Zero emission Truck cost estimation – India

Final Report

13 April 2023

icct
THE INTERNATIONAL COUNCIL ON CLEAN TRANSPORTATION

EY Parthenon

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EY Parthenon

EYP conducted expert & supplier discussions to estimate vehicle BoM cost; Volume, technology, raw material & policy changes will drive component cost projections till 2040

WP#1: Baseline Cost & Weight Estimation

Scope

- Create vehicle bill of materials (BOM) for a traditional ICE vehicle, electric truck, and electric bus for study
- Compile price & weight related information for components listed in the BOM from supplier
- Carry out bottom-up costing where supplier information is not sufficient

Our Approach

- EYP used a combination of experts & suppliers discussion, secondary research, supplier quotations & EYP internal data to estimate BoM Cost & Weight for an electric bus, electric truck and diesel truck

Results

Powertrain (Battery & Motor) accounts for ~53% of the BoM cost in an e-bus & ~83% in an e-truck

Body + Chassis system accounts for ~56% of the overall component weight for e-bus & ~34% in electric truck

WP#2: Cost Projections for key ZET components

Scope

- Use the baseline estimates of component costs derived in WP 1 for future projection of identified components
- Factor in influential factors such as increased demand, technology evolution, etc and their impact on cost projections
- Develop an overall cost reduction model to forecast a system cost scenario for 2040

Our Approach

- EY-P used a combination of factors to arrive at the cost projections till 2040 with key considerations given to battery, motor and power electronics
- Influential factors taken into considerations were technology evolution, raw material costs, economies of scale, policy, and productivity to project costs to 2040

Results

- Battery Pack costs in India are likely to fall by 50-60% by 2040

- Motor costs likely to drop to 2400- 3000 ₹/kW by 2040 owing to local production

- PE costs are expected to fall by ~15% driven by increase in volume of e-CVs

- Favourable volumes till 2040, TCO, Govt's PLI Scheme will be the key enabler for driving down costs of key components down by local manufacturing

Source: EY-Parthenon analysis

EY Parthenon

Supply chains of critical ZET components were analyzed along with their potential for localisation

WP#3: Evaluation of supply chain & localization potential

Scope

- Analyse current supply chain and compare with the prospective supply chain required to manufacture ZET components indigenously
- Evaluate the prospects of indigenous manufacturing of select high-value components, i.e., batteries, motors & other ZET components
- Evaluate potential impact of policy changes that promote localized production

Our Approach

- EYP laid out the local value chain of the Battery, Motor & PE to indicate current status of localization & then determined the localization potential
- Based on volumes, technology, raw material availability and govt. Policy, we assessed the plausibility of localization for each of the high-value components

Results

- The local battery value chain is still evolving in key areas such as materials extraction, etc.
- Currently cells are imported

For motors, component casing & system integration done locally; Inverter & control systems yet to be started

PE components have high potential for localisation; Semiconductor components for HV systems will not be fully localised

Source: EY-Parthenon analysis

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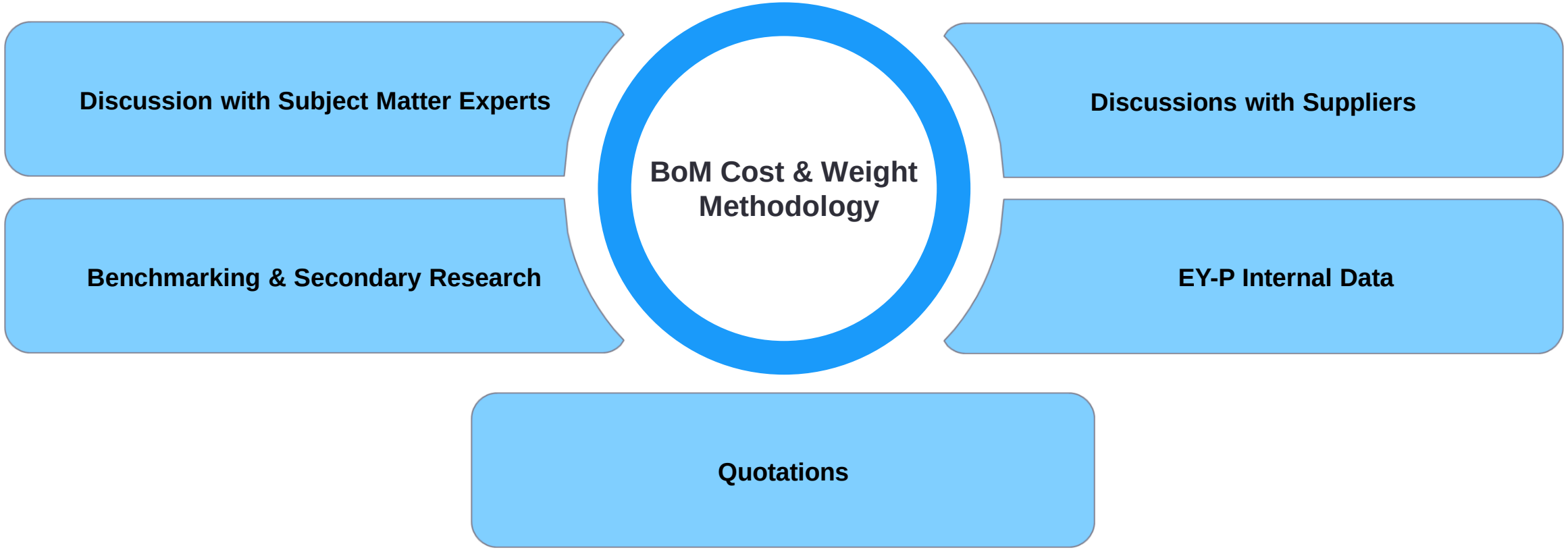
EY Parthenon

EYP has used combination of discussion with experts & suppliers, supplier quotations & internal data to estimate BoM Cost & Weight for the considered vehicles

BoM Cost & Weight Estimation Methodology



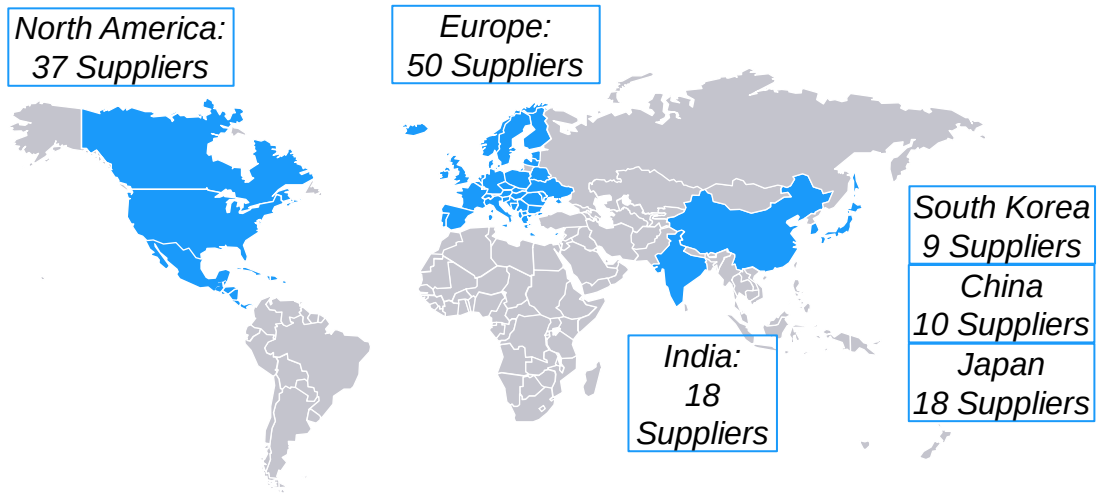
EYP in addition to engaging with the suppliers, also tapped into subject matter experts, EYP resources & secondary research to estimate & validate BoM cost & weight for the electric vehicle

Source: EY-Parthenon analysis

EYP began with identifying a long- list of 140+ suppliers for the Cost Identification of various components present in BOM, successfully reaching out to over 20 suppliers

EYP Outreach Effort

140+ Suppliers contacted



5+

Expert Interviews

- EYP reached out to over 5 industry veterans within India and outside to gain an in-depth understanding of the state of technology for commercial vehicles locally and globally

20+

Supplier Interactions

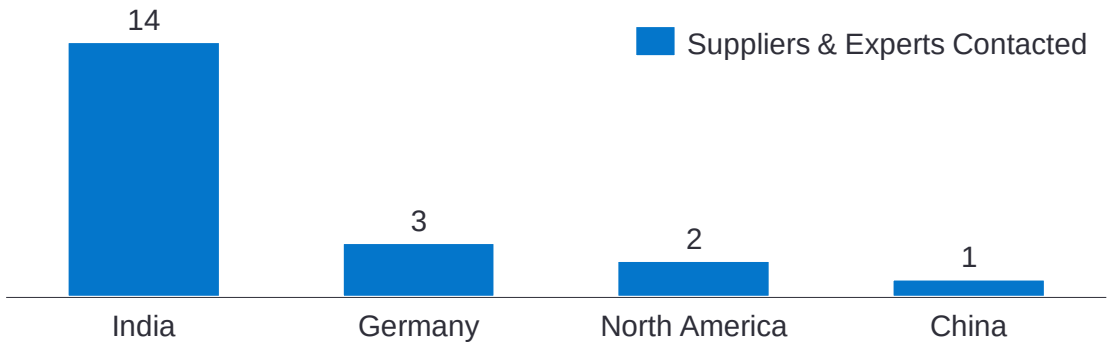
- Out of the 140+ identified suppliers, EYP had in-person meets/virtual discussions/received quotations from over 20 suppliers from across the globe

Key Sources

SIEMENS · Olectra · Subros · ZF · TRW · ASHOK LEYLAND · TATA MOTORS · JAI Jamna Auto Industries Ltd. · TATA AUTOCOMP SYSTEMS LTD

Supplier and Expert Global Footprint

- EYP gathered component costs through a combination of efforts including supplier outreach, expert interviews and leveraging EYP internal data



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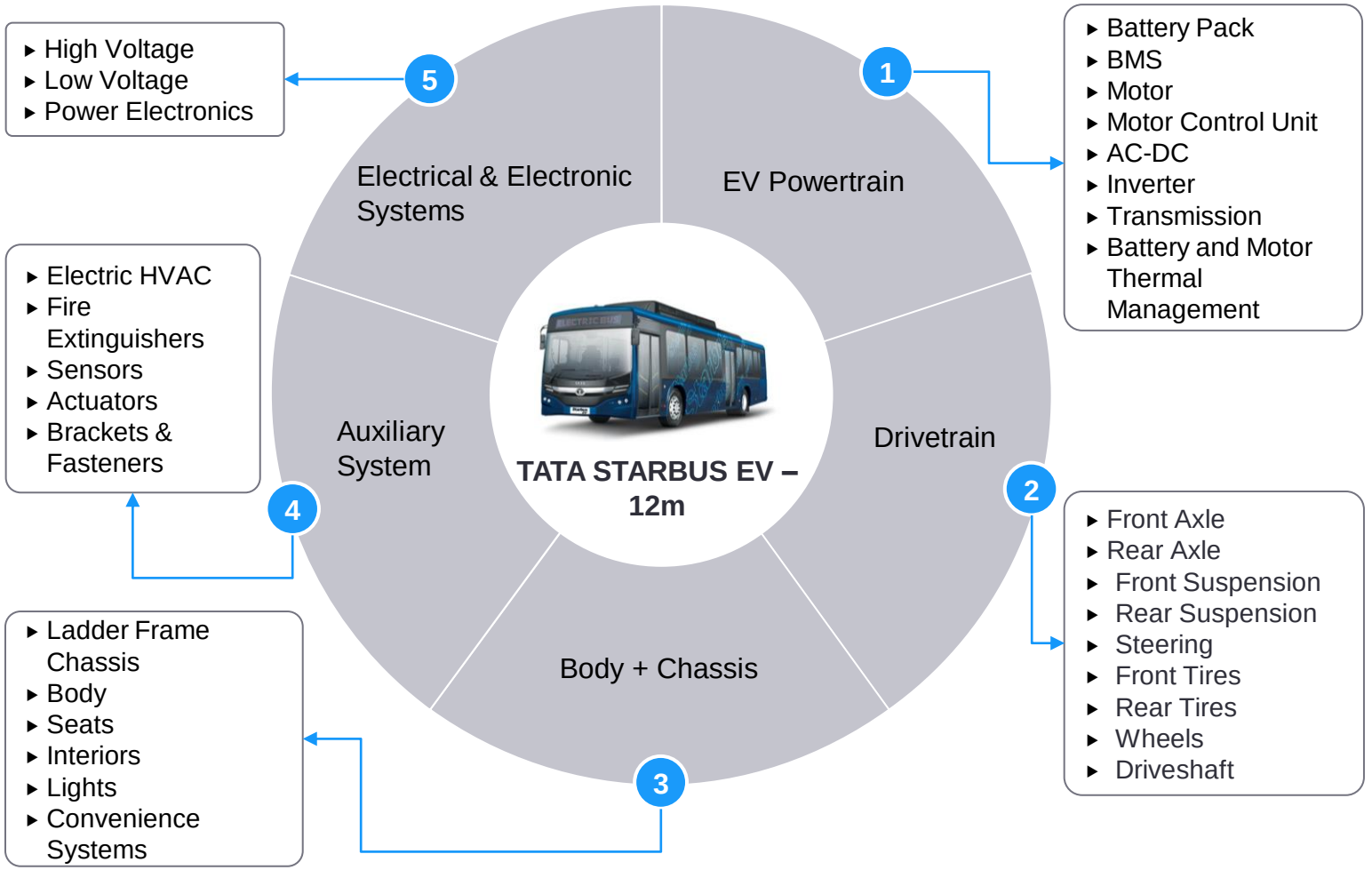
TATA Starbus EV has been shortlisted for BOM Analysis; The main components to be used for the cost study have been identified along with necessary specifications

Electric Bus Model Identification

Domain	Specifications
GVW[1]	17,800+/-500 kg
Dimensions	12m (L) 2.58m (W) 3.35m (H)
Motor	Traction Motor (Integrated Motor Generator) Max Power: 245 kW Continuous Power: 145 kW
Battery*	186 kWh LFP
Brakes	Dual Circuit full air S-cam Brake
Suspension	Front Weveller, Rear Air
Max. Speed	75 kmph



