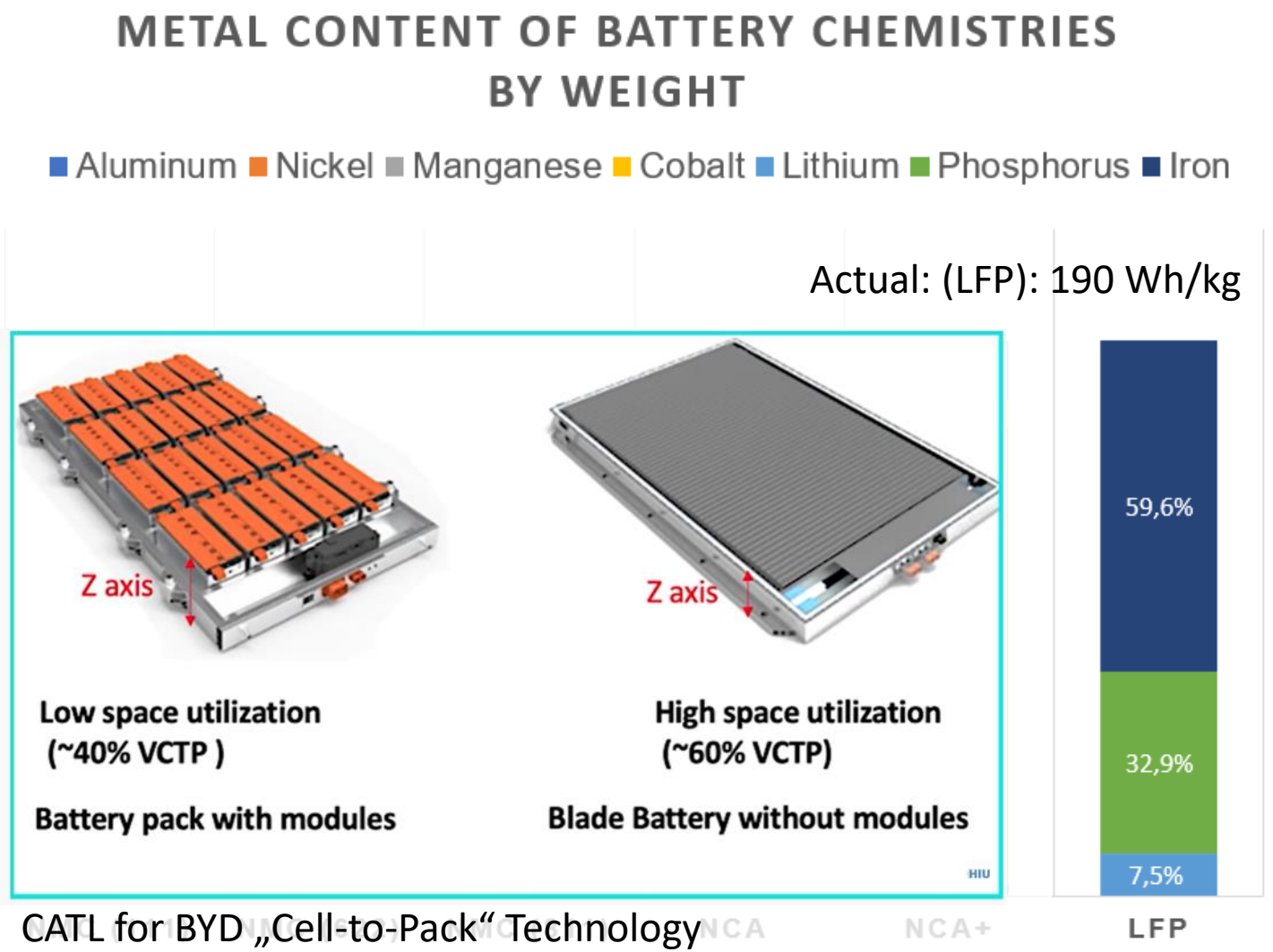


Source: Prof. M. Fichtner / HIU, BloombergNEF

Cathode- Material LFP = Lithium Ferrite Phosphate



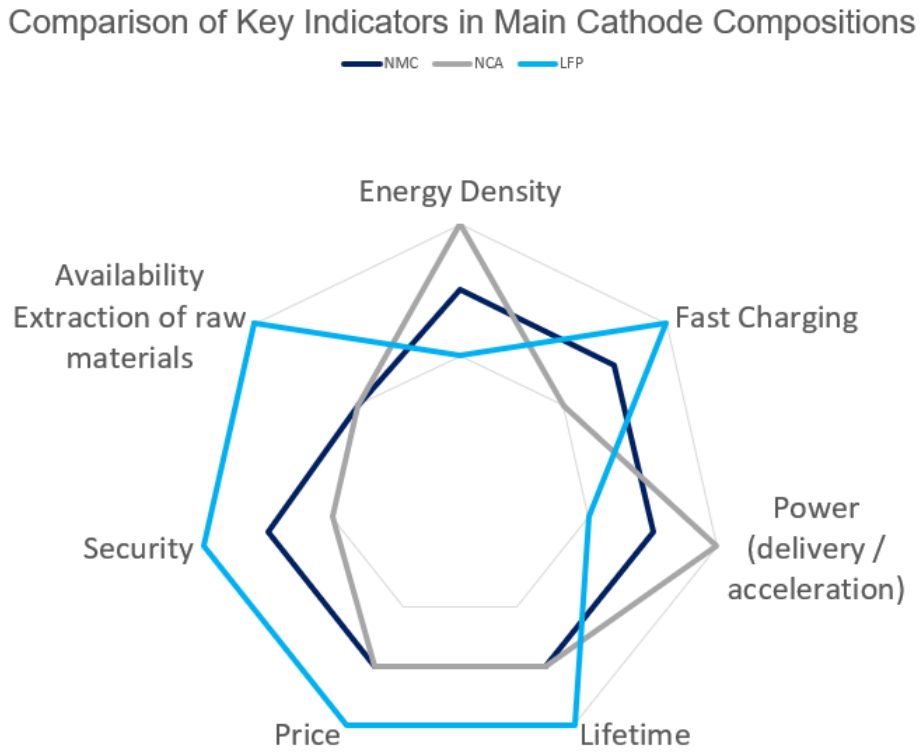
Sustainable and low-cost, long lifetime

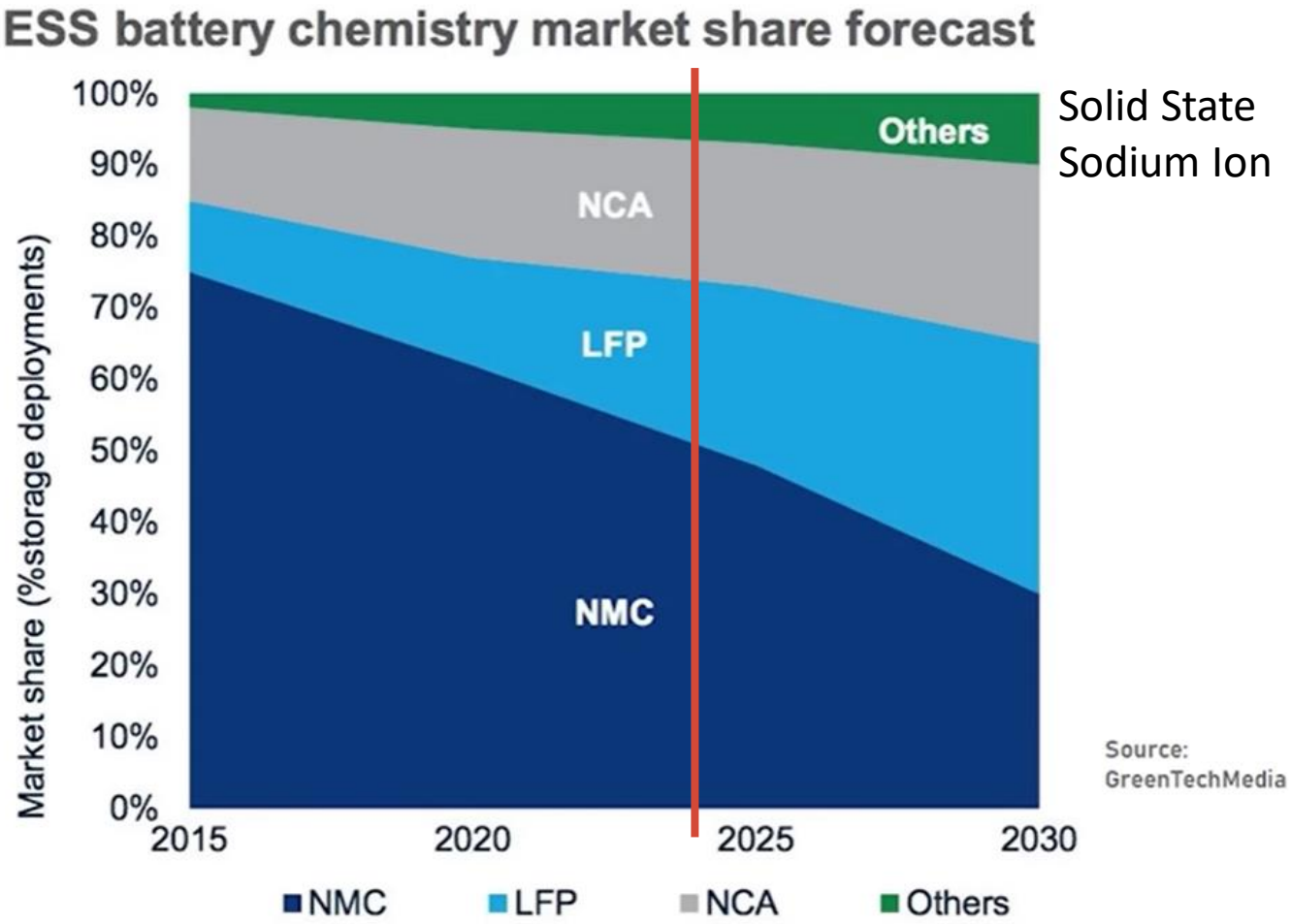


