HEFT

D1.1 Market need analysis

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D1.1. Market need analysis

CONTENTS

GLOSSARY

OEM	Original Equipment Manufacturer
OES	Original Equipment Supplier (Tier 1)
SUV	Sport Utility Vehicle
LV	Light Vehicle
NEV	New Electric Vehicle
ICE	Internal Combustion Engine
BEV	Battery Electric Vehicle
4WD	Four Wheel Drive
Tier 1	Direct supplier to OEM
Tier 2	Direct supplier to Tier 1
REE	Rare Earth Element
LREE	Light Rare Earth Element
HREE	Heavy Rare Earth Element
LCA	Life Cycle Analysis / Life Cycle Assessment
CRM	Critical Raw Materials
CBAM	Carbon Border Adjustment Mechanism

1 EXECUTIVE SUMMARY

This document identifies the needs of the automotive industry for an effective implementation of the novel eMotors to develop in HEFT project.

As during the project eMotors for two different segments are going to be developed, the market analysis has been done separately too.

2 BACKGROUND

The aim of this report is to identify the needs of the automotive industry for the effective implementation of novel motor concepts into two vehicle segments (Segments A+B and Segments C+D+E) and to provide technical criteria for the validation phase.

The report will lead to a set of specifications for the potentially marketable products and for the eMotor prototypes that will be built during the project for concept validation, and will interact with other project work packages.

For this analysis, market segments have been grouped together with the intention of generating two eMotor variants to cover multiple applications.

Interest in motors for vehicle segments A+B (Motor A) is declining in Western markets as with the associated high costs of electrification are pushing OEMs to seek the higher margins of larger vehicles. On the other hand, A+B segment motors will also continue to have a market as the secondary motor of higher performance and larger vehicles. In this category, the consortium proposes a low-cost, yet highly efficient Permanent Magnet based machine featuring recycled Rare Earth magnets.

For the vehicle segment C+D+E motor (Motor C), the reference machine is taken as the motor for the 2021 Mercedes EQS. The study of this machine will determine the torque and power densities targets for the project. The lower relative cost of the electric motor is less problematic for this vehicle segment than for the A+B segments. Technological advancements are seen as important differentiators by the OEM.

3 MARKET ANALYSIS AND ROADMAP FOR 5-10 YEAR

The increased cost of manufacturing battery electric vehicles, combined with a desire to increase margin rather than invest in volume, is leading the established global OEMs to abandon the A and B segments, e.g. Mercedes, in favour of higher margin larger and predominantly SUV formats. For example, Ford is abandoning the small car and saloon market, with storied names such as Fiesta and Mondeo consigned to history in favour of SUVs.

3.1 The Impact of Constraints on Market Forecast

Figure 1 displays the historical and future forecasts of global light vehicle production from 2019.

The blue light line in Figure 2 is the industry's hoped-for recovery mirroring that of 2009 (after the financial crisis) with a strong immediate bounce taken from May 2021. Unfortunately, the consequences of the pandemic led to far greater medium-term disruption to supply chains than anticipated at the time. The impact on microchip and power electronic devices availability was extreme. A combination of OEM cutting orders and other markets, such as gaming, flourishing, led to significant global shortages within the industry lasting well into 2022, demonstrated by the dark blue line forecast for May 2022. The impact of Russia's war of aggression on Ukraine, the disruption to supply chains and super inflation have put an end to any hope of rebound recovery from the pandemic instead, the forecasts from February (gold) and May 2023 (yellow) have agreed on a long slow recovery for light vehicle production volumes.

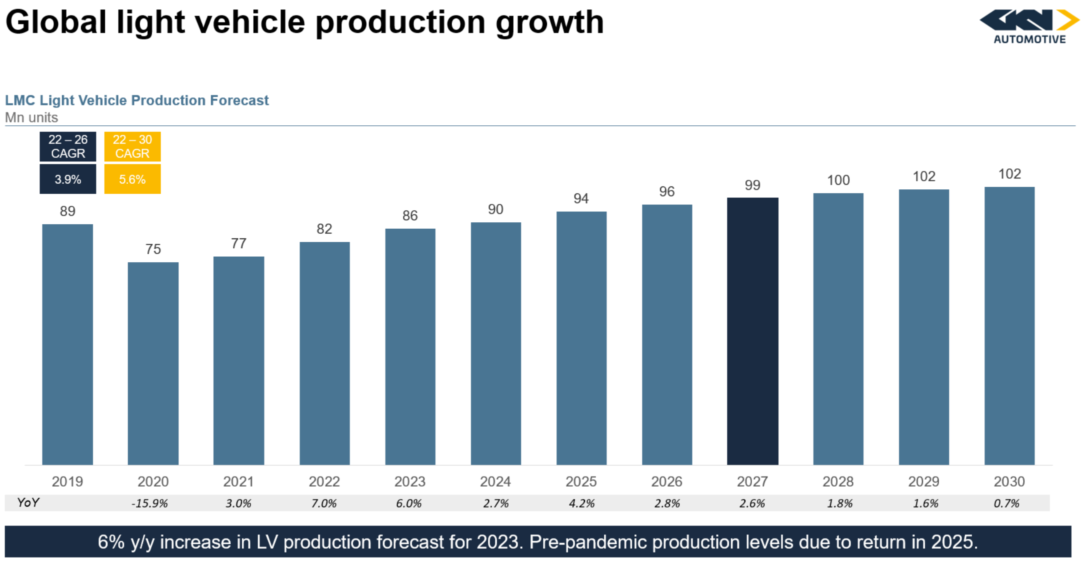
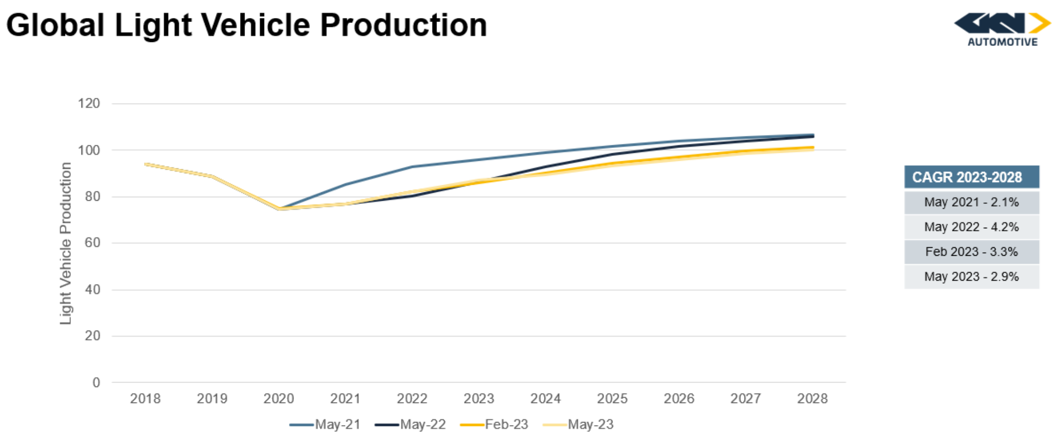