* For the purposes of this report, battery type taken is LFP for the bus

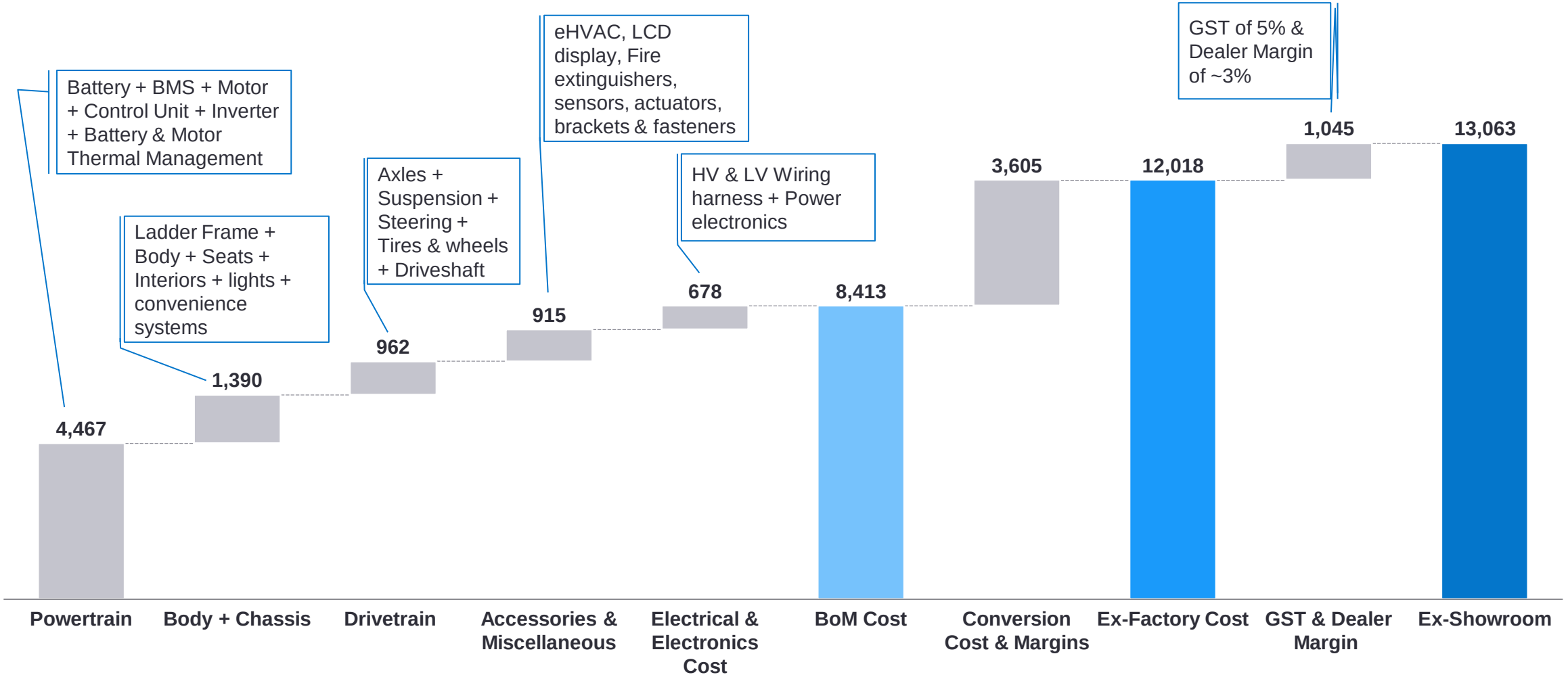
1: Gross Vehicle Weight

Source: Company website, Discussion between ICCT & EYP, EY-Parthenon analysis

Powertrain (Battery & Motor) accounts for ~53% of the BoM cost; Body + Chassis, Electronics & Electricals constitute remaining ~25% of BoM Cost of e-bus

Electric Bus Price Build-up (in '000 ₹)

12M Bus



GST: Goods and service tax

Source: EY-Parthenon analysis, Supplier quotations, Triangulation from expert interviews

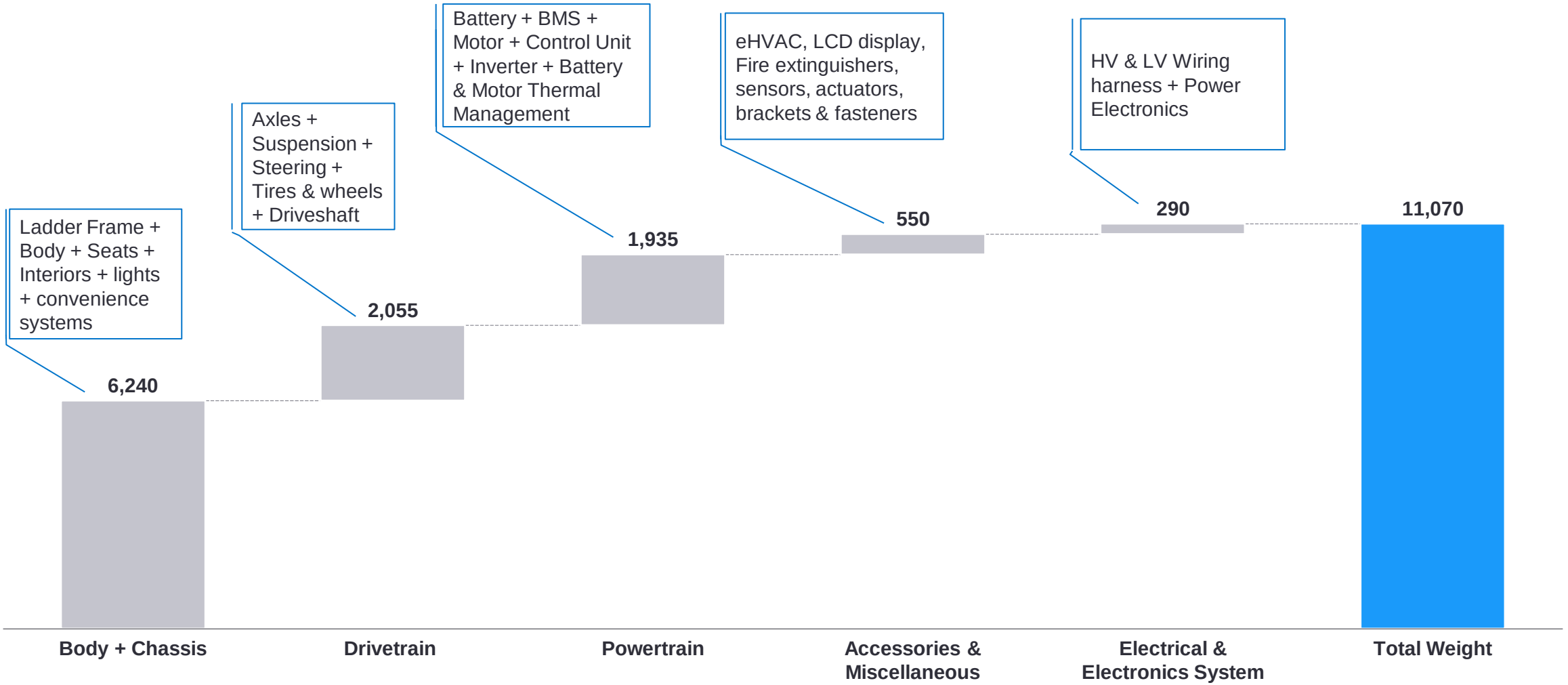
Click to go to the detailed conversion costs slide

EY Parthenon

Body + Chassis system accounts for ~56% of the overall component weight for e-bus; Powertrain and drivetrain accounts for ~36% of the remaining weight

Electric Bus Weight Build-up (in Kg)

18T GVW



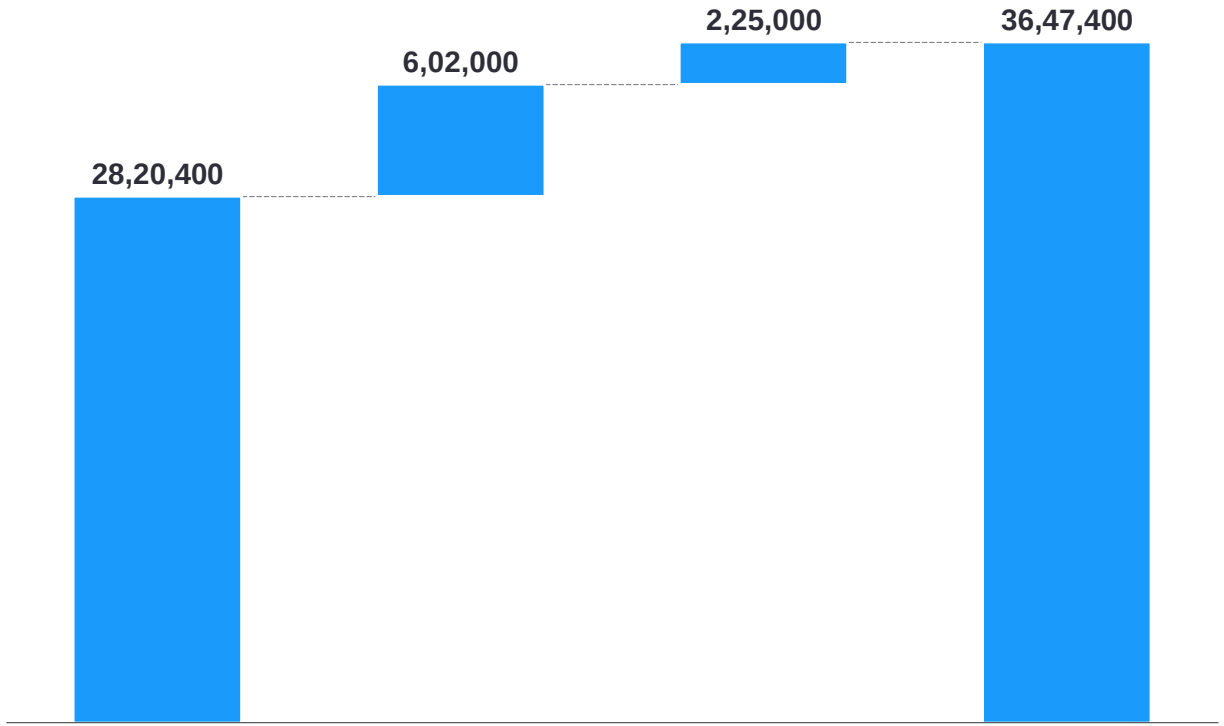
Source: EY-Parthenon analysis, Supplier quotations, Triangulation from expert interviews

EY Parthenon

The Battery System in the electric bus makes up ~43% of the overall BOM cost, making it one of the primary cost drivers for the overall vehicle

Electric Bus – Battery Cost in (₹)

12M Bus



Technical Specs	
Capacity (kWh)	186
Chemistry	LFP
Energy Density (Pack level)	115 Wh/Kg
Operating Voltage (V)	600
Total Cells (@ 60Ah Capacity/cell)	~950 (Prismatic Cells)
Cooling	Liquid Cooled (40% Ethylene Glycol)

- The delivered cost of an assembled battery pack sold in India (including the BMS) falls within the range of 220-240 USD/kWh (17,600 – 19,200 INR/kWh*)
- The assembly of cells into battery packs and the BMS each, make up ~20% of the total costs
- The primary cost of the BMS can be attributed to the software that it runs, making up ~85% of the total cost
- Suppliers in India typically provide fully assembled battery packs, with the BMS and thermal management solutions included
- The thermal management solutions include cooling channels, heat exchanger (chiller), pump and a fan. The overall weight is ~60kg

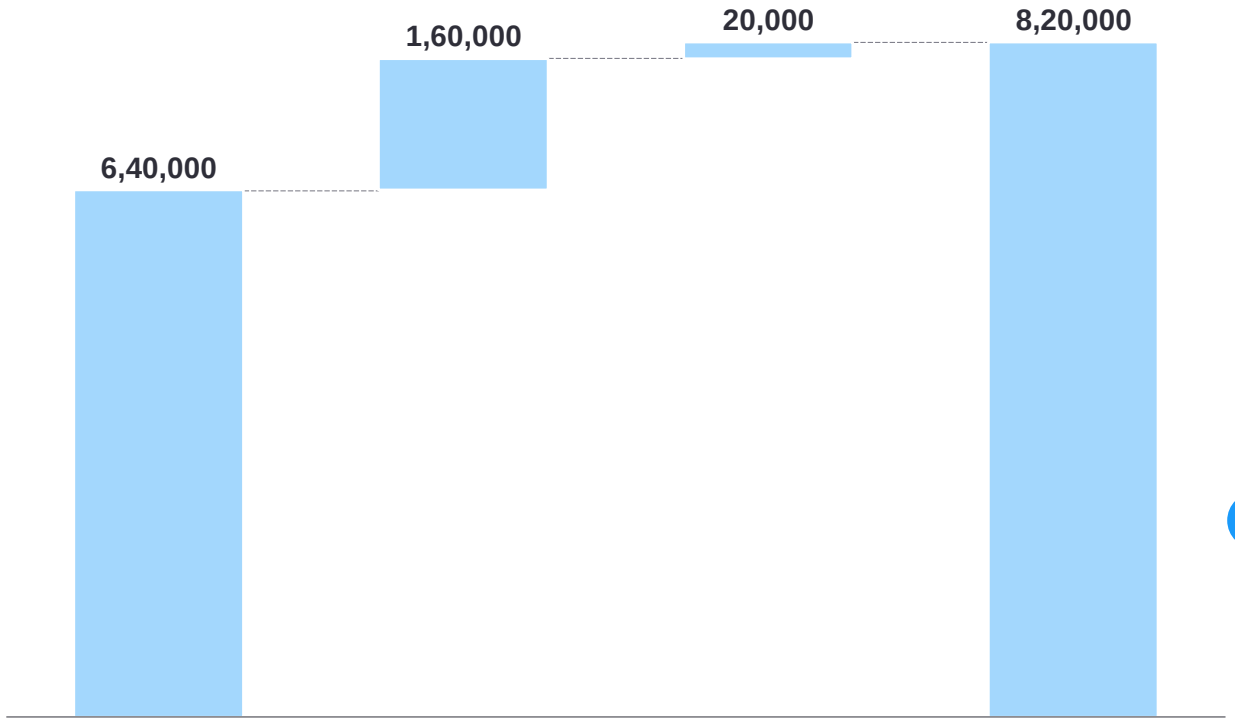
* 1 USD = 80 INR
BMS: Battery Management System
Source: EY-Parthenon analysis, Supplier Quotations, Expert Interviews

EY Parthenon

Motor & its components account for ~10% of the overall BoM cost & ~2% of overall component weight of e-bus; Inverter is ~20% of the overall delivered cost of the motor

Electric Bus – Motor Cost (₹)

12M Bus



KG	220	11	30	261

Technical Specs	
Peak Power (kW)	220
Continuous Power (kW)	160
Peak Torque (Nm)	2400
Continuous Torque (Nm)	1275
Max RPM	2700
Total System Weight (kg)	261 (231 for Motor Inverter + 30 for Thermal Management)

- For the electric bus application, PMSM motor is used
  - PMSM is likely to continue to be the preferred motor type for CVs going forward in India
- Total Motor cost from supplier quotation & expert interviews is given as ₹5000 / kW (delivered cost)
  - Inverter / Control unit is part of the package & accounts for ~20% of overall motor cost, thermal management system is not a part of this
- Operating temperature of the motor is high (~60 deg)
  - Thermal management of the motor is essentially a radiator & electric fan