CATL for BYD „Cell-to-Pack“ Technology

Source: Prof. M. Fichtner / HIU, BloombergNEF, CATL

Cathode- Material Trends





Solid State
Sodium Ion

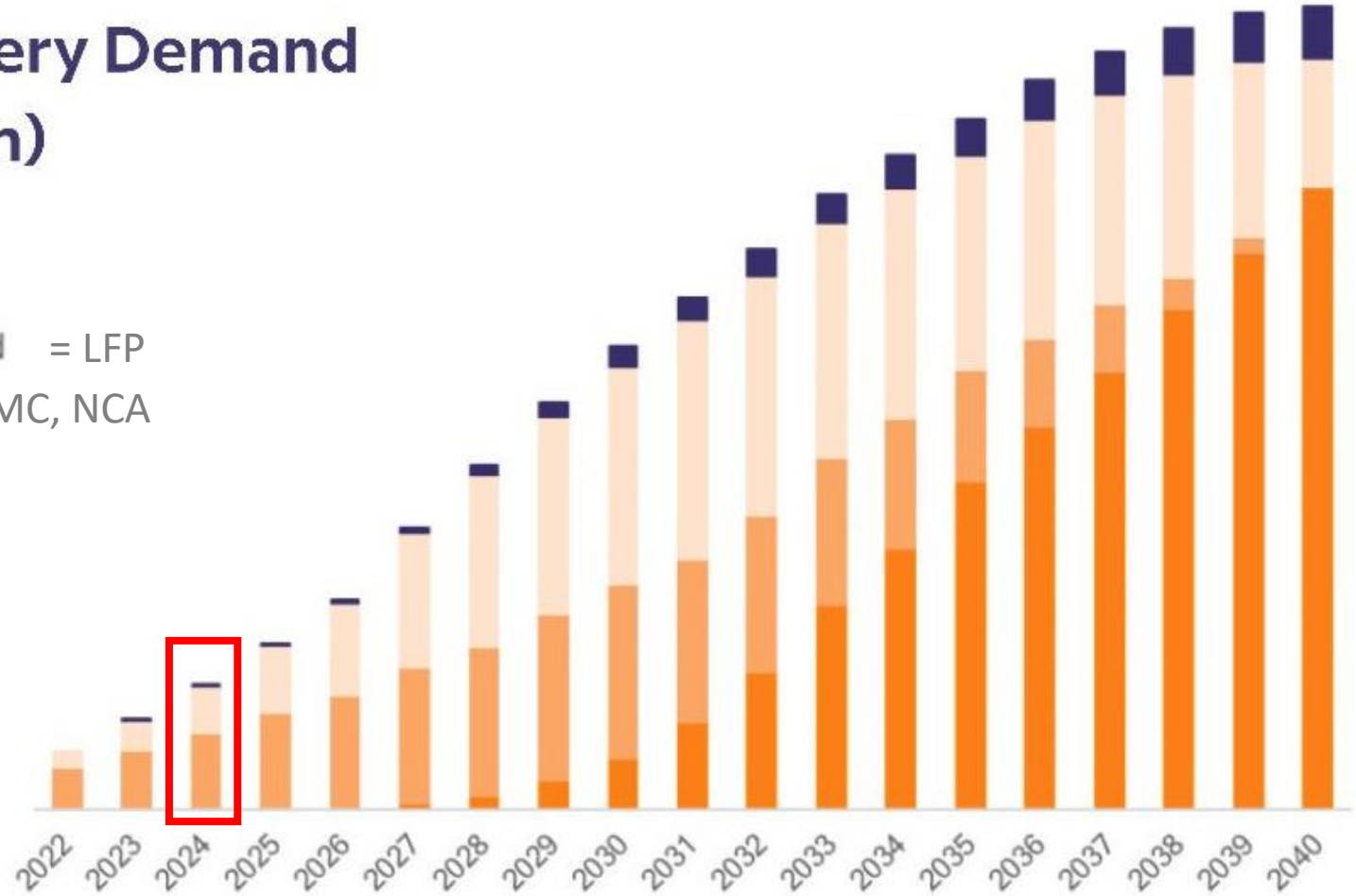
Source: Prof. M. Fichtner / HIU, BloombergNEF