Figure 1. Global Light Vehicle Production Forecast Evolution

(Based on Q2 2023 LMC Automotive, a Global Data Company LV Engine Forecast)

Figure 2 shows a forecast based on a 2.9% CAGR, meaning that global volumes would surpass pre-pandemic levels in 2024, and rise above 2018's peak car production in 2026.



	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028
May 2021	94.08	88.75	74.62	85.32	92.89	95.91	99.04	101.57	103.92	105.49	106.62
May 2022	94.14	88.82	74.68	76.86	80.12	86.23	92.97	98.16	101.66	103.95	105.65
Feb 2023	94.14	88.79	74.72	76.93	82.27	85.89	90.18	94.20	97.01	99.50	101.09
May 2023	94.14	88.79	74.69	76.92	82.27	87.07	89.58	93.19	95.93	98.48	100.24

Figure 2. Global Volumes Forecast to Exceed Pre-Pandemic by 2025

(Based on Q2 2023 LMC Automotive, a GlobalData Company LV Engine Forecast)

3.2 The Evolution of Light Vehicle Powertrains

The forecast in Figure 3 from LMC shows the rapid growth of xEV production at the expense of ICE, with a 41% of global production being electric, fuel cell or full hybrid by 2027. The exploitation of the project is more dependent on the expansion of xEV than that of overall light vehicle production.

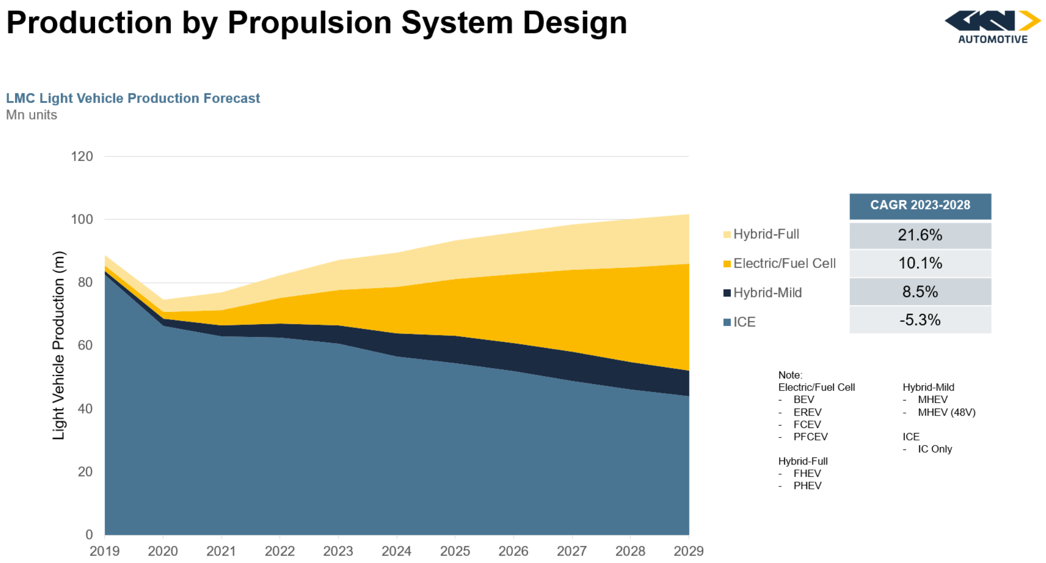


Figure 3: xEV Forecast to exceed ICE.