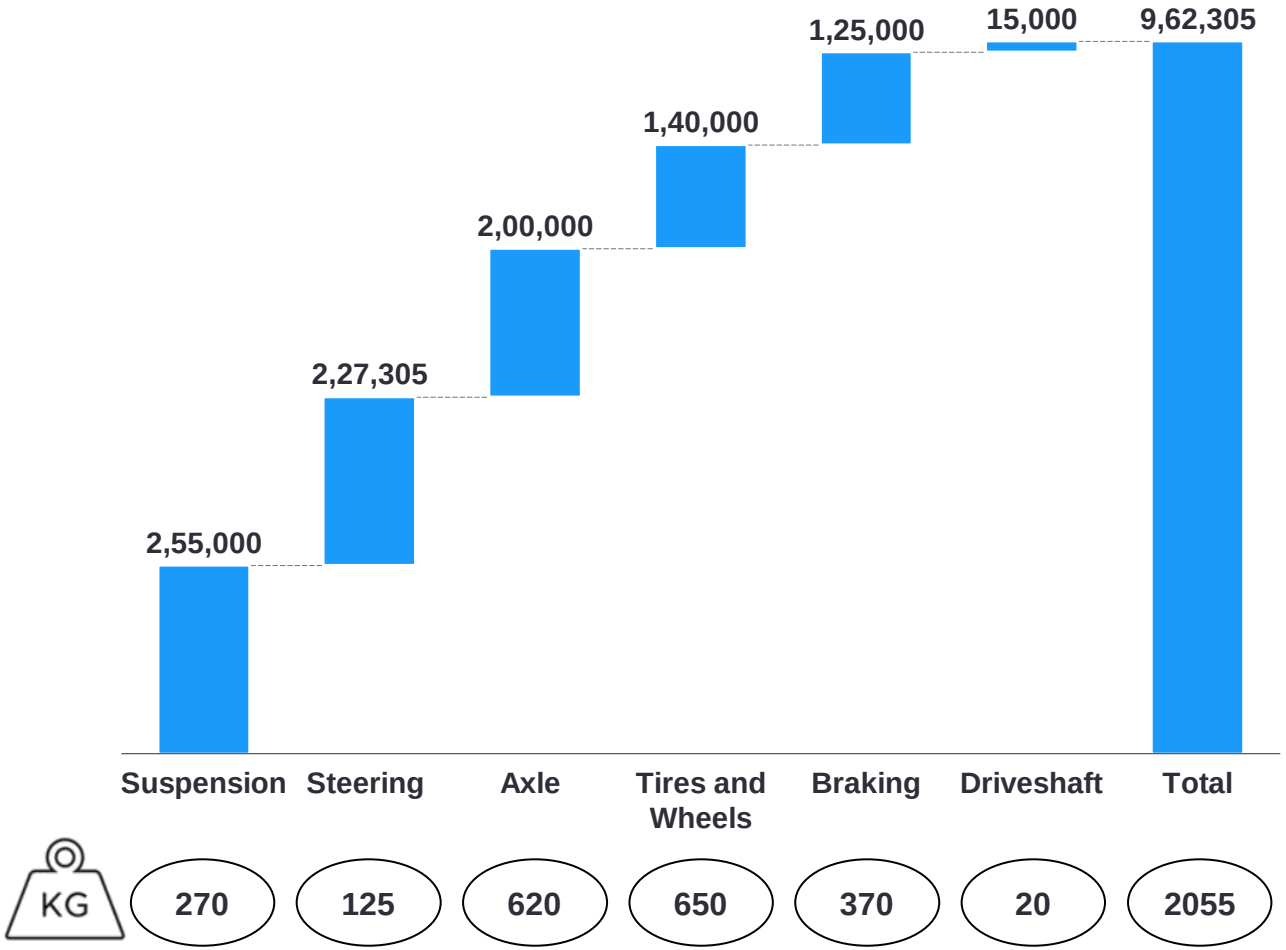
Source: EY-Parthenon analysis, Supplier Quotation, Expert Interviews

EY Parthenon

The Drivetrain systems makes up for ~11% of the overall cost of the Electric Bus and covers for ~19% of overall component weight

Electric Bus – Drivetrain Cost (₹)

12M Bus



Technical Specs	
Front + Rear Braking	Dual circuit full air S-cam drum brakes
Compressor	Electric Scroll Compressor
Steering	Hydraulic Power Steering
Front Suspension	Weveller Suspension
Rear Suspension	Air Suspension
Total Weight (kg)	2055

- The Braking system is integrated with the compressor system and the ABS (anti-lock braking system) including the brake pedal
- EBS (electronic braking system) is optional but is not considered in the cost analysis
- The Power Steering system has an integrated, mechanical steering gear assembly and e-steering pump
- The Axle system considered is a fixed rigid axle with a differential/ direct drive unit included along with the brake drums, brake shoes and chambers
- There is no requirement of a Transmission system in an electric bus since the electric motor serves the purpose

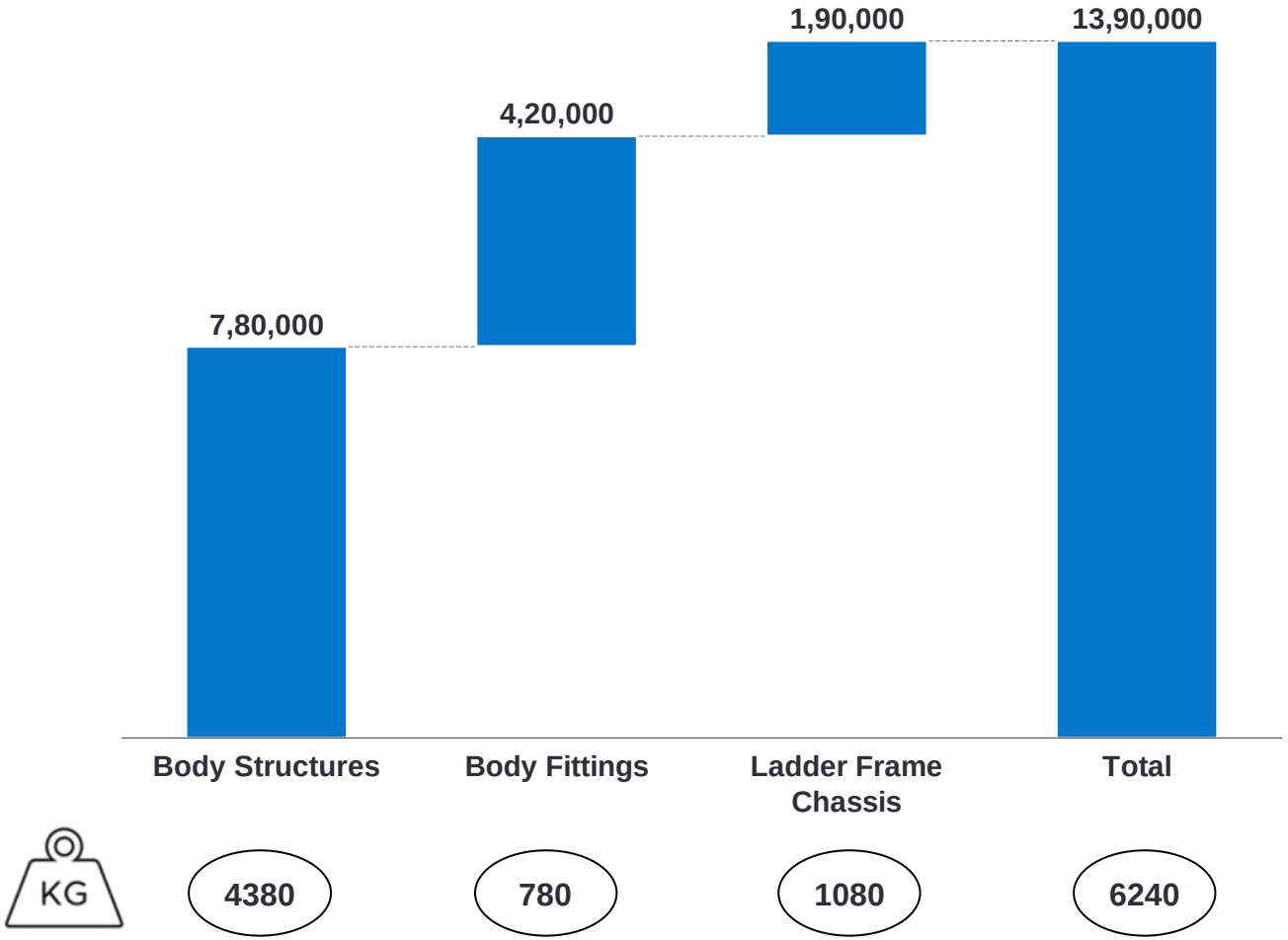
Source: EY-Parthenon analysis, Supplier Quotations, Expert Interviews

EY Parthenon

The Body and Ladder frame Chassis systems of the Electric Bus makes up for ~17% of the overall cost but covers for ~56% of overall component weight

Electric Bus – Body + Chassis Cost (₹)

12M Bus



Technical Specs	
Chassis Type	Ladder Frame
Chassis Material	BSK-46 Steel
Body Structure[1] Material	Aluminium + Galvanised Iron
Seats	40+D
Total weight (kg)	6240

- The Outer structure will be made from galvanized iron and includes the front, rear, floor, roof, side and the tailgate structures and the paint.
- The Body Fittings[2] will include various systems –
  - Seats – plastic molded seats considered are estimated to be of INR 4500 and 12.5 kg per seat
  - Lighting for the Front and Tailgate
  - Convenience & safety systems like Fire Detection and Suppression
  - Frond and rear windshield made from single piece laminated glass
  - Windows made from flat toughened glass
  - Electronically controlled doors – 2
  - Interior trims systems (plastics), dashboard, cluster systems, floor assembly, wiper systems

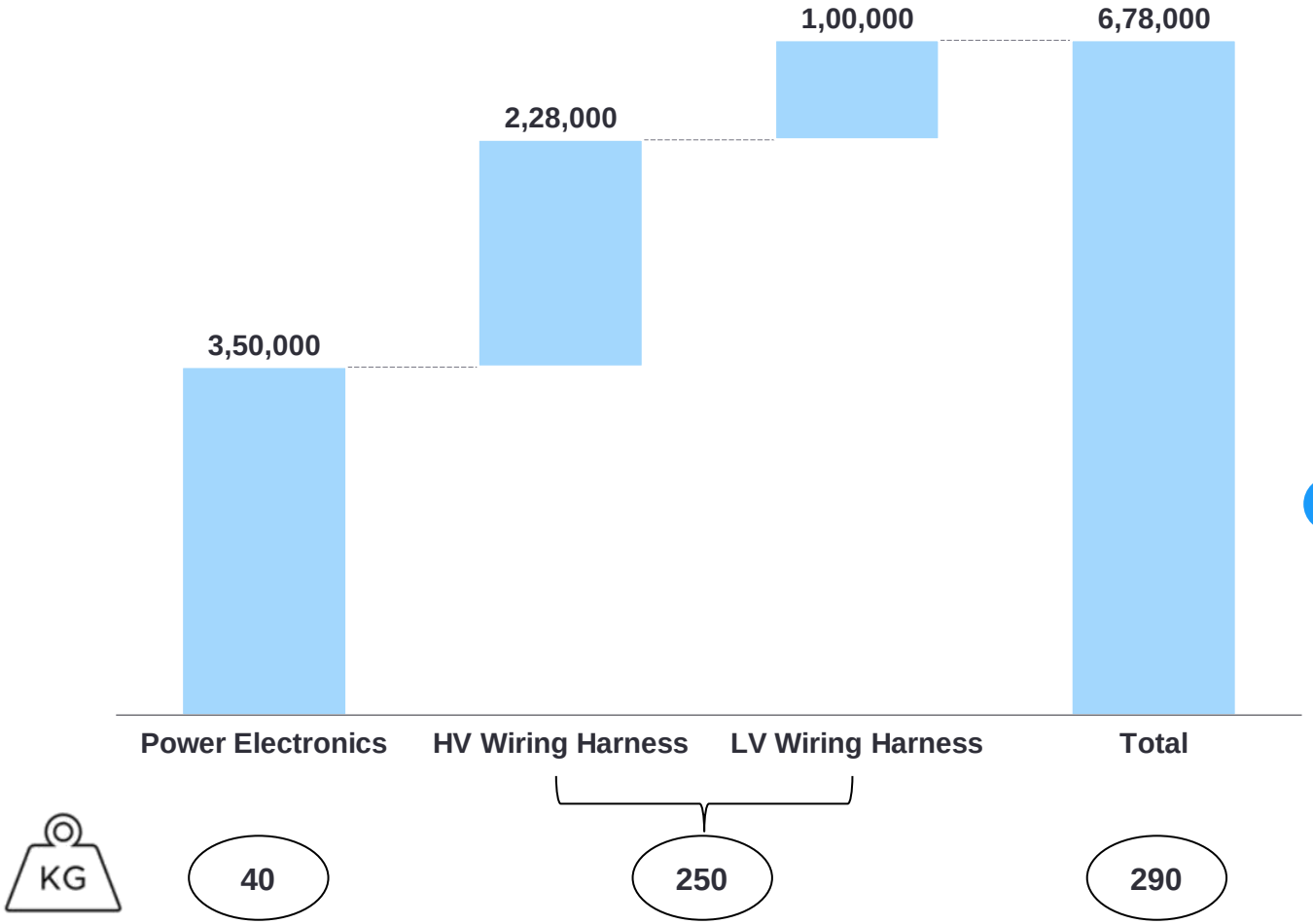
1: Inner and Outer structure, Paneling and Flooring
2: Seats, Windshield, Windows, Instrumentation, Lighting, Control systems, Convenience and safety systems
Source: EY-Parthenon analysis, Supplier Quotations, Expert Interviews

EY Parthenon

The Electrical and Electronics systems make up ~8% the total BOM cost, with power electronics accounting for more than 50% of that cost

Electric Bus – Electrical & Electronics Systems Cost (₹)

12M Bus



Technical Specs	
High Voltage (V)	600
Low Voltage (V)	24
System Weight (kg)	290

- The power electronics system includes the PDU[1], DC/DC converters, junction box and the auxiliary motor inverters and their respective control units
- The auxiliary motor control units and inverters are considered separately from the traction motor control unit and inverter
- An Onboard Charger has been omitted from the design after consideration of real-world use-case scenarios wherein charging typically takes place through high voltage DC fast chargers
- The wiring harness weight is primarily comprised of the HV wiring required to deal with the high system operating voltage, running across the length of the bus
- The LV wiring harness is responsible for all electrical connections, lightings, cabin lights etc.

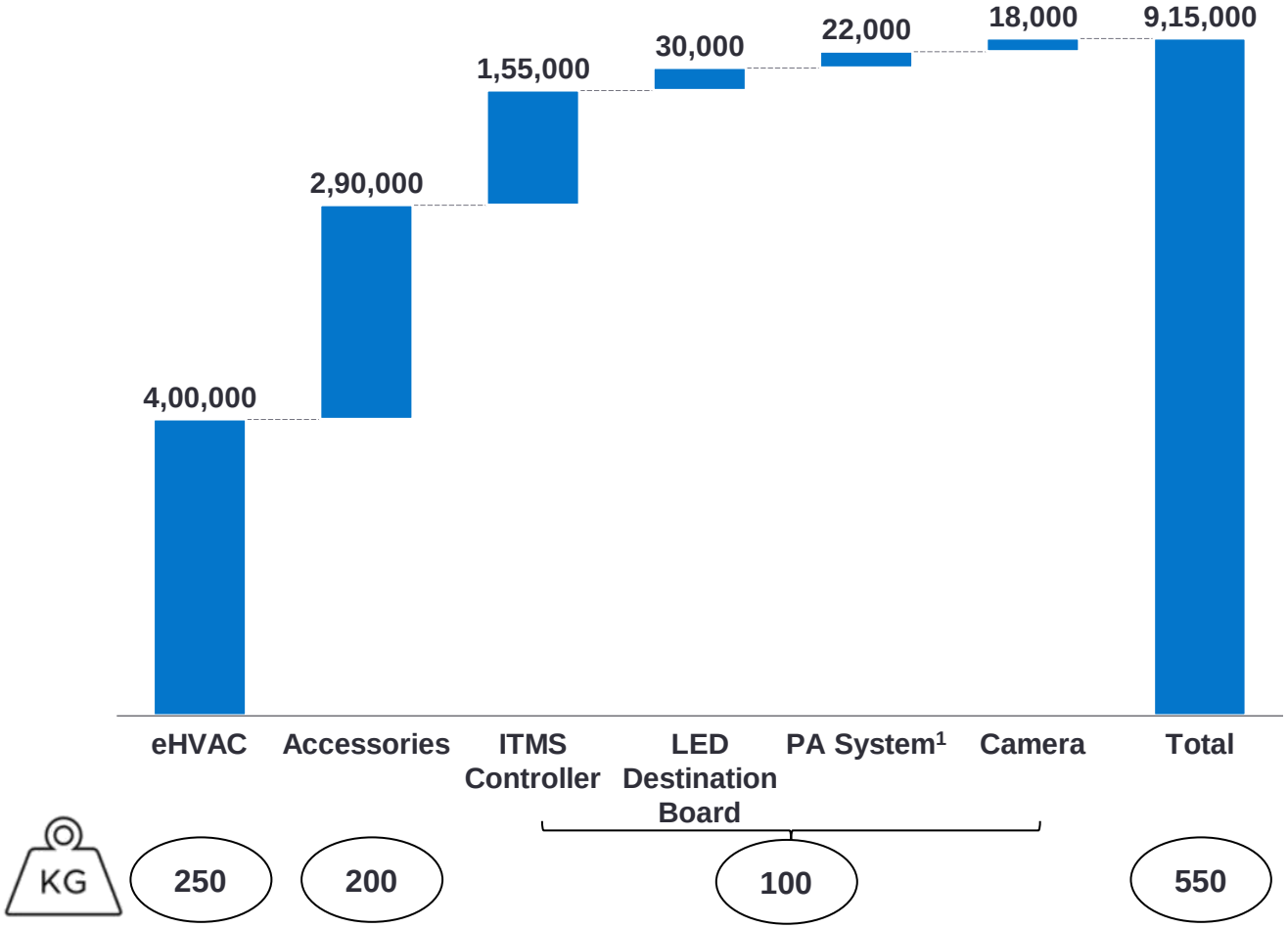
1. PDU: Power Distribution Unit
Source: EY-Parthenon analysis, Supplier Quotations, Expert Interviews