Cathode- Material Trends up to 2040

Global Annual Battery Demand by Chemistry (GWh)

- Sodium Battery Demand
- Lithium Phosphate Battery Demand = LFP
- High Nickel Battery Demand = NMC, NCA
- ASSB Annual Battery Demand

ASSB = All Solid-State Batteries
Series Start 2027



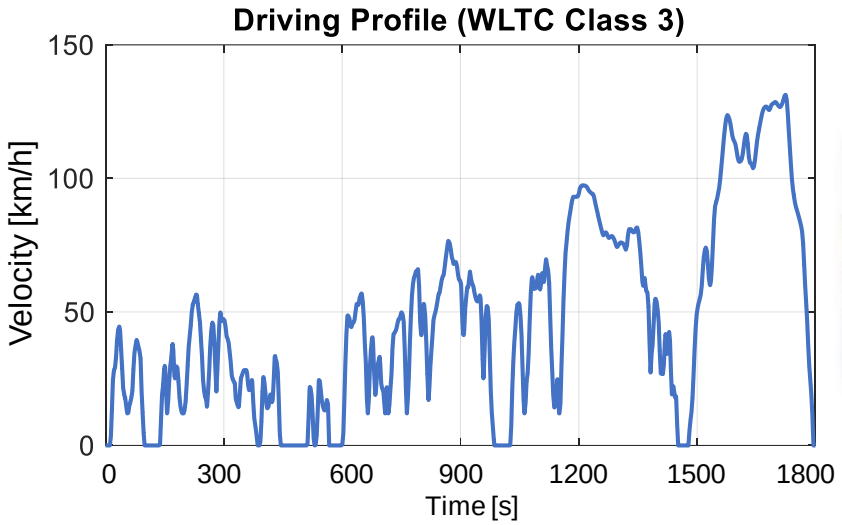
ReTHINK Energy

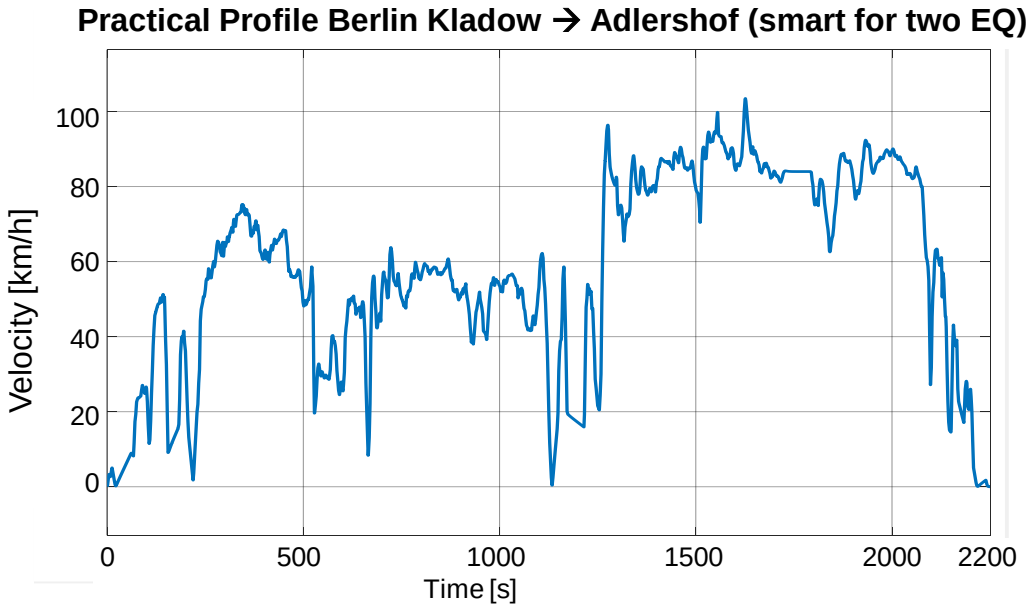
Source: Rethink Energy

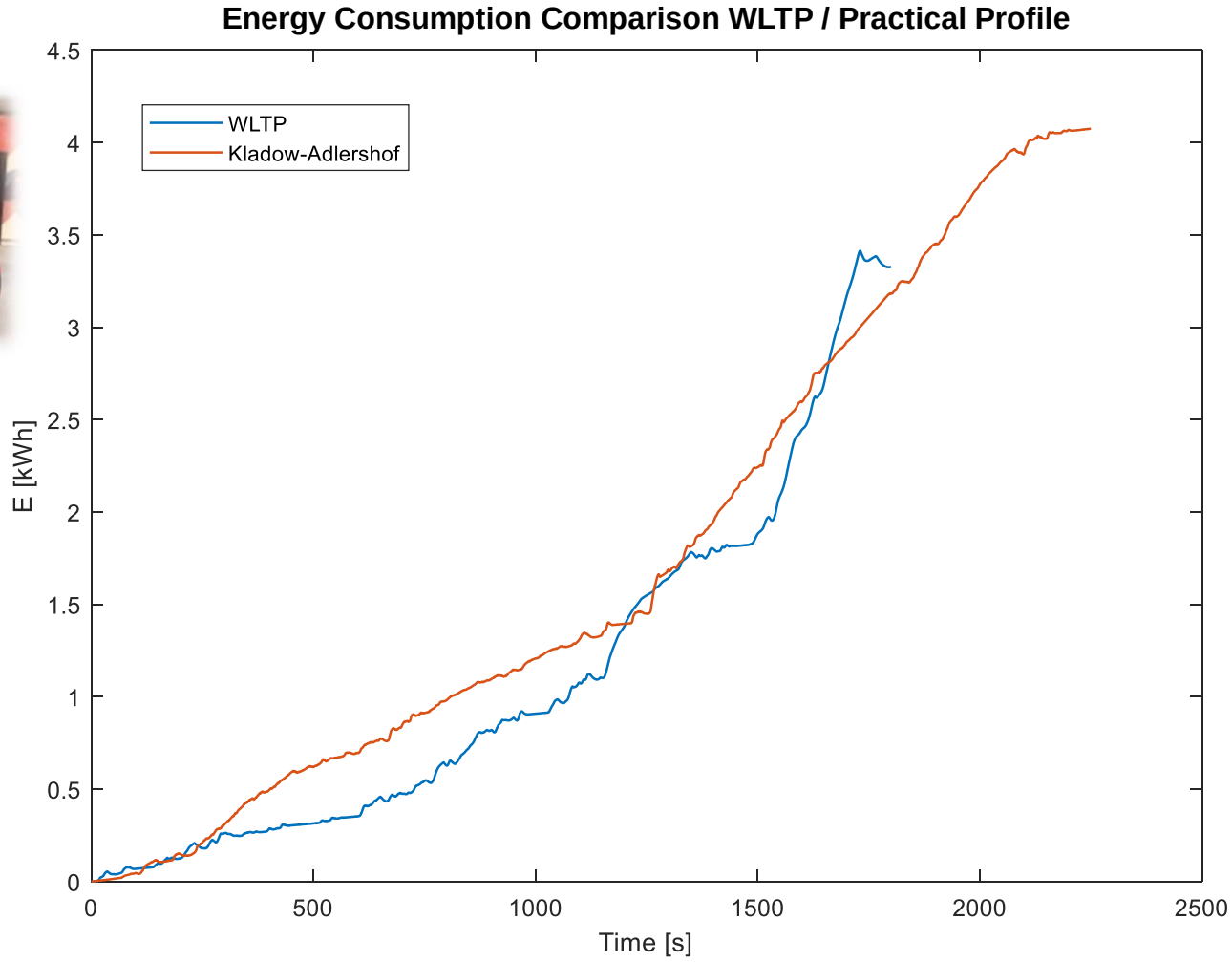
SYSTEM CONSIDERATION

- WLTP discussion
- Overview
- MATLAB Simulink Model
- Results

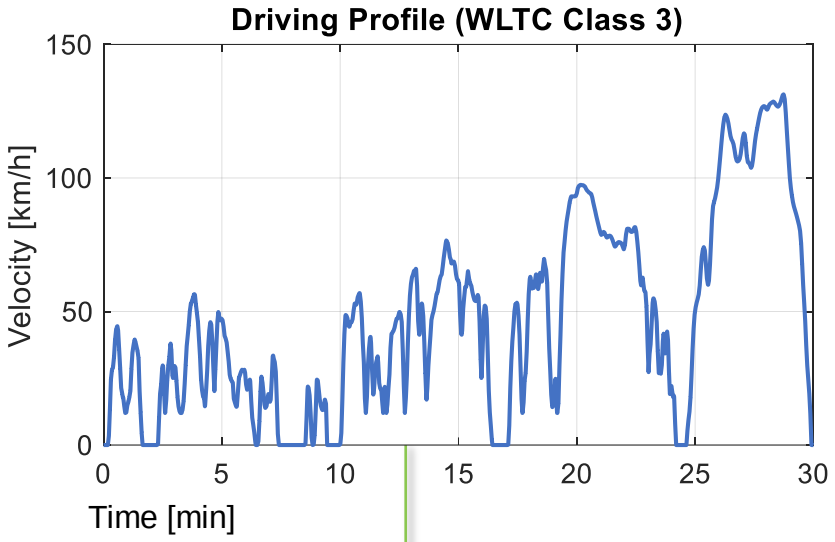
Discussion compare WLTC to a example of a real driving cycle