(Based on Q2 2023 LMC Automotive, a GlobalData Company LV Engine Forecast)

3.3 xEV Production in 2023

The Graphic in Figure 4 shows that in Europe vehicles with optional hybrid lead the top five sales with Tesla's model Y compact SUV the top plugin. In developing markets ICE still dominate however in China plugin SUV dominate with Tesla top, leading to Tesla's Model Y leading the Global production charts at the time of writing.

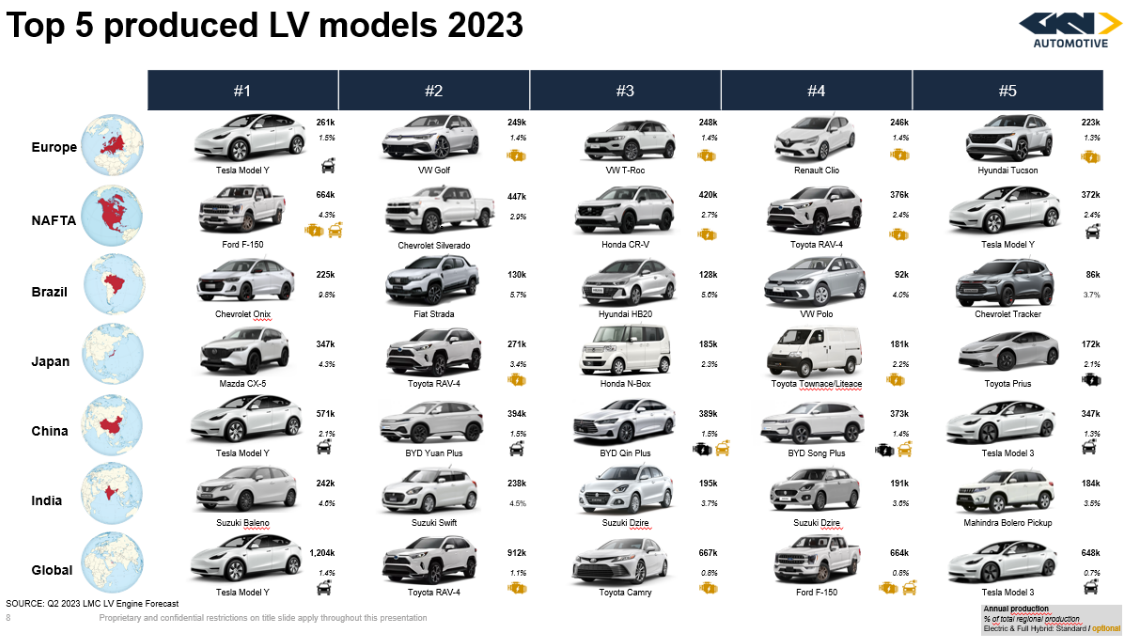


Figure 4: Top 5 Light Vehicles by Region 2023

(Based on Q2 2023 LMC Automotive, a GlobalData Company LV Engine Forecast)

3.4 Light Vehicle Segment Share

What is also clear is that the SUV is the dominant global form factor of light vehicle production across the globe in 2023, as it is shown in Figure 8. Even in the grip of global cost of living crisis, LMC forecast that this trend will continue with the SUV form factor increasing by a further 3 to 4%

to half (of what?), primarily at the expense of lighter, cheaper, more economical, and sustainable cars.

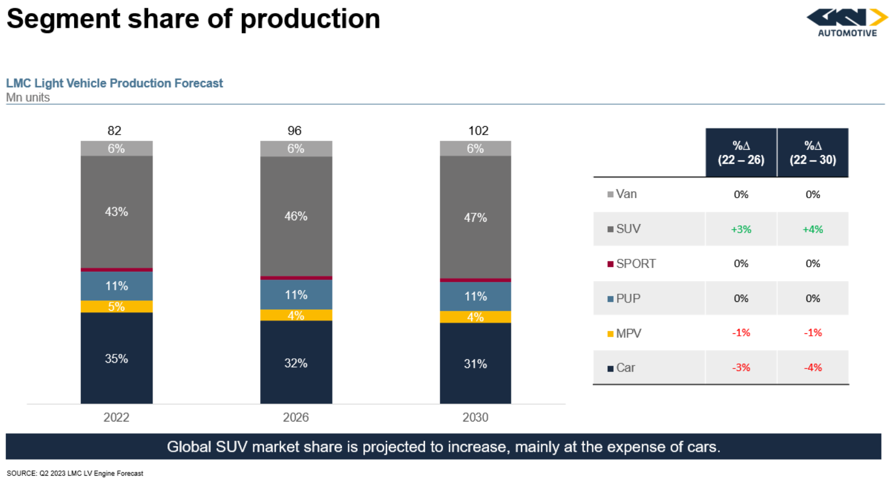


Figure 5. Light Vehicle Production by vehicle Form. SUV set to become Dominant (Based on Q2 2023 LMC Automotive, a GlobalData Company LV Engine Forecast)

3.5 System Power by Segment

The larger CDE segment dominates the production of xEV's accounting for a total of 41 million out of a forecast total of 51 million units by 2032.

Analysis of the market trends combined with customer requests at GKN Automotive enable specific power and torque requirements to be set as shown in Figure 6 and Figure 7. The high-speed of the project machine provides a higher specific power than segment analysis, enabling greater flexibility of use in practice. This market study is influenced not just on the motor minimum requirements/needs but as well on availability/development of other components such as inverter and battery which can limit the system. Inverter rated levels will limit the maximum current for the motor (hence torque for a fixed volume) as well as maximum continuous power. Battery limitations will affect not just the operating voltages but as well due to its size the maximum available power for the motor.