EY Parthenon

The eHVAC system and accessories makes up for ~11% of the overall cost and covers for ~5% of the component weight; eHVAC accounts for majority of the cost

Electric Bus – Accessories & Miscellaneous Cost (₹)

12M Bus



Technical Specs	
eHVAC	22 kW Cooling Capacity, R407C refrigerant
Total Weight (kg)	550

- Accessories and ITMS include –
  - Rear-View Mirrors
  - Front + Rear Bumper
  - Driver seat belt and cabin fan
  - Mobile Charging Sockets
  - Brackets, mounts and fasteners
  - Driver Warning system
  - Plastics and LED for cabin
- The Public Announcement System includes a microphone, amplifier and loudspeakers
- eHVAC includes the complete Air Conditioning system of the bus; system includes the compressor, EM clutch, the condenser and the complete ducting for the system

1. Public Announcement System
Source: EY-Parthenon analysis, Supplier Quotations, Expert Interviews

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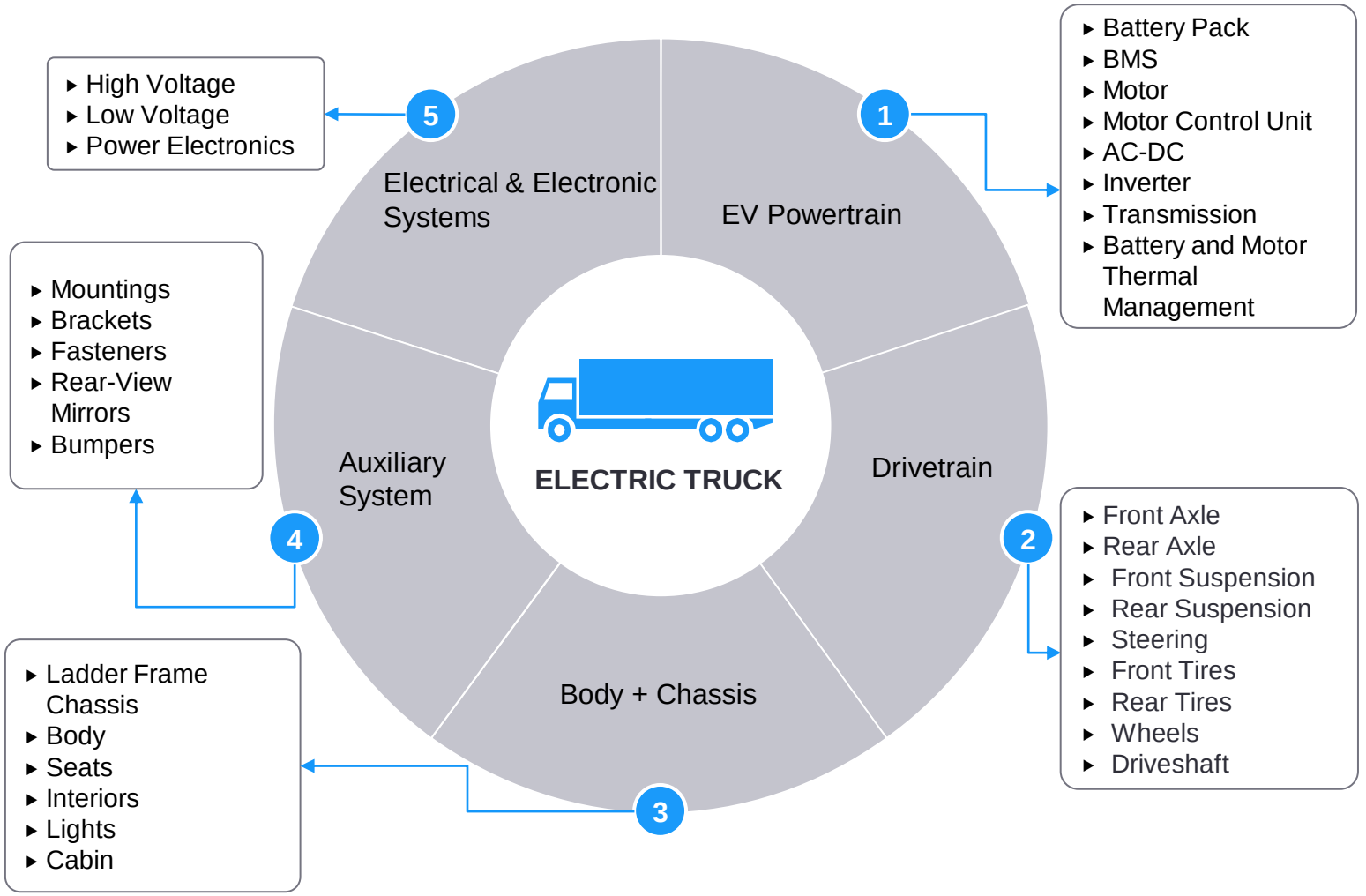
Electric Truck to be used for BOM analysis will be based on a virtual model by EYP; Main components to be used for BOM have been identified

Electric Truck Model

16T GVW

Domain	Specifications
GVW[1]	16,200
Dimensions	7.5m (L)
	2.4m (W)
	2.6m (H)
Motor	160 kW Continuous Power
	220 kW Peak Power
Battery	295 kWh NMC
Brakes	Full air S-Cam Brakes
Suspension	Front - Parabolic Leaf Spring Rear - Semi Elliptical Leaf Spring
Max. Speed	75



1: Gross Vehicle Weight

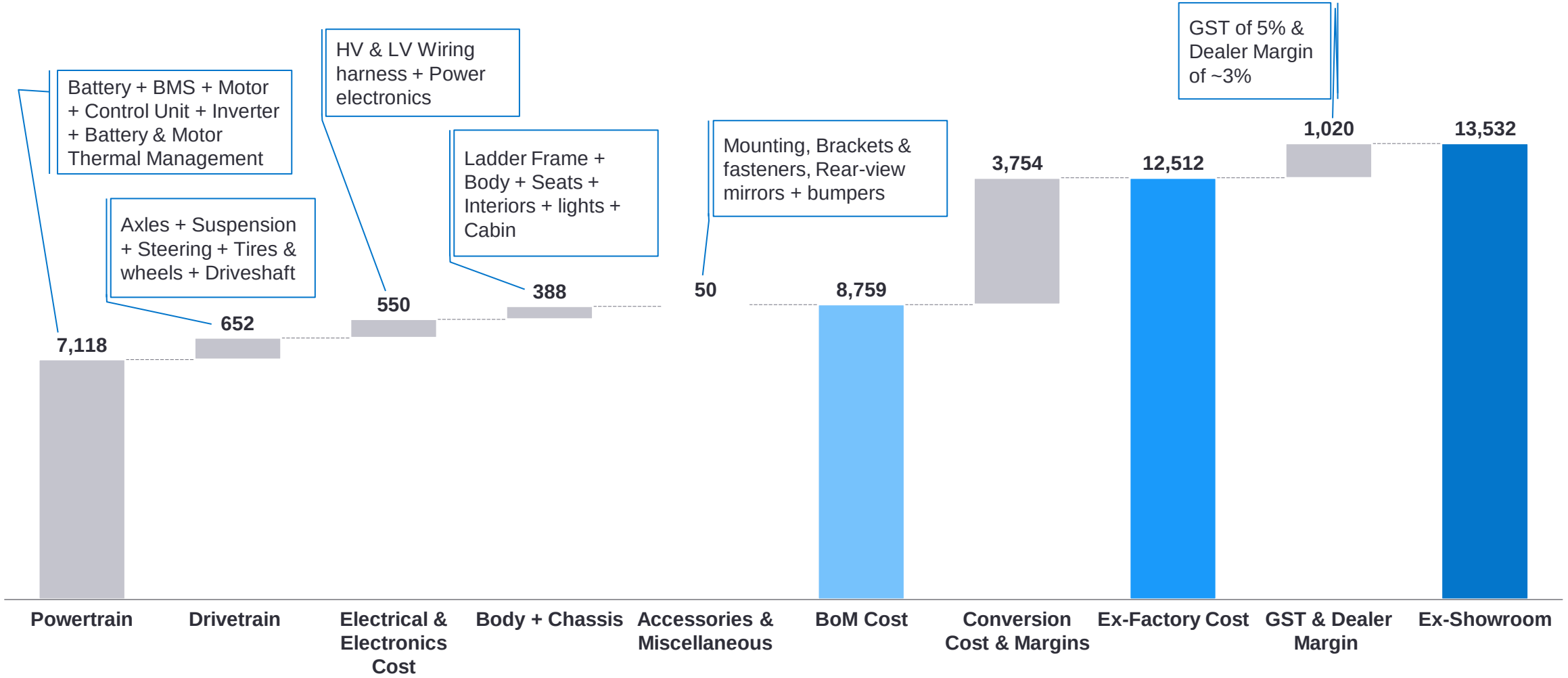
Source: Company website, Discussion between ICCT & EYP, EY-Parthenon analysis

EY Parthenon

Powertrain (Battery & Motor) accounts for ~81% of the BoM cost; Body + Chassis, Electronics & Electricals constitute remaining ~19% of BoM Cost of e-truck

Electric Truck Price Build-up (in '000 ₹)

16T GVW



Axle, Braking, Suspension, Ladder frame, Load Body and Tires & wheels systems are kept common across the Diesel and Electric Truck

GST: Goods and service tax

Source: EY-Parthenon analysis, Supplier quotations, Triangulation from expert interviews

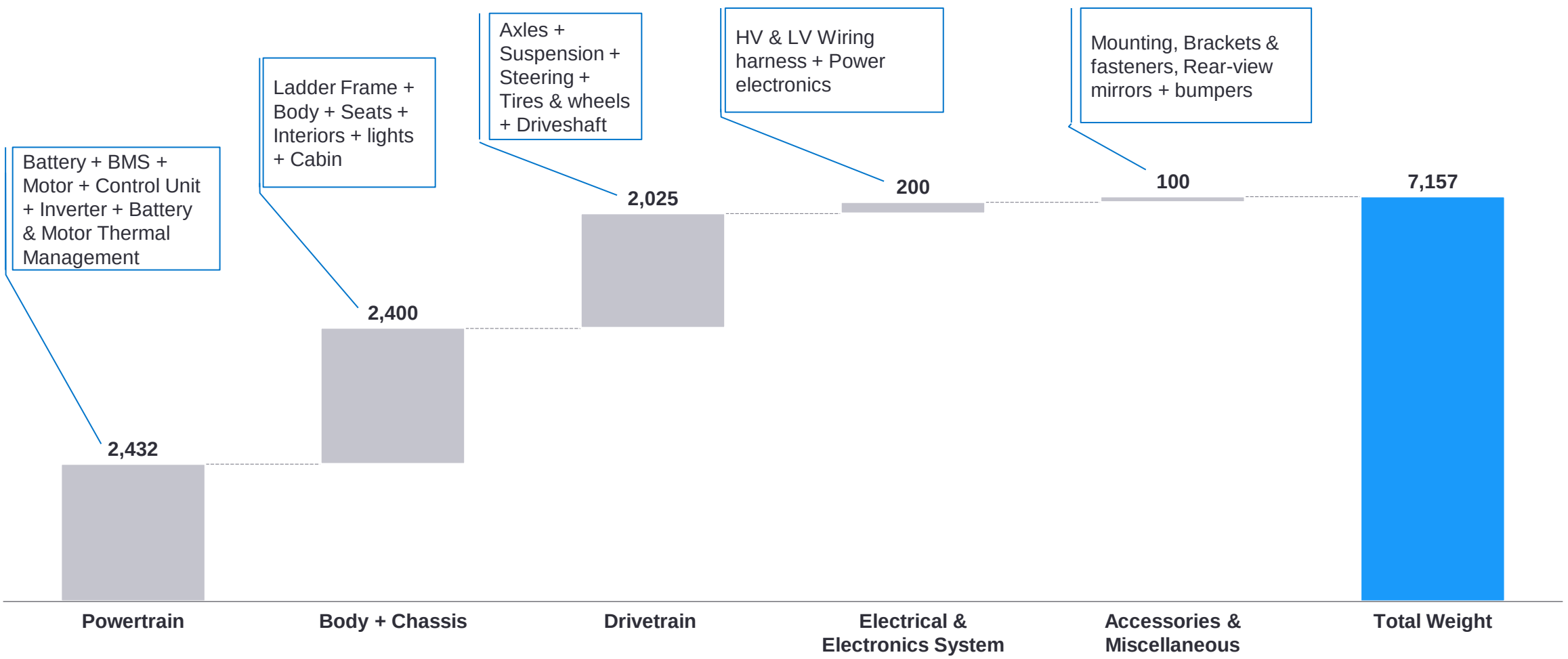
Click to go to the detailed conversion costs slide

EY Parthenon

Body + Chassis system accounts for ~34% of the overall component weight for e-truck; Powertrain and electronics systems account for ~38% of remaining weight

Electric Truck Weight Build-up (in Kg)

16T GVW



Axle, Braking, Suspension, Ladder frame, Load Body and Tires & wheels systems are kept common across the Diesel and Electric Truck

Source: EY-Parthenon analysis, Supplier quotations, Triangulation from expert interviews