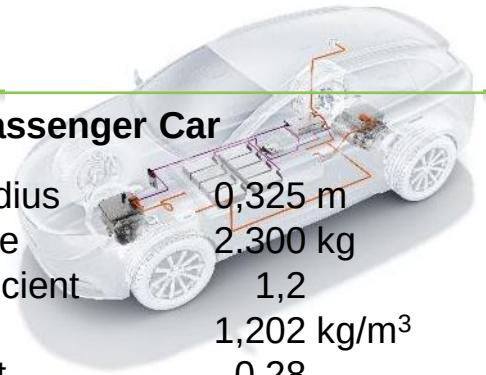






System- Overview (Standard Simulation Base) **+ 800 V + SiC**

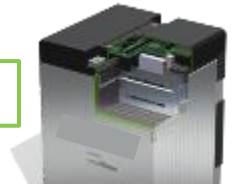




Passenger Car

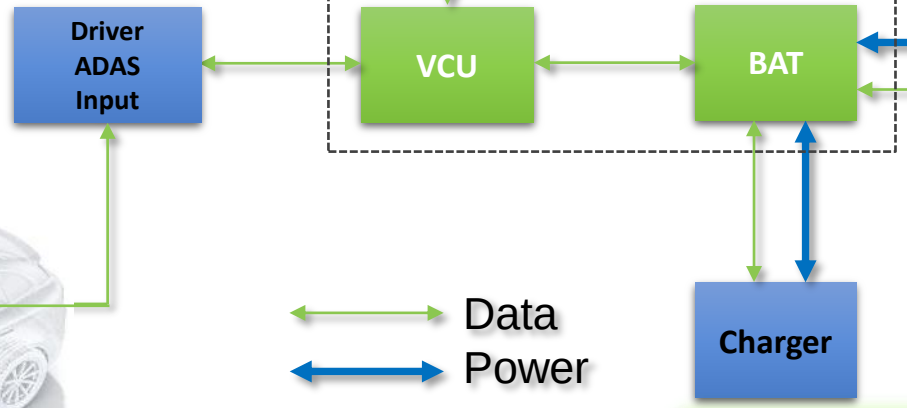
Dynamic wheel radius	0,325 m
Weight of vehicle	2.300 kg
Wheel friction coefficient	1,2
Air density	1,202 kg/m^3
Drag coefficient	0,28
Front surface	2,4 m^2
Rolling friction coefficient	0,011

Quelle: Glasauto Bosch



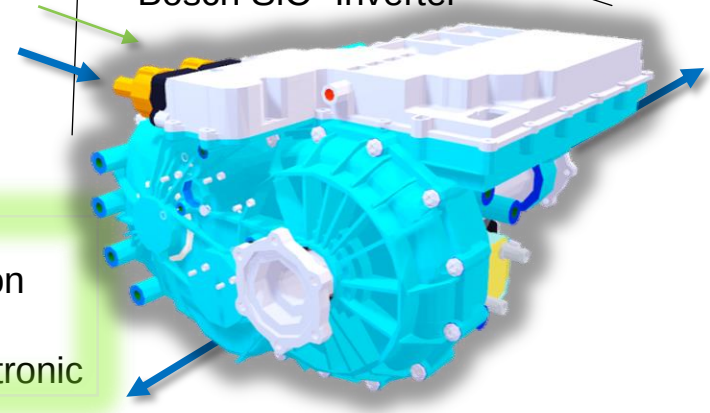
NMC 42 kWh

Improve:
- Battery cells and chemistry
- BMS / VCU *)
- Special Capacitors (e.g. Supercaps)