Similarly for larger vehicles, the segment demonstrates a consistent need from time of writing to 2031 for applications of 150kW capability at both 400V and 800V, consistent with bid specification. The ability to combine the machines as both primary and secondary drives provides significant market flexibility and scope, from humble city car to sports or executive express with over 300kW peak power.

Bid specification closely matches market analysis.

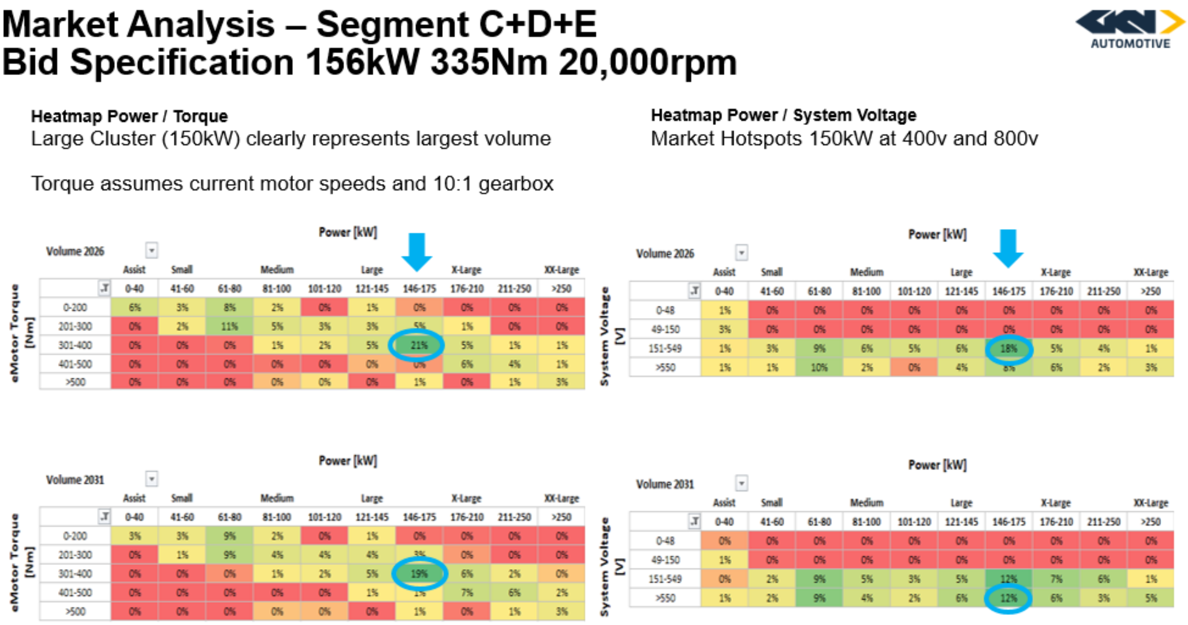


Figure 6. Market Analysis of segments C, D, E (Source GKN Internal Analysis)

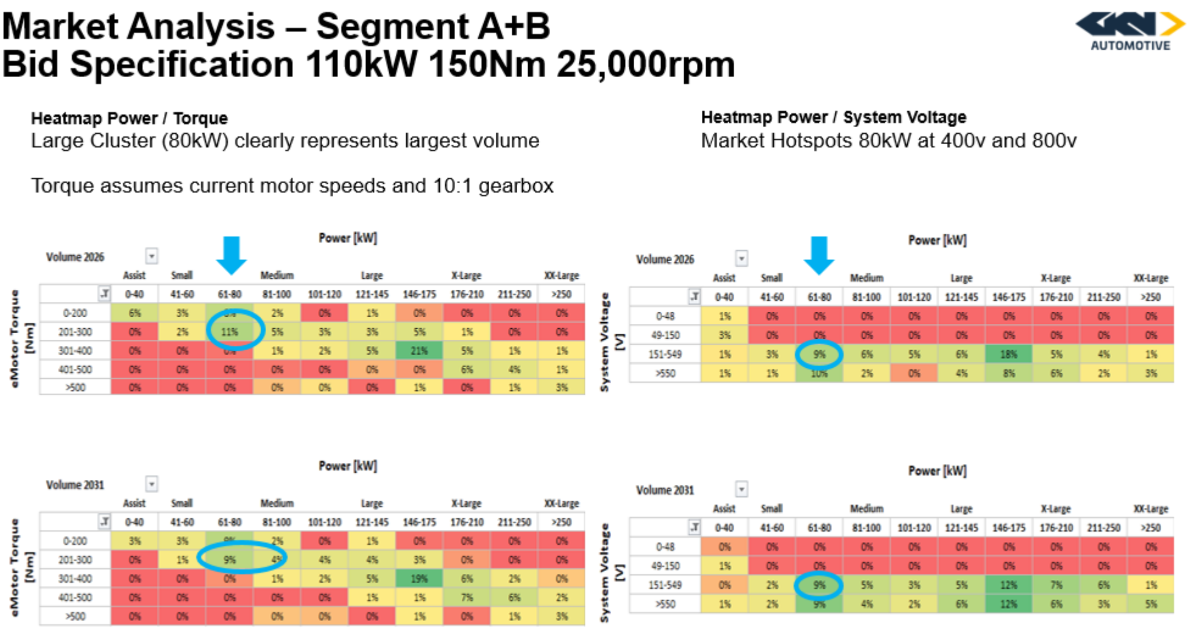


Figure 7. Market Analysis Segment A+B (Source GKN Internal analysis)