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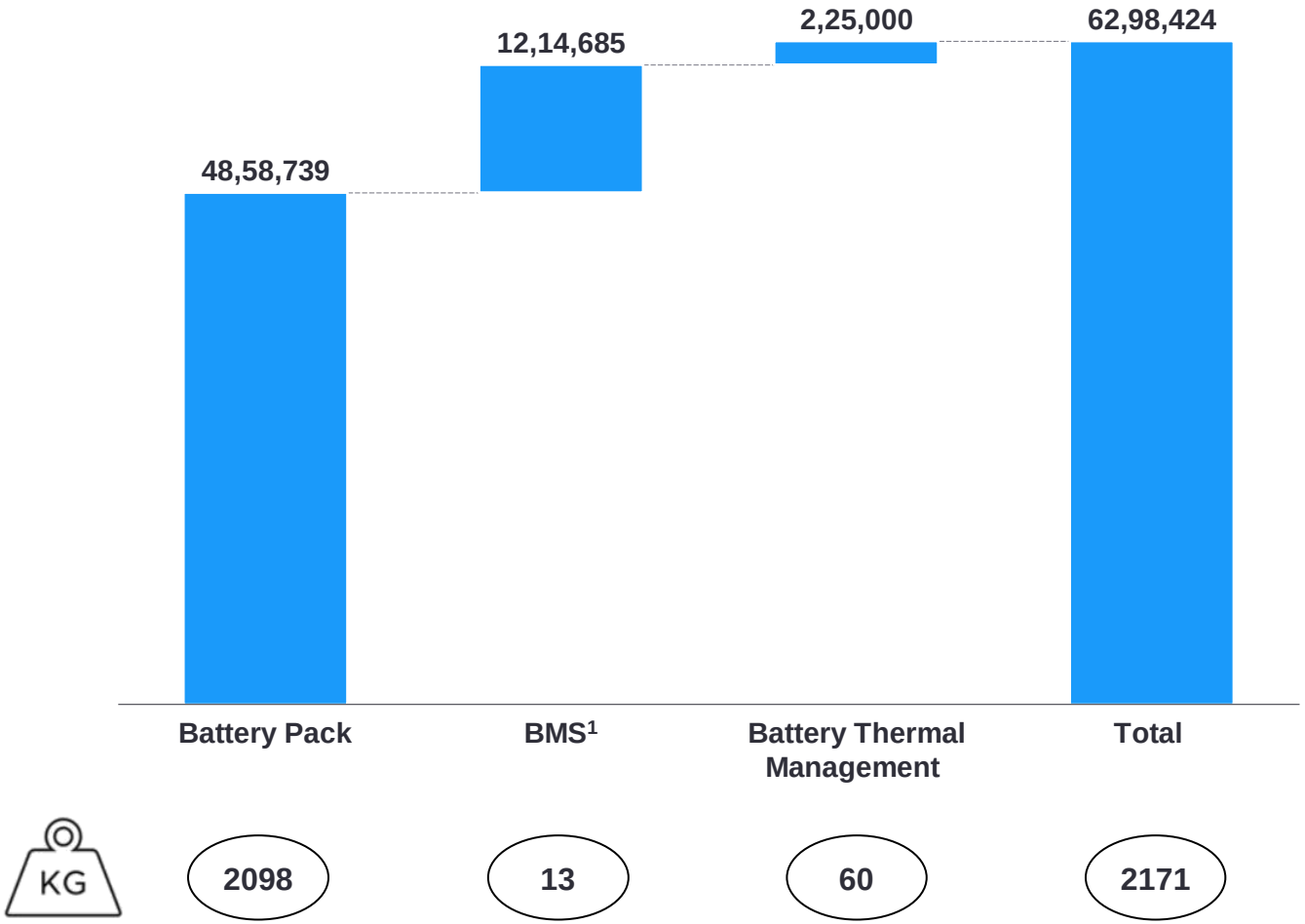
The Battery System in the electric truck makes up ~72% of the overall BOM cost, making it one of the primary cost drivers for the overall vehicle

Electric Truck – Battery Cost in (₹)

16T GVW



Technical Specs	
Capacity (kWh)	295
Chemistry	NMC
Energy Density* (Pack level)	140 Wh/Kg
Operating Voltage (V)	600
Cooling	Liquid Cooled (40% Ethylene Glycol)

- NMC has been used as the battery chemistry due to higher energy density than LFP which can translate to higher real-world range and better duty cycle for the electric truck
- The delivered cost of NMC cells are ~20% higher than that of LFP cells, hence the NMC battery pack cost (including the BMS) falls within the range of 250-260 USD/kWh (20,000-20,800 INR/kWh*) – Other costs (including BMS costs) are same for LFP & NMC
- Suppliers in India typically provide fully assembled battery packs, with the BMS and thermal management solutions included
- The primary cost of the BMS can be attributed to the software that it runs, making up ~85% of the total cost
- The thermal management solutions include cooling channels, heat exchanger (chiller), pump and a fan. The overall weight is ~60kg

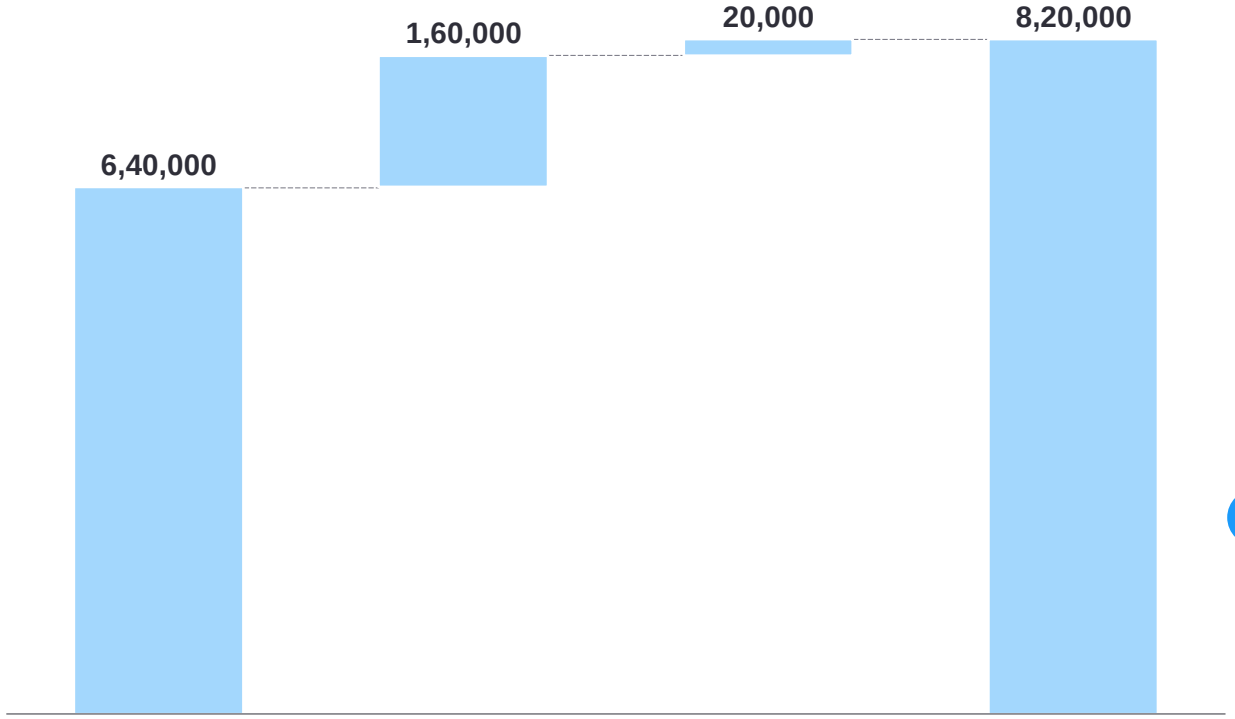
* Energy density of NMC batteries can vary highly according to various types based on nickel percentage in the battery, * 1 USD = 80 INR
BMS: Battery Management System
Source: EY-Parthenon analysis, Supplier Quotations, Expert Interviews

EY Parthenon

Motor & its components accounts for ~11% of the overall BoM cost & ~3% of overall component weight of e-truck; Inverter is ~20% of the overall delivered cost of the motor

Electric Truck – Motor Cost (₹)

16T GVW



KG	220	11	30	261

Technical Specs	
Peak Power (kW)	220
Continuous Power (kW)	160
Peak Torque (Nm)	2400
Continuous Torque (Nm)	1275
Max RPM	2700
Total System Weight (kg)	261 (231 for Motor Inverter + 30 for Thermal Management)

- For the electric truck application, PMSM motor is used
  - PMSM is likely to continue to be the preferred motor type for CVs going forward in India
- Total Motor cost from supplier quotation & expert interviews is given as ₹5000 / kW (delivered cost)
  - Inverter / Control unit is part of the package & accounts for ~20% of overall motor cost, thermal management system is not a part of this
- Operating temperature of the motor is high (~60 deg)
  - Thermal management of the motor is essentially a radiator & electric fan

Source: EY-Parthenon analysis, Supplier Quotation, Expert Interviews

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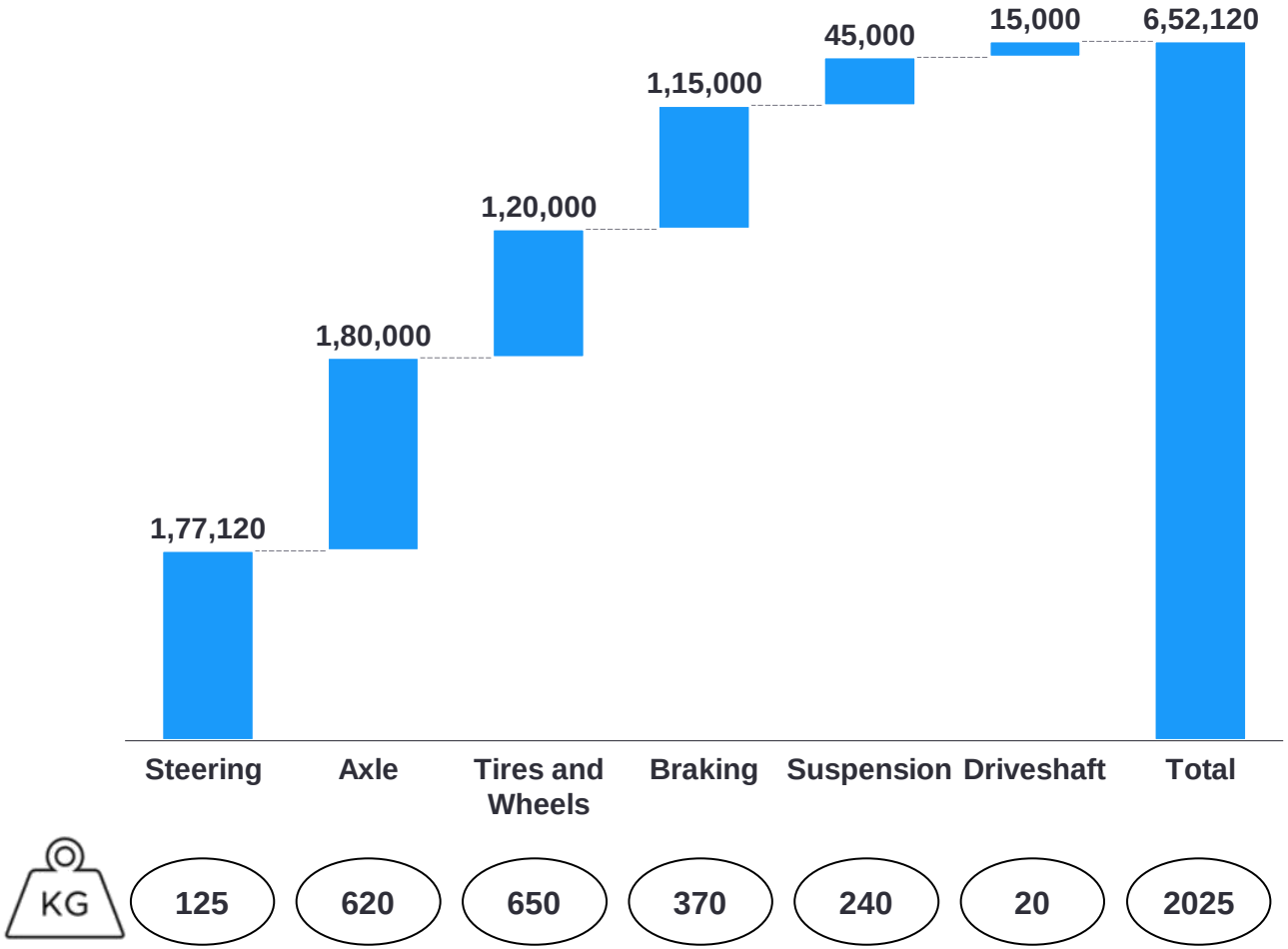
The Drivetrain systems makes up for ~8% of the overall cost of the Electric Truck and covers for ~28% of overall component weight

Electric Truck – Drivetrain Cost (₹)

16T GVW



Technical Specs	
Front + Rear Braking	Dual circuit full air S-cam drum brakes
Compressor	Electric Scroll Compressor
Steering	Hydraulic Power Steering
Front Suspension	Parabolic leaf spring
Rear Suspension	Semi elliptical leaf spring
Total Weight (kg)	2025

- The Braking system is integrated with the compressor system and the ABS (anti-lock braking system) including the brake pedal
- EBS (electronic braking system) is optional but is not considered in the cost analysis
- The Power Steering system has an integrated, mechanical steering gear assembly and e-steering pump
- The Axle system considered is a fixed rigid axle with a differential/ direct drive unit included along with the brake drums, brake shoes and chambers

Source: EY-Parthenon analysis, Supplier Quotations, Expert Interviews

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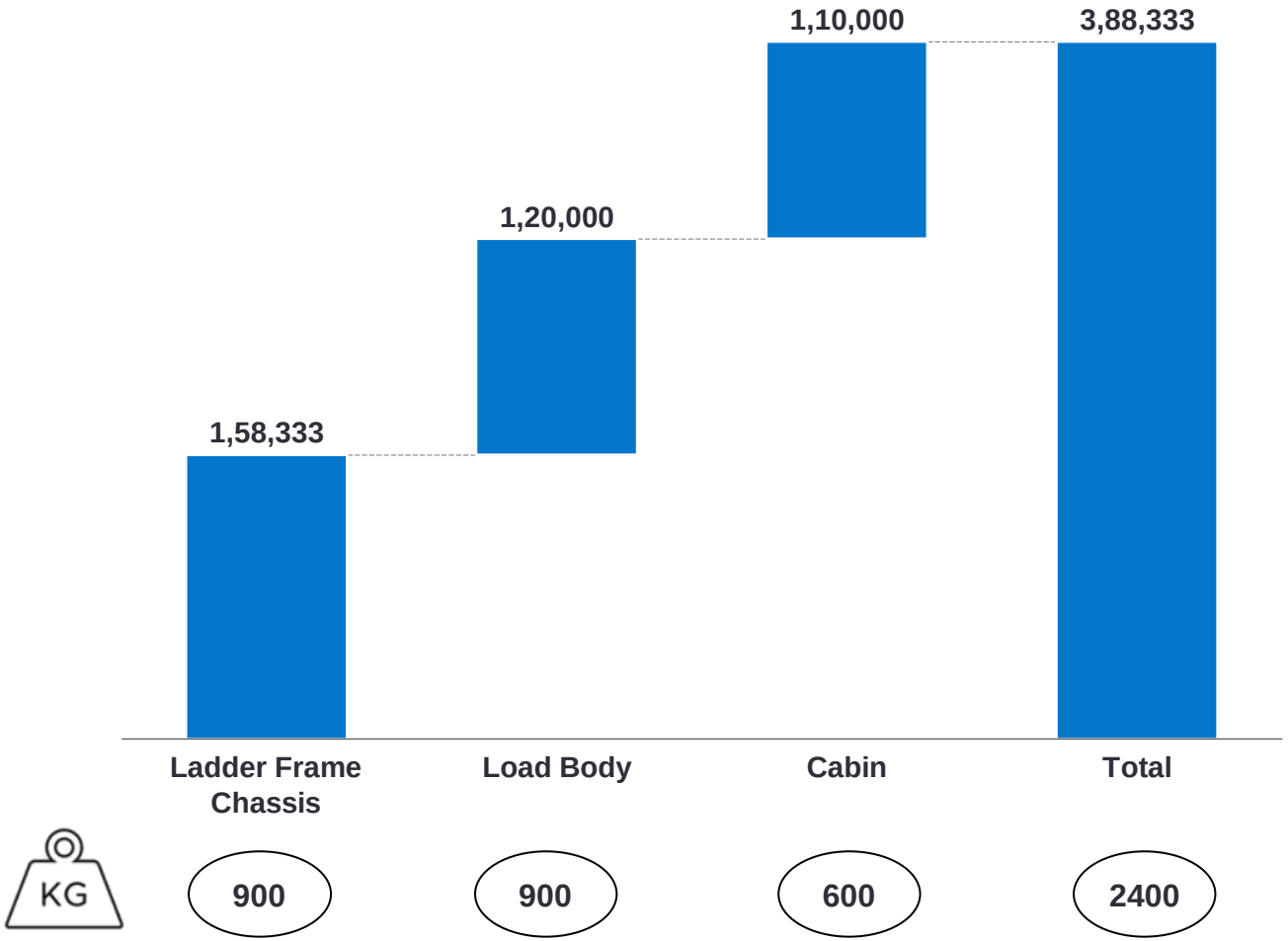
The Body and Ladder frame Chassis systems of the Electric Truck makes up for ~4% of the overall cost but covers for ~34% of overall component weight