Improve:
- Transmission
- E- Machine
- Power Electronic

Bosch SiC- Inverter

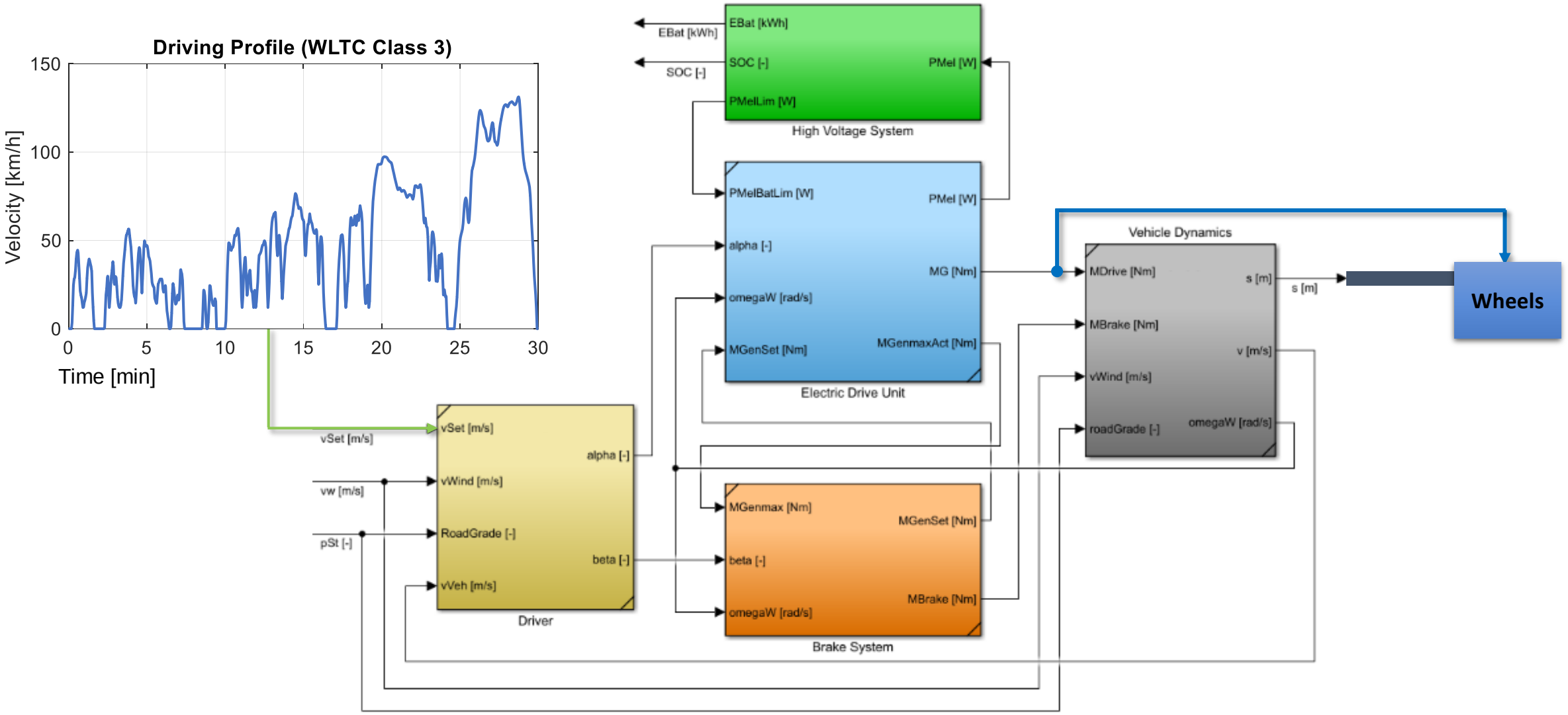


eAx EM220-205-800

*) BMS = Battery Management System
VCU = Vehicle Control Unit

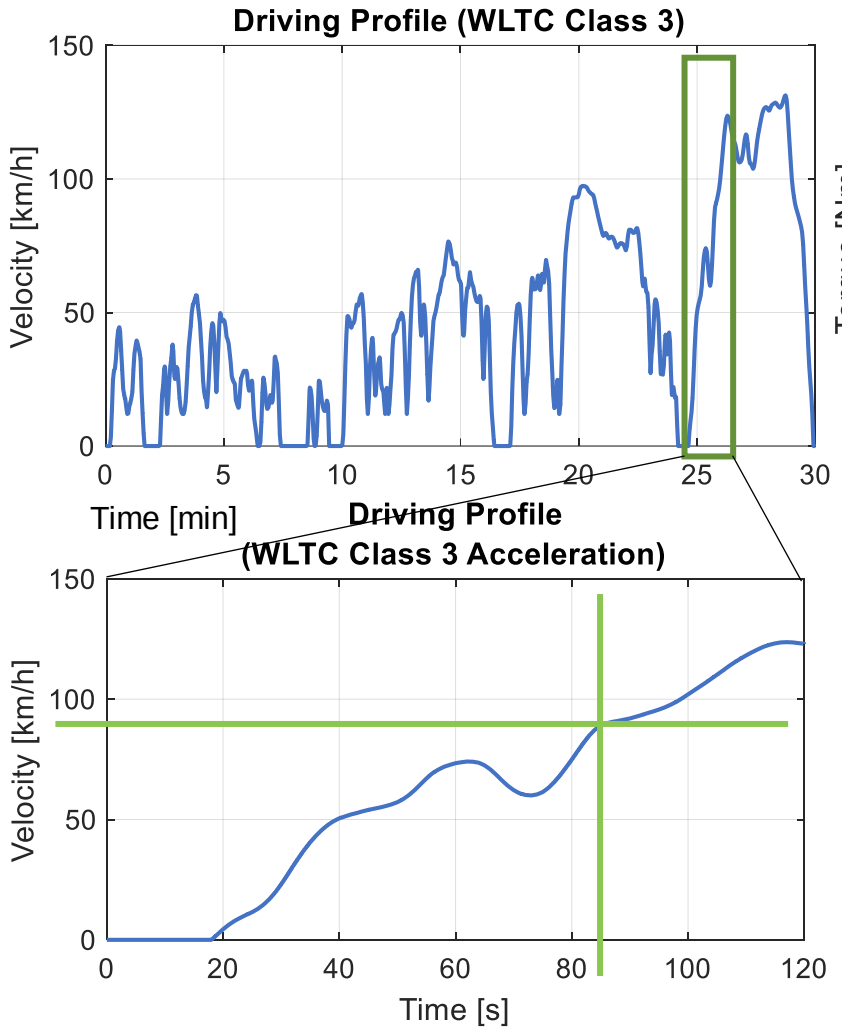
Grafik: eAx solutions GmbH

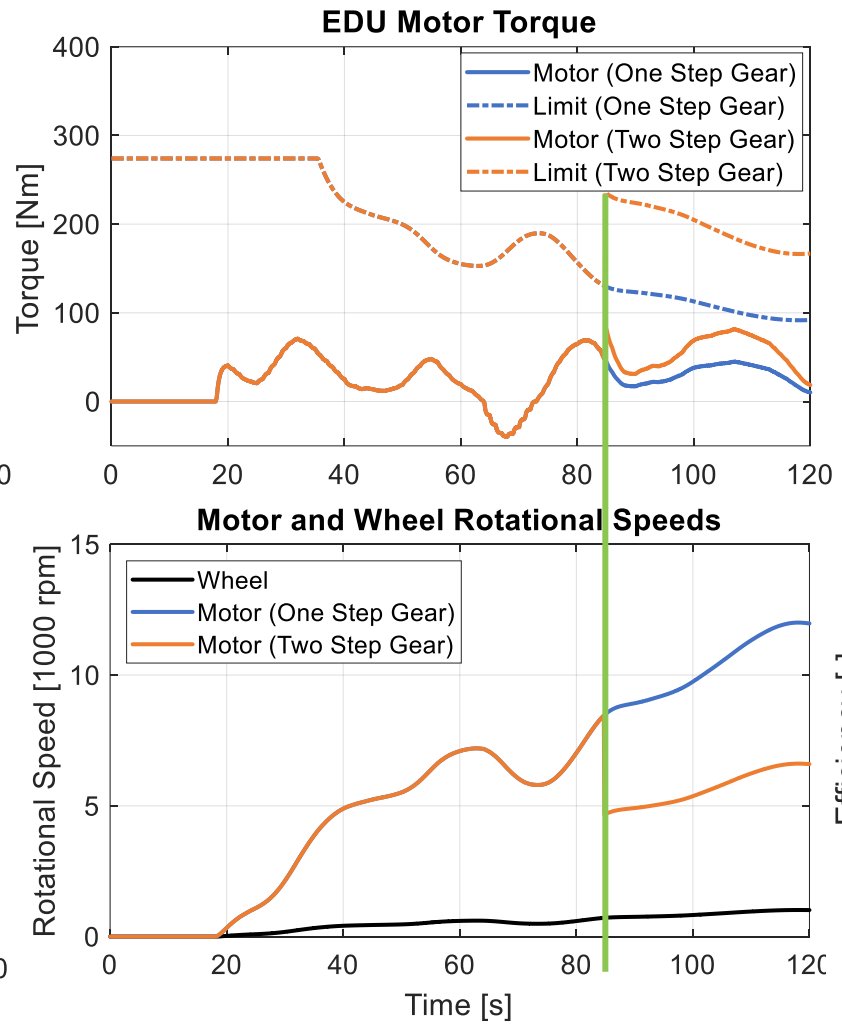
MATLAB Simulink- System model

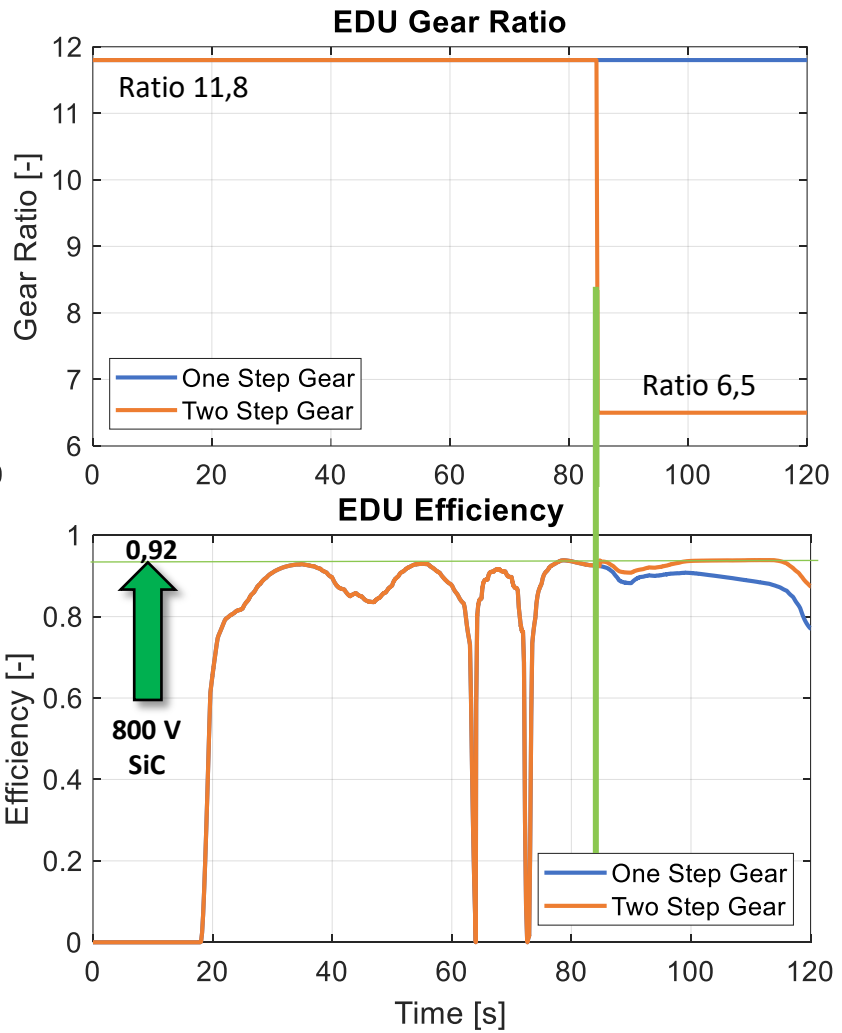


Grafik: eAx solutions GmbH / Otto-von-Guericke-Universität Magdeburg