Figure 7 refers to the proposed original project bid 110kW. However, as it can be seen in the heat maps, the Market Analysis indicates that this power is not demanded for the vehicle applications, in the mid or long term for the A+B segment. Therefore, with the agreement of the consortium, the specification for the vehicle whole system will be limited to 80 kW. At the same time, the power specification for A+B motor is maintained to 110kW (as it was indicated in the proposal), for future vehicle applications. It is concluded, that HEFT innovations could allow to achieve a power of 110kw for A+B motors, increasing the number of vehicle applications to be cope with the same motor . It should be notice that a 110kW motor could be directly use in vehicles with lower power level demand.

4 TECHNICAL REQUIREMENTS

We are seeing demand from the market for an increased continuous power delivery from eMotors in comparison to peak performance delivery. Table 1 shows the expected roadmap of power density vs cost per kW over the coming decade. Not only is volumetric power density expected to increase by 350% but cost per kW is expected to fall to half of the current state of the art.

Table 1. APC UK Electric Machine Road Map

Electric machine indicators	2020	2025	2035
Cost ($/kW)	6	4.8	3.3
Volumetric Power Density (kW/l)	8	25	30
Gravimetric Power Density (kW/kg)	4	8	10
WLTP Average Efficiency	93%	95%	97%

4.1 Motor Specification for A+B Segment

Based on market research, we have selected a typical A+B segment vehicle as a basis to develop the motor specification. The vehicle data, in combination with drive cycle and load cases, has been used to determine the speed / torque / power envelope required of the motor.

Simulation of WLTP cycle is shown in Figure 8 and power-torque curve displayed in Figure 9, main parameters for the design are shown in Figure 10. Peak power is set up to 110kW (as it was indicated in the proposal).