Electric Truck – Body + Chassis Cost (₹)

16T GVW



Technical Specs	
Chassis Material	HSS 800
Load Body Material	Aluminium + Galvanised Iron
Total weight (kg)	2400

- Chassis used in the truck is a ladder frame chassis
- The Cabin structure will be made from galvanized iron and includes the front, roof, floor, roof and side structure -
  - Front Windshield made from single piece laminated glass, paint
  - Windows from flat toughened glass
  - Lighting, Plastics and Wiper systems
  - Instrument Panel
  - 2 plastic molded seats and interior systems

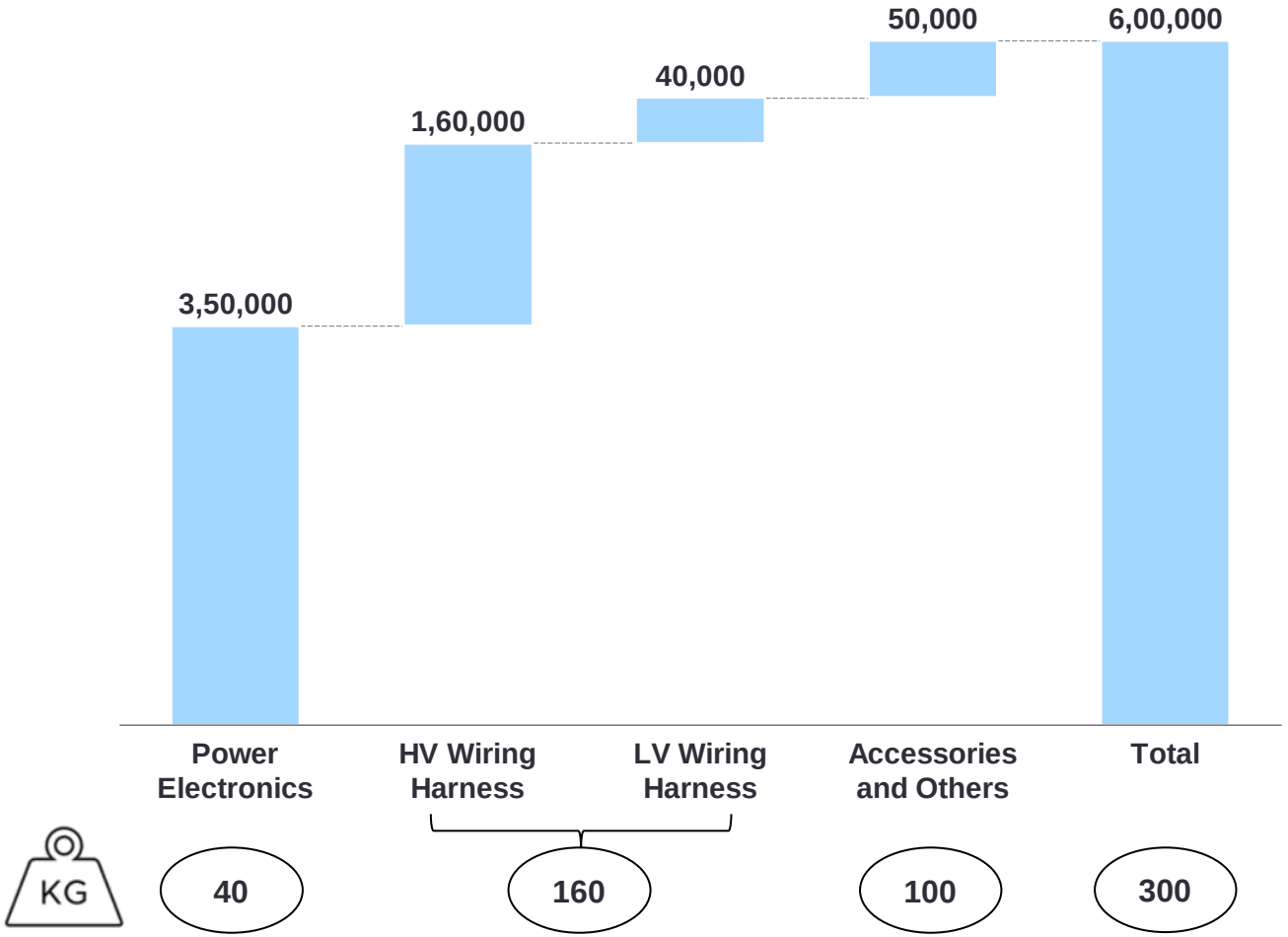
Source: EY-Parthenon analysis, Supplier Quotations, Expert Interviews

EY Parthenon

The Electronics system and accessories make up ~7% the total BOM cost, with power electronics accounting for more than 50% of that cost

Electric Truck – Electrical & Electronics Systems Cost (₹)

16T GVW



Technical Specs	
High Voltage (V)	600
Low Voltage (V)	24
System Weight (kg)	300

- The power electronics system includes the PDU[1], DC/DC converters, junction box and the auxiliary motor inverters and their respective control units
- The auxiliary motor control units and inverters are considered separately from the traction motor control unit and inverter
- An Onboard Charger has been omitted from the design after consideration of real-world use-case scenarios wherein charging typically takes place through high voltage DC fast chargers
- The wiring harness weight is primarily comprised of the HV wiring required to deal with the high system operating voltage, running across the length of the truck
- The LV wiring harness is responsible for all electrical connections, lightings, cabin lights etc.
- Accessories & others include the bolts, nuts, rivets, fasteners, rear-view mirrors, bumpers etc.

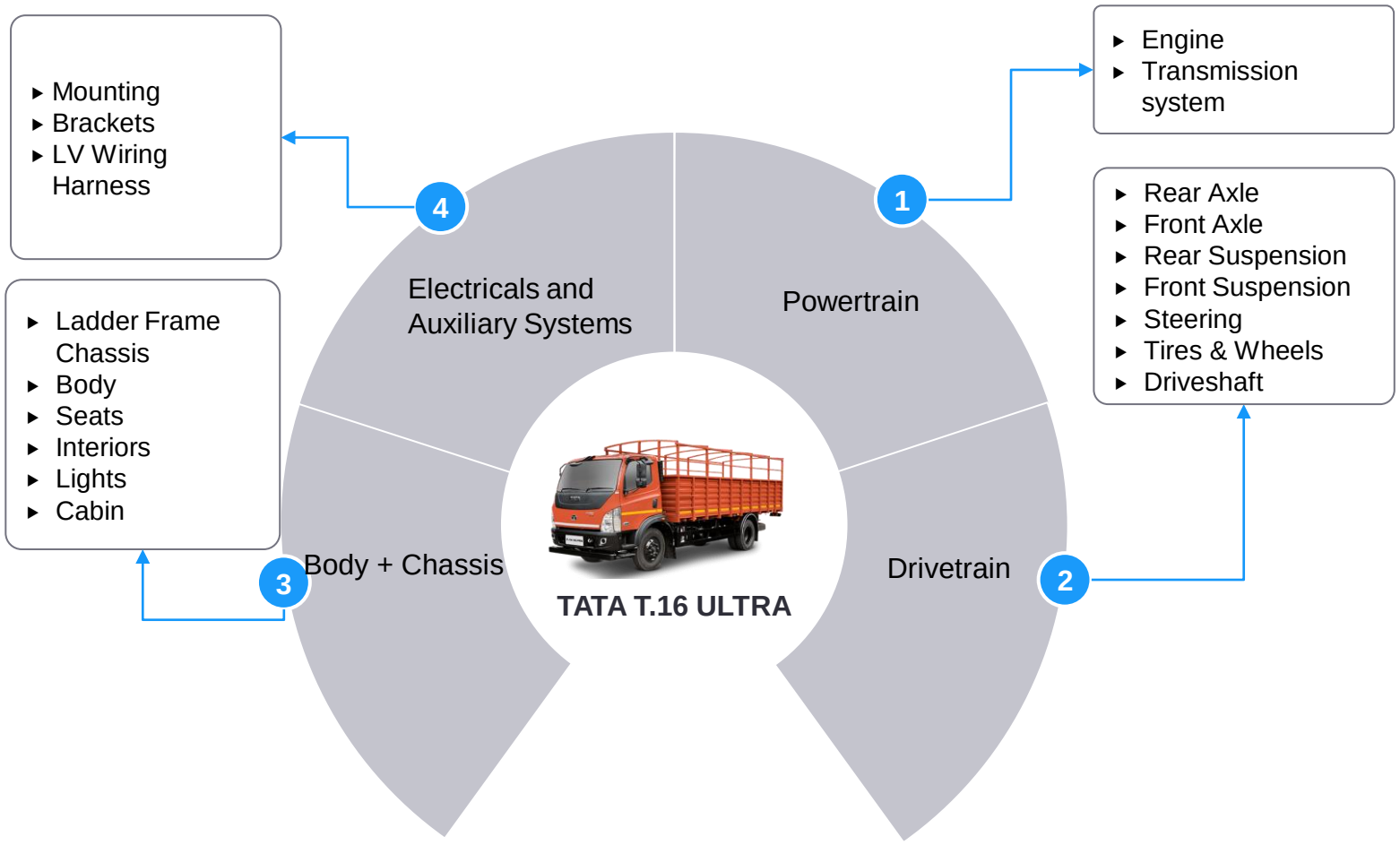
1. PDU: Power Distribution Unit
Source: EY-Parthenon analysis, Supplier Quotations, Expert Interviews

EY Parthenon

TATA 1.6 Ultra Truck to be used for the Cost study of ICE based HDV; Components needed for BOM analysis have been identified along with necessary specifications

Diesel Truck Model Identification

Domain	Specifications
GVW[1]	16,140 kg
Dimensions	7.5m (L)
	2.4m (W)
	2.6m (H)
Engine	5L NG Having Power of 132 kW
Transmission	G750, Manual Synchromesh Gearbox
Brakes	Full air S-Cam Brakes
Suspension	Front - Parabolic Leaf Spring, Rear - Semi Elliptical Leaf Spring
Max. Speed	80 kmph



1: Gross Vehicle Weight

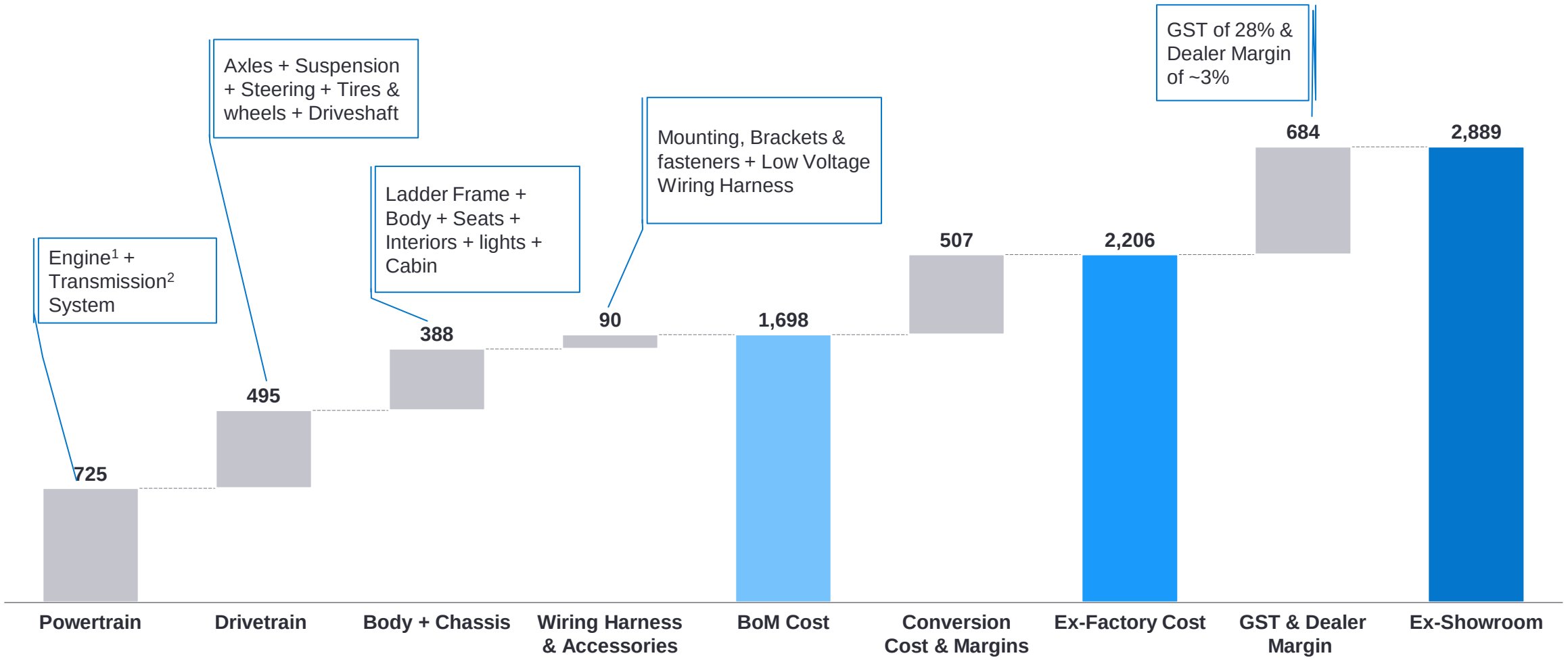
Source: Company website, Discussion between ICCT & EYP, EY-Parthenon analysis

EY Parthenon

Powertrain (Engine & Transmission) accounts for ~43% of the BoM cost; Drivetrain and Body + Chassis system constitutes remaining ~52% of BoM Cost of the diesel truck

Diesel Truck Price Build-up (in '000 ₹)

16T GVW



GST: Goods and service tax | Axle, Braking, Suspension, Ladder frame, Load Body and Tires & wheels systems are kept common across the Diesel and Electric Truck

1: Includes Fuel system, Thermal Management system and exhaust system

2: Includes Clutch, Transmission and Pressure plate

Source: EY-Parthenon analysis, Supplier quotations, Triangulation from expert interviews