MATLAB Simulink- Simulation **Two Step Gear + 800 V + SiC**

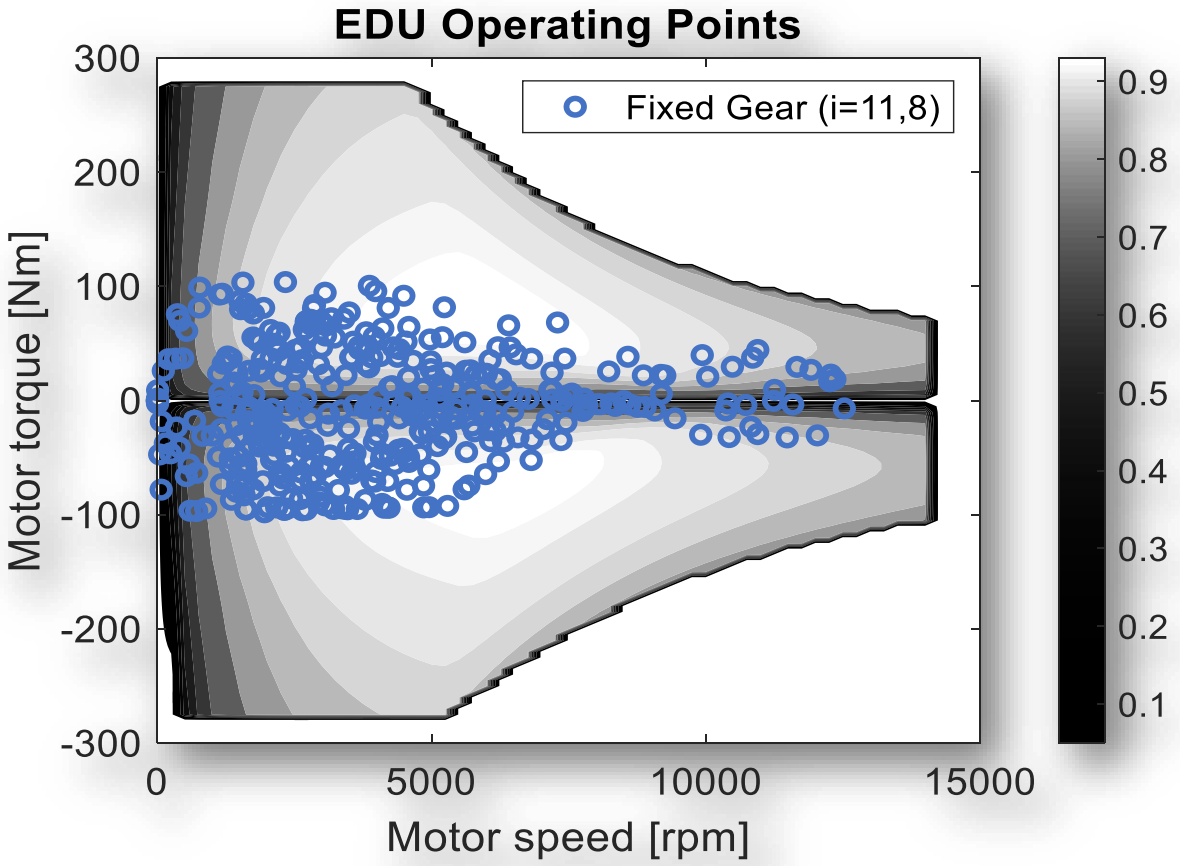


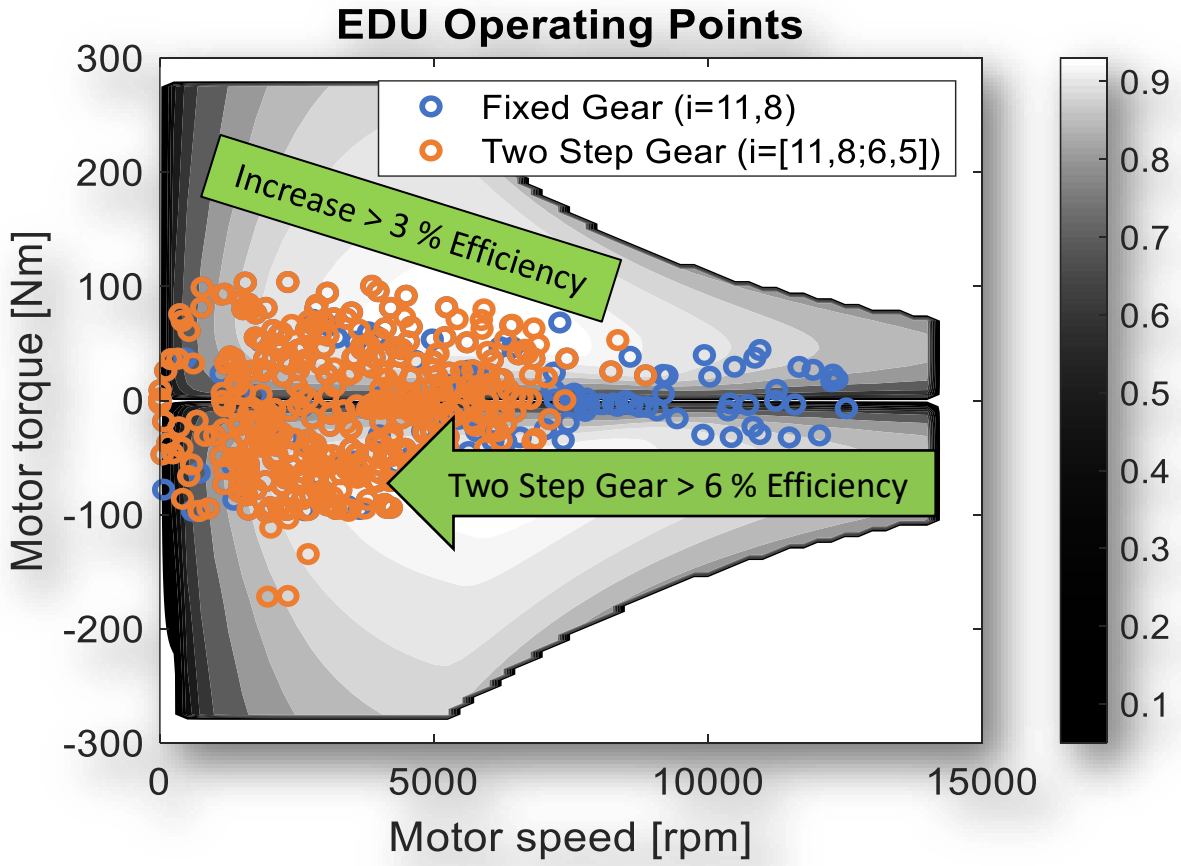




Grafik: eAx solutions GmbH / Otto-von-Guericke-Universität Magdeburg

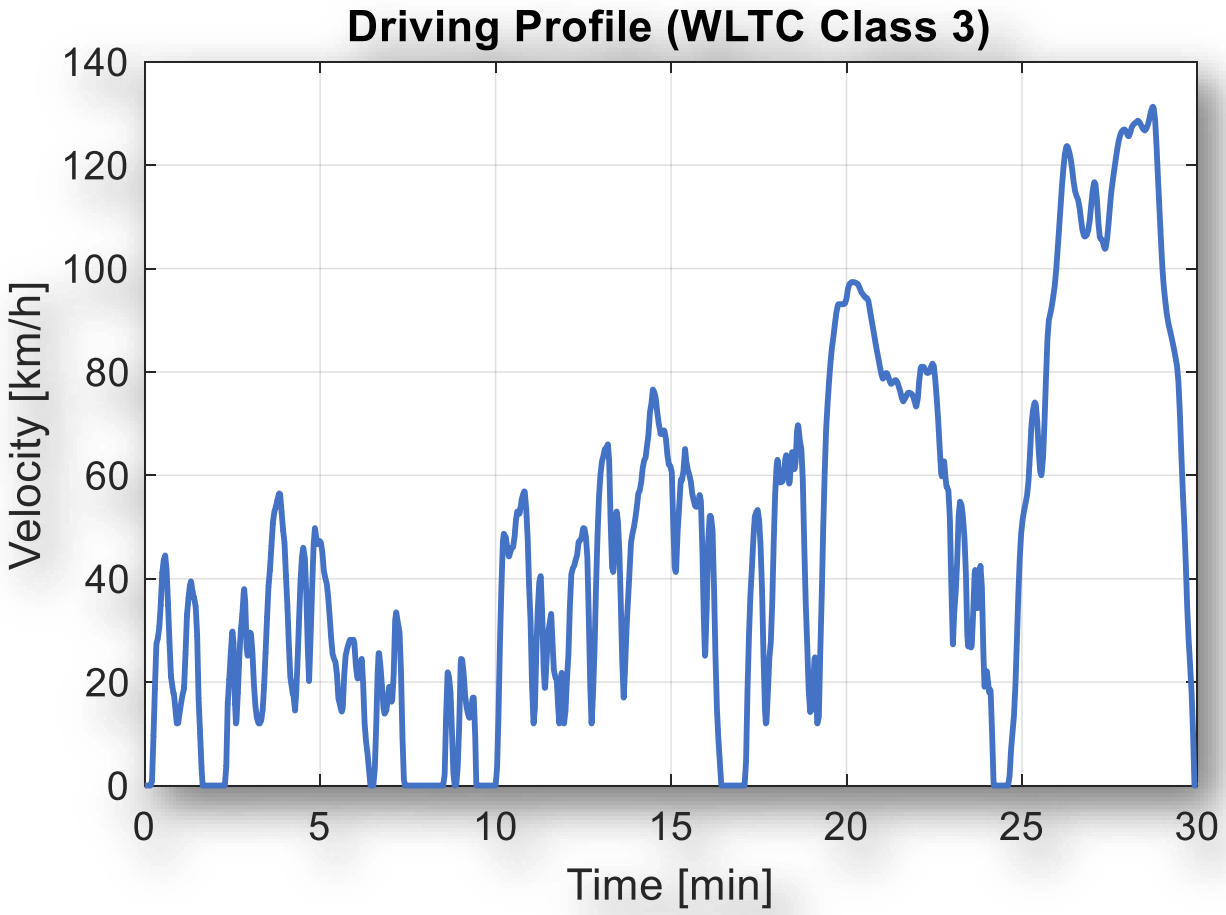
Efficiency Map – w/o **Two Step Gear + 800 V + SiC**

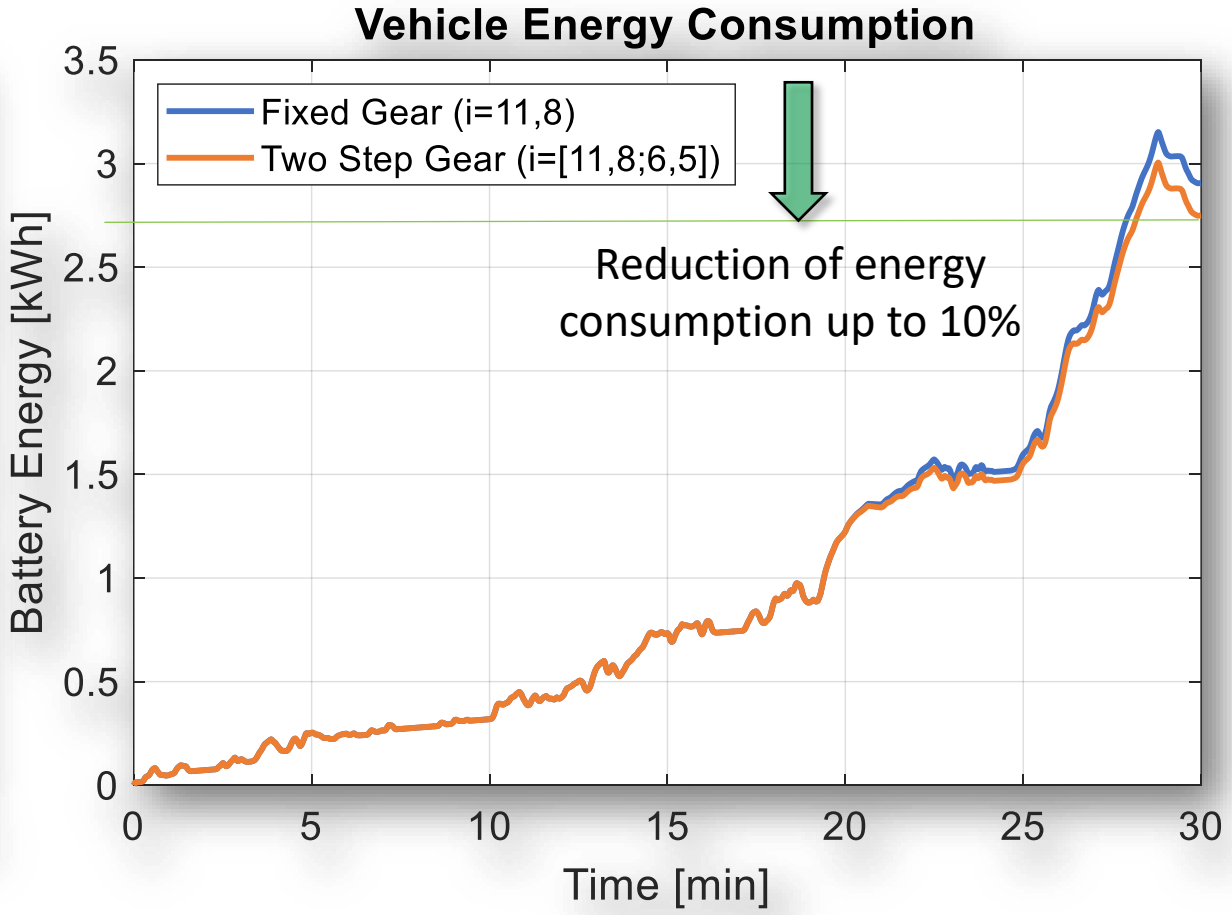




Grafik: eAx solutions GmbH / Otto-von-Guericke-Universität Magdeburg

Summery Energy Saving Potential **Two Step Gear + 800 V + SiC**





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CONCLUSION

Conclusion

E- Axle:

- PSM – eAx preferred solution for high efficiency applications
- ESM / ASM are alternative technologies today, especially against high price magnets
- New standard: 800 V SiC- Inverter Technology
- More Step Gear and 800 V SiC- Technology will increase system efficiency

Batterie- systems

- LFP as Cobalt free alternative and with more charging performance
- Sodium- Ion & Solid State will come to series not before 2027
- Second life before recycling

Systems- Solutions with Optimization E- Axle- Drive

- Two Step Gear Box – SiC Inverter – 800 V Technology → e- machine downsizing
- Optimization Potential of 10 % lower power consumption
- System Cost Saving Potential of Battery = 2 kWh ≡ 240 € *)

*) Assumption: Power consumption 20 kWh / 100 km and today 120 € / kWh battery storage (split NMC / LFP)

Thank you for your attention!

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