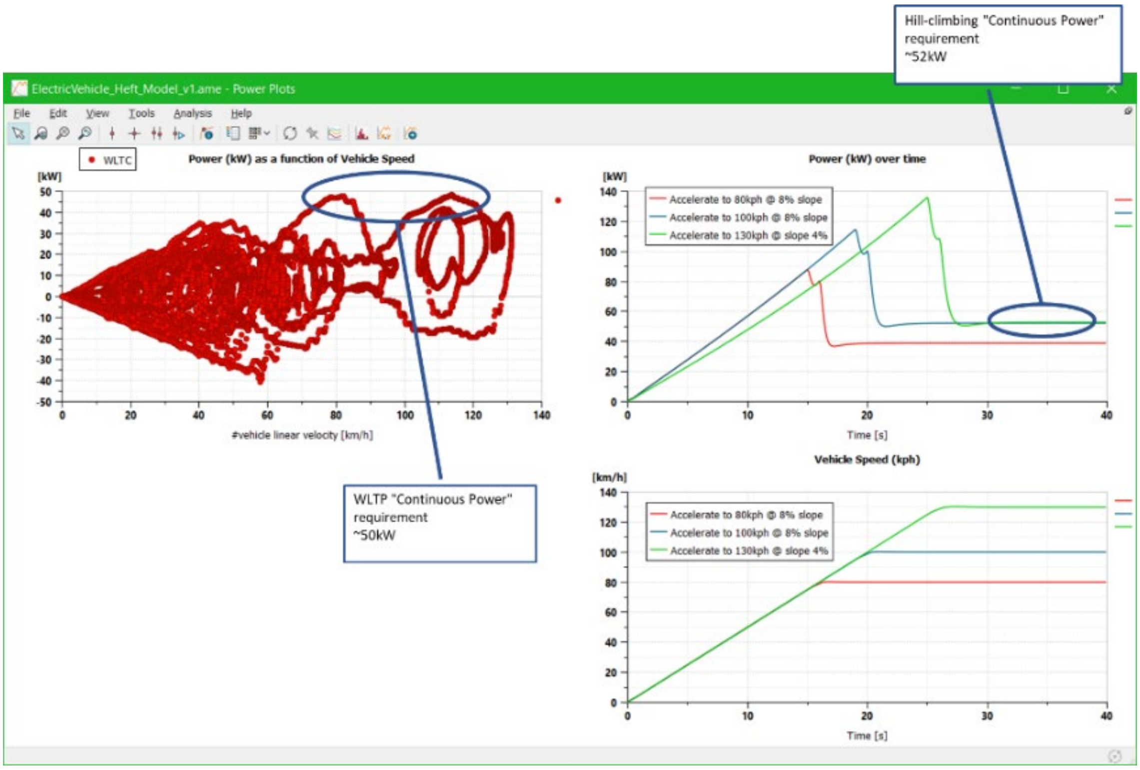


Figure 8 Simulation of WLTP Drive Cycle & Hill Climbing Power Requirement

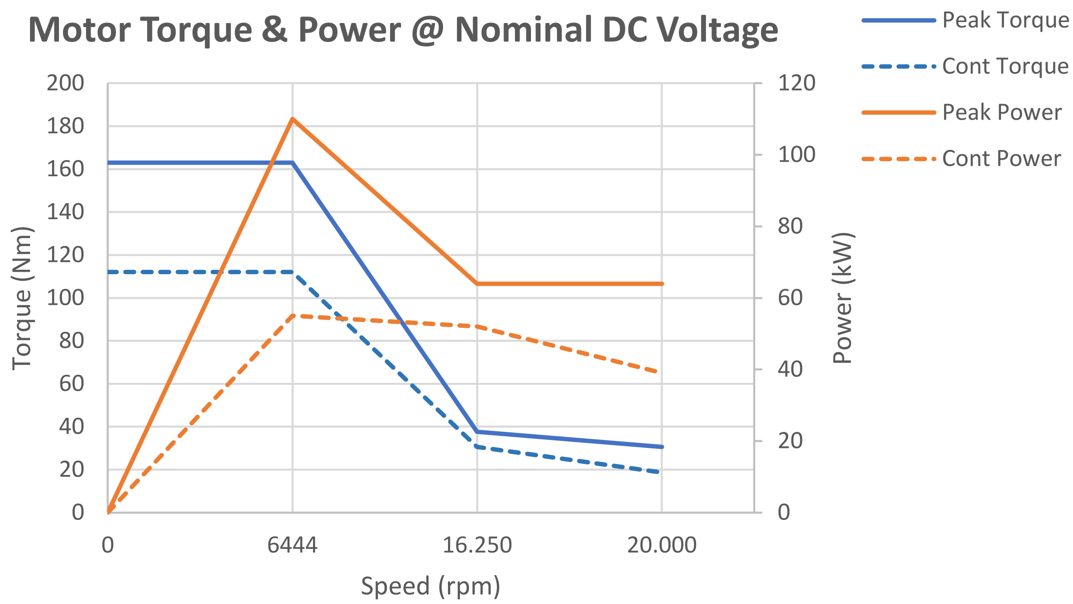


Figure 9 Motor Power & Torque Curve for A+B Segment Vehicle

Vehicle - Fiat 500e				
Max vehicle speed	km/h	160		Required - from Market Analysis
Vehicle weight - kerb	kg	1365		Kerb Vehicle Weight - used for WLTC & ADAC cycles
Vehicle weight - gross	kg	1750		Gross Vehicle Weight - worst case for hill-climbing
Tyre circumference	m	1,800		Typical 195/65R14
Aerodynamic drag area (Af*CD)	m2	0,6624		
Predicted 0-100kph Acceleration	secs	7,5		Simulation prediction using proposed torque curve and gear ratio
Battery Voltage Class - Vehicle Level	V	800		Market Analysis shows equal sales for 400V & 800V in 2026-2013

System Level (includes Gearbox)				
Max axle torque	Nm	2200		Required - from Market Analysis
Motor corner speed @ wheels	kph	40		
Maximum sideshaft speed	rpm	1481		
Gear ratio - example	x:1	13,5		Used here for "What-if" studies
Max gear ratio - NVH constraint	x:1	16		Do not exceed : NVH limit for 2-stage offset design
Gearbox efficiency - typical	%	97%		Average torque eff. and spin-loss for WLTP analysis
Power for Max Speed	kW	39		Informs Continuous Power (from simulation)
Power for Hill-climb	kW	52		Informs Continuous Power (from simulation)
Minimum efficiency over operation range	%	92% WLTC		Guideline : OEM expectation, informs motor loss (Wh/km) below
Gearbox internal volume	L	5,56		Use for Power/Torque density calcs

Project Motor				
	Units	Peak	Continuous	Comment
Duration of operation point	s	30	1800	For peak between 5 -30s, continuous 1800s
Shaft power	kW	110	55	Peak from Market Analysis, Cont. 69% of Peak is good stretch target
Max Shaft torque - example	Nm	163		Function of gearbox ratio selection
Corner speed	rpm	6.444		Max torque speed range
Maximum speed - example	rpm	20.000		Function of wheel size, gear ratio, etc
Maximum speed - market constraint	rpm	20.000		Market acceptance limit, e.g. bearing life, rotor balance
Maximum overspeed	rpm	+10%		Rotor Burst mitigation
Nominal DC Voltage	Vdc	650		At the operating point, from LV123 "Unlimited operating capability"
Maximum phase current	Arms	350		Required - from Market Analysis, inverter cost, IGBT or SiC
Power Density - Continuous		~27,7kW/L (KPI3.2) & ~8,39kW/kg (KPI 4.1)		Minimum targets from Call Option A (>23kW/L & >7kW/kg)
Torque Density - Continuous		~55,87 Nm/L & ~35,84Nm/kg (KPI 4.2)		Minimum targets from Call Option B (>50Nm/L & >20Nm/kg)
Motor losses - Mean over WLTP	Wh/km		11,4	~ 20% reduction over baseline eMotor
Maximum temperature on winding	°C	180	180	
Maximum rotor temperature	°C	100	150	

Inverter & Motor Insulation				
dV/dt & Risetime (maxDCBus / (dU/dt) = risetime)	[kV/µs]	5 typical	10 stretch	To determine insulation system
Max Switching Frequency	[Hz]	20.000		For better PID current control at high RPM
Fundamental Frequency max	[Hz]	~1000		Motor AC loss analysis will define this. Also for inverter SW task timing
Number of phases	[-]	3		
max. DC-Bus-Voltage	Vdc	800		Max survivable with no damage, inverter off (from LV123 Standard)
PDIV Phase-Phase	Vpk-pk	3726		Partial Discharge Inception Voltage from IEC 60034-18-41 with a moderate stress category (1.5)
PDIV Phase-Ground	Vpk-pk	2381		

Figure 10 Key Parameters for A+B Segment eMotor

4.2 Motor Specification for C+D+E Segment

Using the same methodology as used for A+B segment, we selected a target C+D+E vehicle to develop the motor specification for this segment.