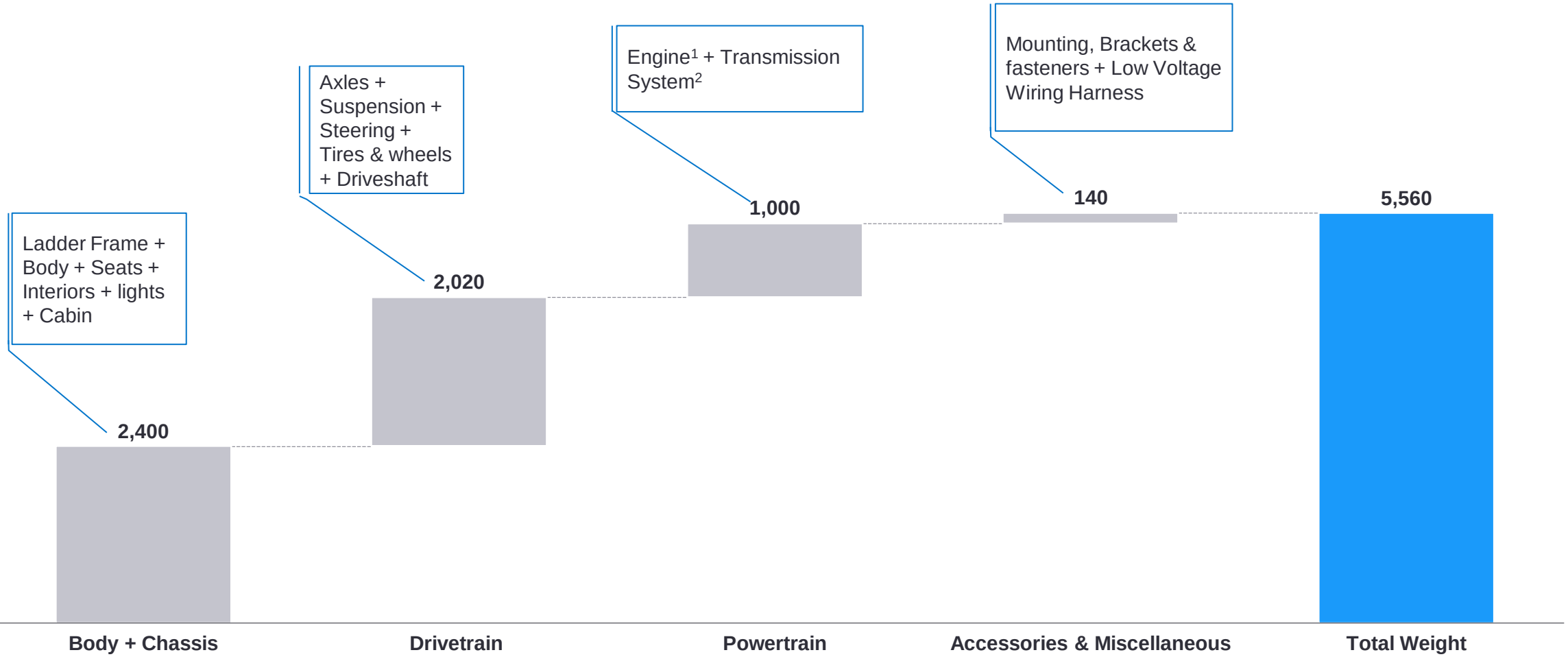
Click to go to the detailed conversion costs slide

EY Parthenon

Body + Chassis system accounts for ~43% of the overall component weight for the truck; Powertrain & drivetrain accounts for ~54% of the remaining weight

Diesel Truck Weight Build-up (in Kg)

16T GVW



Axle, Braking, Suspension, Ladder frame, Load Body and Tires & wheels systems are kept common across the Diesel and Electric Truck

1: Includes Fuel system, Thermal Management system and exhaust system

2: Includes Clutch, Transmission and Pressure plate

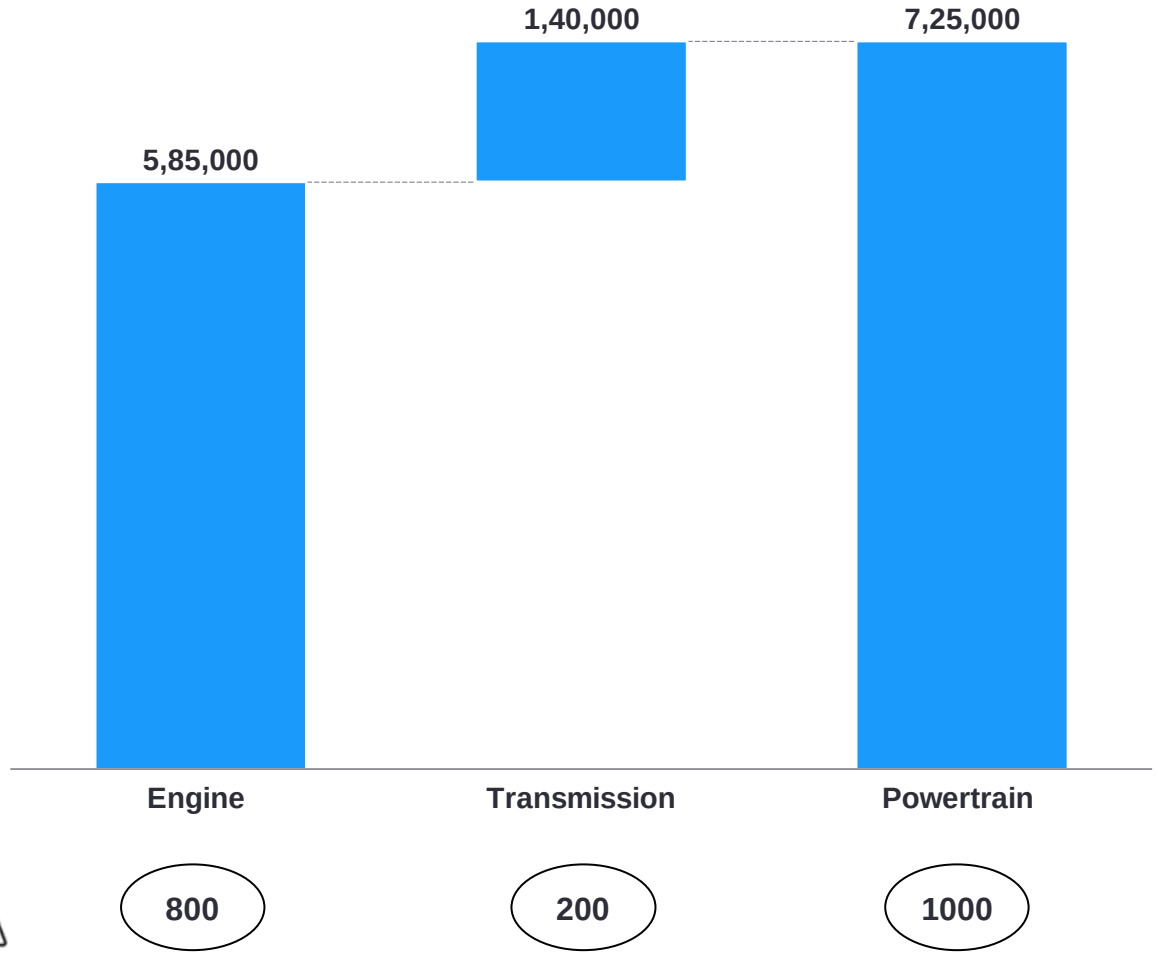
Source: EY-Parthenon analysis, Supplier quotations, Triangulation from expert interviews

EY Parthenon

Engine & Transmission combined accounts for ~43% of the overall BOM cost, making it one of the primary cost drivers for the overall vehicle

Diesel Truck – Powertrain Cost in (₹)

16T GVW



Technical Specs	
Engine Type	5L new generation BSVI engine
Displacement	5000 CC
Max Output	132 kW
Max torque	590 Nm
Transmission Type	G750, Manual Synchromesh

- The Engine cost also includes the Fuel system, thermal management and exhaust system
- The Transmission cost includes the clutch, pressure plate & the transmission – Uses a single plate dry friction clutch of 352mm Diameter
- Majority of the M&HD trucks use a manual transmission – 6+1 Speed Transmission
- Engine & Transmission are currently manufactured by Tata in-house

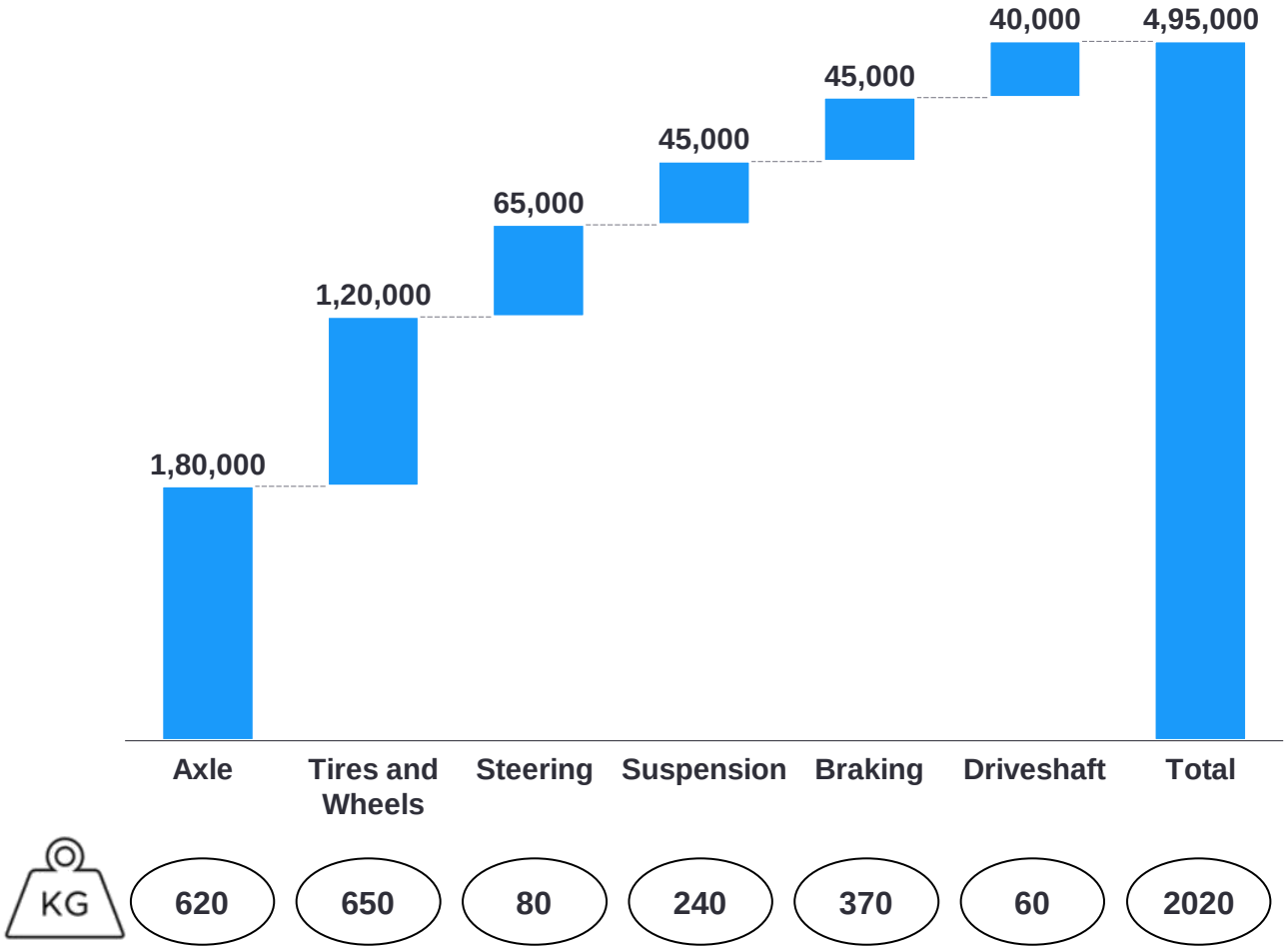
Source: EY-Parthenon analysis, Supplier Quotations, Expert Interviews

EY Parthenon

The Drivetrain systems makes up for ~29% of the overall cost of the Diesel Truck and covers for ~36% of overall component weight

Diesel Truck – Drivetrain Cost (₹)

16T GVW



Technical Specs	
Front + Rear Braking	Dual circuit full air S-cam drum brakes
Compressor	Electric Scroll Compressor
Steering	Hydraulic Steering System
Front Suspension	Parabolic leaf spring
Rear Suspension	Semi elliptical leaf spring
Total Weight (kg)	2020

- The Braking system is integrated with the compressor system and the ABS (anti-lock braking system) including the brake pedal
- The Steering system has an integrated, mechanical steering gear assembly & also comes with tilt & telescopic adjustment
- The Axle system considered is a fixed rigid axle with a differential/ direct drive unit included along with the brake drums, brake shoes and chambers

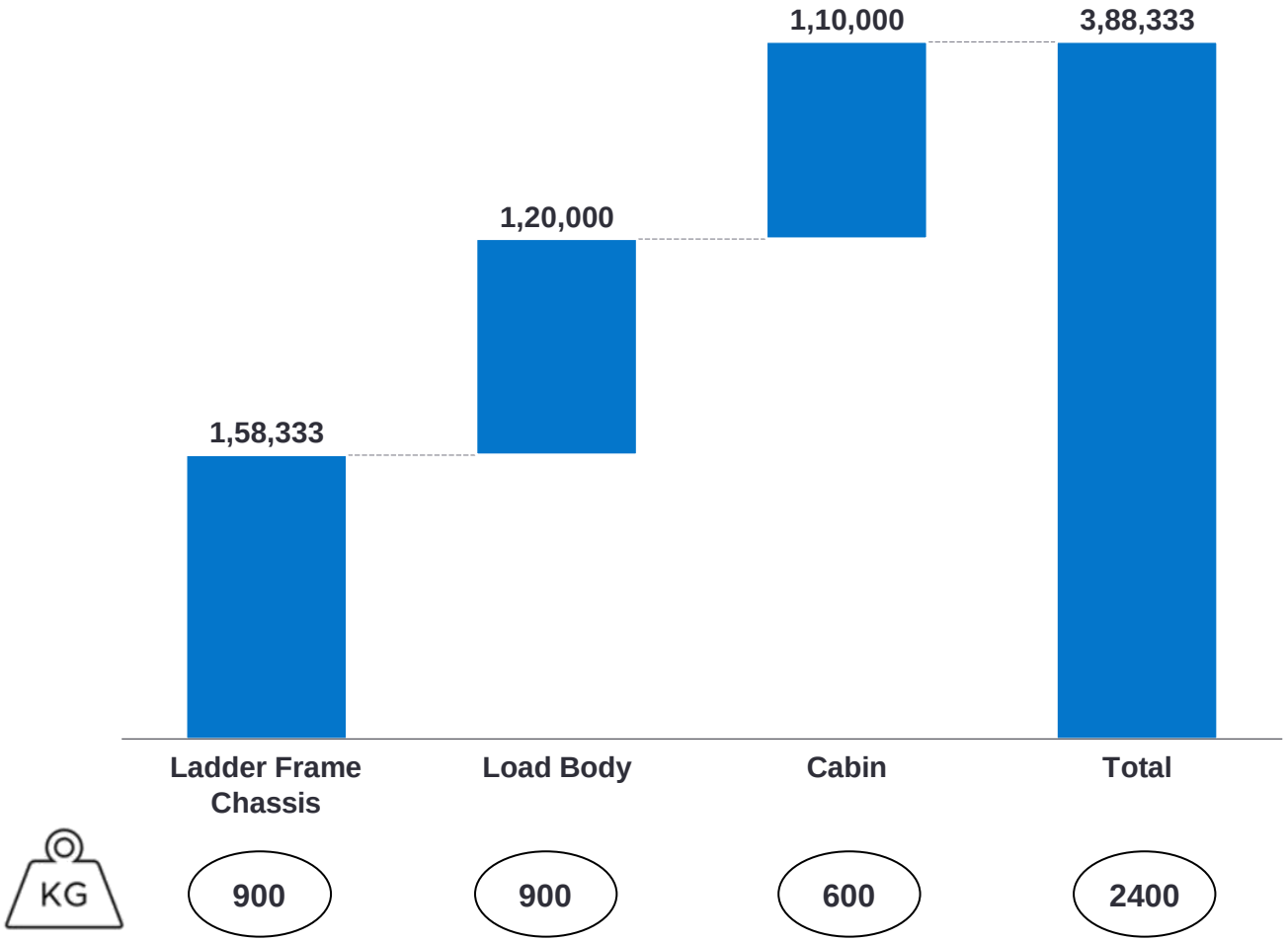
Source: EY-Parthenon analysis, Supplier Quotations, Expert Interviews