As in the A+B segment, in Figure 11 and Figure 12 the WLTP cycle simulation, the power-torque curve and the main parameters of the eMotor are shown.

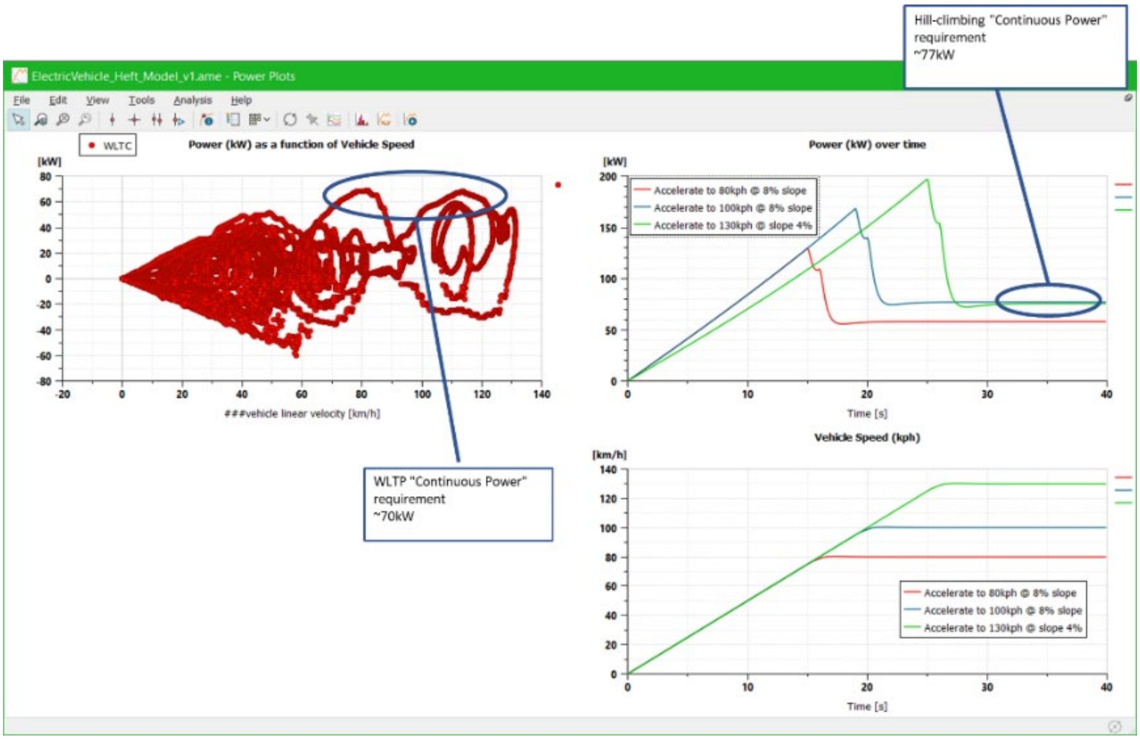


Figure 11 Simulation of WLTP Drive Cycle & Hill Climbing Power Requirement

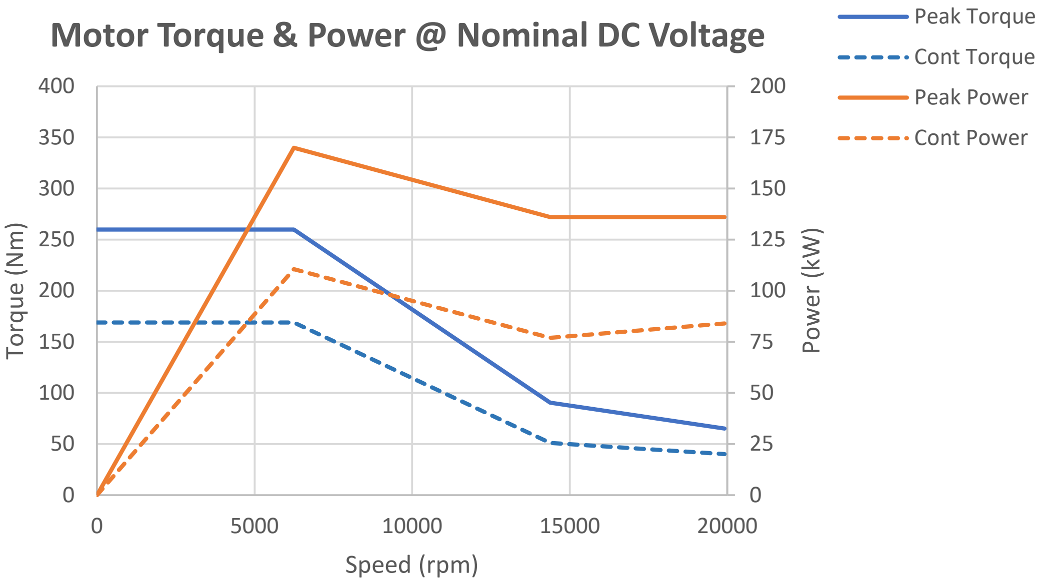


Figure 12 Motor Power & Torque Curve for C+D+E Segment Vehicle

Vehicle - VW ID4				
Max vehicle speed	km/h	180		Required - from Market Analysis
Vehicle weight - kerb	kg	2068		Kerb Vehicle Weight - used for WLTC & ADAC cycles
Vehicle weight - gross	kg	2560		Gross Vehicle Weight - worst case for hill-climbing
Tyre circumference	m	2,320		Typical 255/45R20
Aerodynamic drag area (Af*CD)	m2	0,8372		
Predicted 0-100kph Acceleration	secs	6,4		Simulation prediction using proposed torque curve and gear ratio
Battery Voltage Class - Vehicle Level	V	800		Market Analysis shows majority sales for 800V in 2026-2013

System Level (includes Gearbox)				
Max axle torque	Nm	4000		Required - from Market Analysis
Motor corner speed @ wheels	kph	40		
Maximum sideshaft speed	rpm	1293		
Gear ratio - example	x:1	15,4		Used here for "What-if" studies
Max gear ratio - NVH constraint	x:1	16		Do not exceed : NVH limit for 2-stage offset design
Gearbox efficiency - typical	%	97%		Average torque eff. and spin-loss for WLTP analysis
Power for Max Speed	kW	84		Informs Continuous Power (from simulation)
Power for Hill-climb	kW	77		Informs Continuous Power (from simulation)
Minimum efficiency over operation range	%	92% WLTC		OEM expectation : informs motor loss (Wh/km) below
Gearbox internal volume	L	TBD		Use for Power/Torque density calcs

Project Motor				
	Units	Peak	Continuous	Comment
Duration of operation point	s	30	1800	For peak between 5 -30s, continuous 1800s
Shaft power	kW	170	111	Peak from Market Analysis, Cont. 65% of Peak is good stretch target
Max Shaft torque - example	Nm	260		Function of gearbox ratio selection
Corner speed	rpm	6.250		Max torque speed range
Maximum speed - example	rpm	19.914		Function of wheel size, gear ratio, etc
Maximum speed - market constraint	rpm	20.000		Market acceptance limit, e.g. bearing life, rotor balance
Maximum overspeed	rpm	+10%		Rotor Burst mitigation
Nominal DC Voltage	Vdc	650		At the operating point, from LV123 "Unlimited operating capability"
Maximum phase current	Arms	350		Required - from Market Analysis, inverter cost, IGBT or SiC
Power Density - Continuous - Option A		~28,1kW/L (KPI3.2) & ~7,07kW/kg (KPI 4.1)		Minimum targets from Call Option A (>23kW/L & >7kW/kg)
Torque Density - Continuous - Option B		~50,18 Nm/L & ~32,19Nm/kg (KPI 4.2)		Minimum targets from Call Option B (>50Nm/L & >20Nm/kg)
Motor losses - Mean over WLTP	Wh/km		TBD	~ 20% reduction over baseline eMotor
Maximum temperature on winding	°C	180	180	
Maximum rotor temperature	°C	150	150	

Inverter & Motor Insulation				
dV/dt & Risetime (maxDCBus / (dU/dt) = risetime)	[kV/µs]	5 typical	10 stretch	To determine insulation system
Switching Frequency	[kHz]	20		For better PID current control at high RPM
Fundamental Frequency max	[kHz]	~1000		Motor AC loss analysis will define this
Number of phases	[-]	3		
max. DC-Bus-Voltage	Vdc	800		Max survivable with no damage, inverter off (from LV123 Standard)
PDIV Phase-Phase	Vpk-pk	3726		Partial Discharge Inception Voltage from IEC 60034-18-41 with a moderate stress category (1.5)
PDIV Phase-Ground	Vpk-pk	2381		

Figure 13. Key Parameters for C+D+E Segment eMotor

The power and torque curves for both eMotors define the minimum performance envelope required by the motors developed by this project.

5 DELIVERY DEVIATIONS FROM THE INITIAL PLANNING

There has been a delay in the delivery of D1.1. Market need analysis.

Contractual delivery: 2023-03-31

Deliverable Date: 2024-04-25

This delay is due to:

Administrative deviations:

The information in the document has been shared with the partners since 2023-04-01. First full version of this document was checked on 2023-06-12. This document uses a previous information belonging to GKN AIC. As this deliverable is public, an extra time has been needed to obtain internal permission for public dissemination within the company.

Delay effect on overall project planning:

Although the document has an important delay, the information in the document has been shared with the partners since April 2023. The last changes before submission are more related to the style and format of the document, and finally to get the permission from GKN AIC to make the document public.

For these all reasons, it is considered that the delay in deliverable submission has not had any effect on the remainder of the project.

6 CONCLUSIONS

The market needs for two different vehicle segments have been analysed.

From the market analysis for the A+B segment, it is concluded that a specification for the vehicle whole system will be limited to 80 kW. At the same time, the power specification for A+B motor is maintained to 110kW (as it was indicated in the proposal), for future vehicle applications.

The market analysis for the CDE segment agrees with the bid specification of 156kW, so the project will continue as proposed.

From this market analysis, the primary parameters to design the new eMotors have been derived and laid out in section 4 of this document.