EY Parthenon

The Body and Ladder frame Chassis systems of the Diesel truck makes up for ~23% of the overall cost and covers for ~43% of the overall component weight

Diesel Truck – Body + Chassis Cost (₹)

16T GVW



Technical Specs	
Chassis Material	HSS 800
Load Body Material	Aluminium + Galvanised Iron
Load Body Dimensions (mm)	Length – 7430 Width – 2286 Height - 1830

- Chassis used in the truck is a ladder frame chassis
- The cabin structure will be made from galvanized iron and includes the front, rear, floor, roof, side etc.
  - Seats – 2 plastic molded seats considered for the day cab variant
  - Frond windshield made from single piece laminated glass, paint
  - Windows made from flat toughened glass
  - Interior trims systems (plastics), dashboard, cluster systems, floor assembly, wiper systems, paint

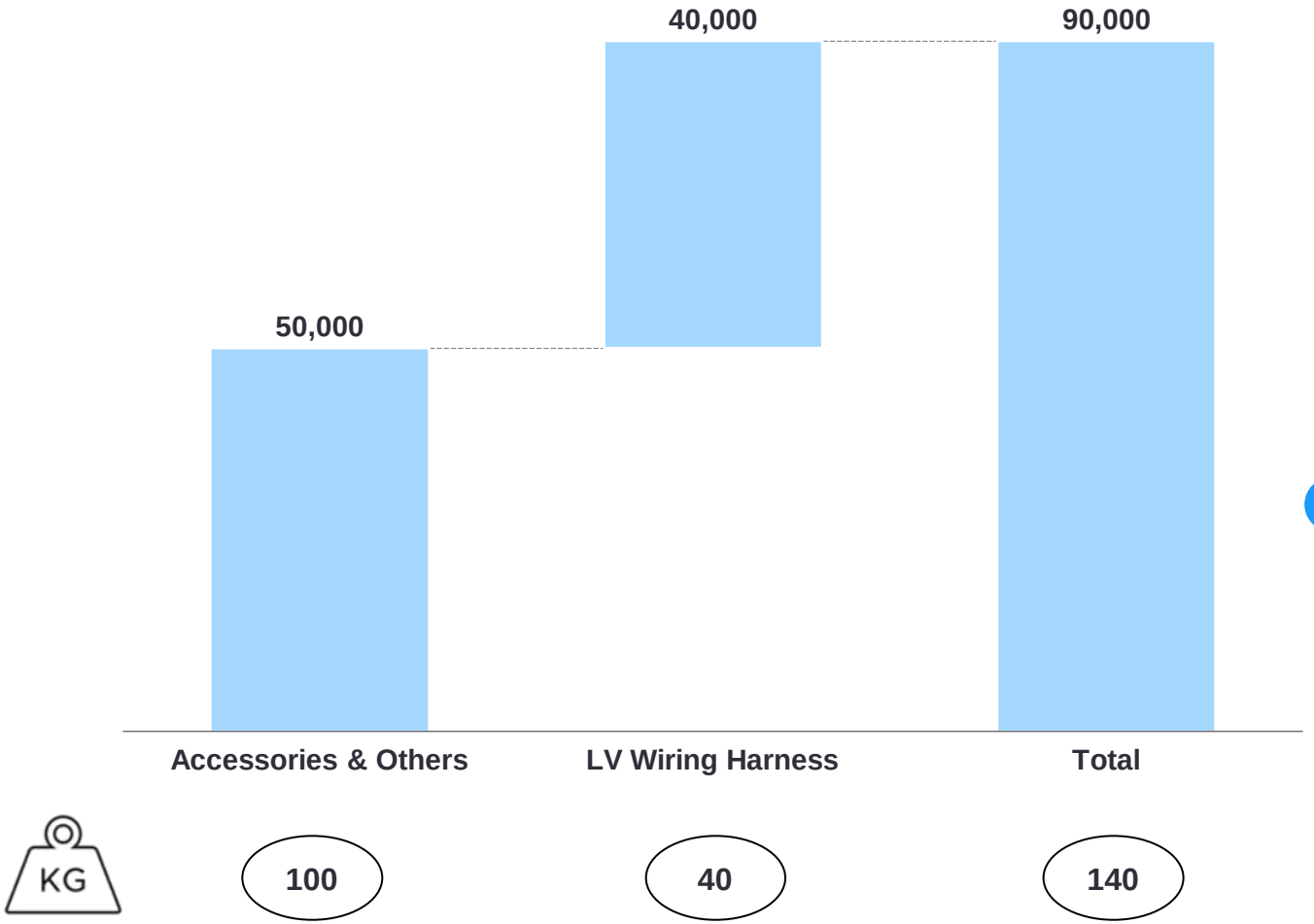
Source: EY-Parthenon analysis, Supplier Quotations, Expert Interviews

EY Parthenon

The Wiring harness & accessories make up ~5% the total BOM cost, with wiring harness accounting for ~45% of that cost

Diesel Truck – Wiring Harness & Accessories Cost (₹)

16T GVW



Technical Specs	
Low Voltage (V)	24
System Weight (kg)	140

- The LV wiring harness is responsible for all electrical connections, lightings, cabin lights etc.
- Accessories & others include –
  - Avg. Fuel Economy Indicator
  - Pressure gauges, Digital Indicators
  - Fuel economy switch
  - Nuts, bolts, fasteners, rivets, rear view mirrors, etc.

Source: EY-Parthenon analysis, Supplier Quotations, Expert Interviews

EY Parthenon

EYP has internally developed scaling factors for different systems and sub-systems of the electric bus based on various scaling parameters and specifications of the systems

Scaling factors for various systems – Electric Bus

12M Bus

System	Scaling Parameter	Existing Cost (₹)	Specifications	Scaling Factor
Battery Pack	kWh rating of the battery	28,20,400	186 kWh LFP	18400 ₹ / kWh
BMS		6,02,000		
Motor	kW rating of the motor	6,40,000	160 kW	5000 ₹ / kW
Control Unit/Inverter		1,60,000		
Battery Thermal Management	kW rating of the system	2,25,000	8 kW	28125 ₹ / kW
Chassis	Weight of the frame	1,90,000	1080 kg	175.9 ₹ / kg
Bus Body Structure	Weight of the structure	7,80,000	4380 kg	178.1 ₹ / kg
Braking System*	Diameter and number of the brake drums	130000	325 mm	100 ₹ / mm
Front Axle	Front and Rear axle rating in ton	45000	7.7 ton	5844.2 ₹ / ton
Rear Axle		60000	10.2 ton	5882.4 ₹ / ton
Front Tires + Wheels	Diameter and number of the wheel rims	70,000	20 inch	1,000 ₹ / inch
Rear Tires + Wheels		70,000		
Power Steering	Front axle rating in ton	2,27,305	7.7 ton	29,520.1 ₹ / ton
Front Suspension	Front and Rear axle rating in ton	85,000	7.7 ton	11039.0 ₹ / ton
Rear Suspension		1,70,000	10.2 ton	16666.7 ₹ / ton
Driveshaft	Weight of the system	15,000	20 kg	750 ₹ / kg
Power Electronics	kW rating (only applicable for the DC-DC converter)	3,50,000	1,00,00 for 5kW DC-DC converter	20000 ₹ / kW
HV Wiring Harness	Weight of the complete wiring system	2,28,000	170 kg	1345 ₹ / kg
LV Wiring Harness	Weight of the complete wiring system	1,00,000	80 kg	1250 ₹ / kg
Compressor	Pressure rating of the compressor	90,000	10 bar	9000 ₹ / bar
eHVAC	kW rating of the AC	4,00,000	22 kW	18182 ₹ / kW

Click to go to comments for scaling factors considered for electric bus and electric trucks

*For scaling factor calculation, the braking system also includes the brake pedals, drums, brake shoes and chambers (unlike the BOM calculation), axle system is separate from the braking unit

Source: EY-Parthenon analysis, Supplier Quotations, Expert Interviews

EYP has internally developed scaling factors for different systems and sub-systems of the electric truck based on various scaling parameters and specifications of the systems

Scaling factors for various systems – Electric Truck


16T GVW

System	Scaling Parameter	Existing Cost (₹)	Specifications	Scaling Factor
Battery Pack	kWh rating of the battery	48,58,739	295 kWh NMC	20588 ₹ / kWh
BMS		12,14,685		
Motor	kW rating of the motor	6,40,000	160 kW	5000 ₹ / kW
Control Unit/Inverter		1,60,000		
Battery Thermal Management	kW rating of the system	2,25,000	8 kW	28125 ₹ / kW
Ladder frame	Weight of the frame	1,58,333	900 kg	175.9 ₹ / kg
Truck Load Body	Weight of the structure	1,20,000	900 kg	133.3 ₹ / kg
Braking System*	Diameter and number of the brake drums	120000	410 mm	73.2 ₹ / mm
Front Axle	Front and Rear axle rating in ton	35000	6 ton	5833.3 ₹ / ton
Rear Axle		50000	10 ton	5000 ₹ / ton
Front Tires + Wheels	Diameter and number of the wheel rims	60,000	20 inch	857.1 ₹ / inch
Rear Tires + Wheels		60,000		
Power Steering	Front axle rating in ton	1,77,120	6 ton	29,520.1 ₹ / ton
Front Suspension	Front and Rear axle rating in ton	20,000	6 ton	3333.3 ₹ / ton
Rear Suspension		25,000	10 ton	2500 ₹ / ton
Driveshaft	Weight of the system	15,000	20 kg	750 ₹ / kg
Power Electronics	kW rating (only applicable for the DC-DC converter)	3,50,000	1,00,00 for 5kW DC-DC converter	20000 ₹ / kW
HV Wiring Harness	Weight of the complete wiring system	1,60,000	119 kg	1345 ₹ / kg
LV Wiring Harness	Weight of the complete wiring system	40,000	40 kg	1000 ₹ / kg
Compressor	Pressure rating of the compressor	90,000	10 bar	9000 ₹ / bar

*For scaling factor calculation, the braking system also includes the brake pedals, drums, brake shoes and chambers (unlike the BOM calculation), axle system is separate from the braking unit

Source: EY-Parthenon analysis, Supplier Quotations, Expert Interviews

EYP has internally developed scaling factors for different systems and sub-systems of the diesel truck based on various scaling parameters and specifications of the systems

Scaling factors for various systems – Diesel Truck


16T GVW

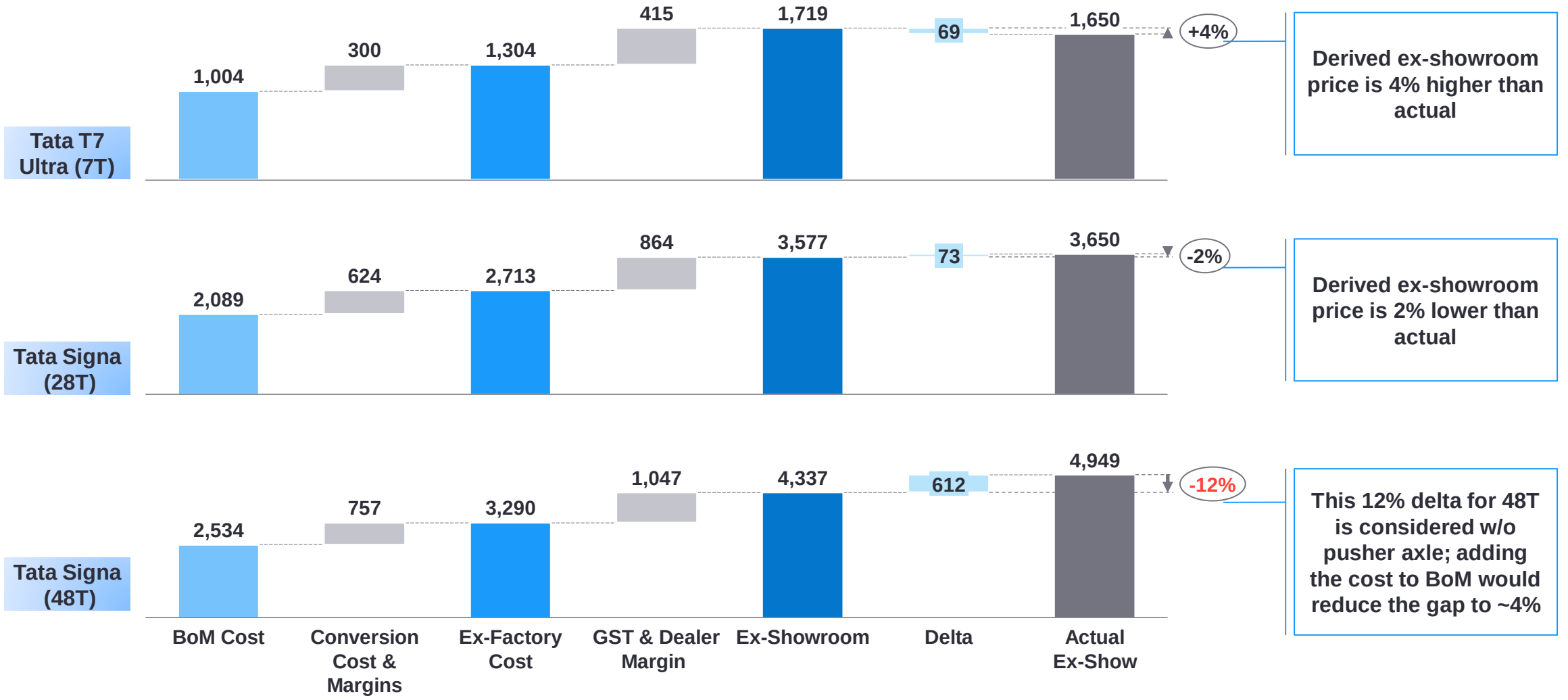
System	Scaling Parameter	Existing Cost (₹)	Specifications	Scaling Factor
Engine	Kilowatt rating of the engine	585000	132 kW	4431.8 ₹ / kW
Transmission System	Input Torque rating	140000	590 Nm	237.3 ₹ / Nm
Ladder Frame	Weight of the frame	158333.3	900 kg	175.9 ₹ / kg
Load Body	Weight of the load body	120000	900 kg	133.3 ₹ / kg
Driveshaft	Weight of the system	40000	60 kg	666.7 ₹ / kg
Braking System*	Diameter and number of the brake drums	120000	410 mm	73.17 ₹ / mm
Front Suspension	Front and Rear axle rating in ton	20000	6 Ton	3333.3 ₹ / kg
Rear Suspension		25000	10 Ton	2500 ₹ / kg
Compressor	Pressure rating of the system	20000	10 bar	2000 ₹ / bar
Front Axle	Front and Rear axle rating in ton	35000	6 Ton	5833 ₹ / ton
Rear Axle		50000	10 Ton	5000 ₹ / ton
Steering	Front axle rating in ton	65000	6 Ton	10833 ₹ / ton
Front Tires + Wheels	Diameter and number of the wheel rims	120000	20 inch	857.1 ₹ / inch
Rear Tires + Wheels				
LV Wiring Harness	Weight of the complete wiring system	40000	40 kg	1000 ₹ / kg

*For scaling factor calculation, the braking system also includes the brake pedals, drums, brake shoes and chambers (unlike the BOM calculation), axle system is separate from the braking unit

Source: EY-Parthenon analysis, Supplier Quotations, Expert Interviews

Scaling factors apply to all trucks with similar axle configuration, the error margins (derived ex-showroom vs actual) for reference 7T, 28T & 48T are all <5%

Vehicle Cost Comparison based on scaling factors – Diesel Truck



Source: EY-Parthenon analysis

EY Parthenon

BoM costs of various Tata Tucks based on EYP scaling factors; Tata T7 Ultra, Tata signa 2818 and 4825 have been used for the analysis across various GVW's

Scaling factors for various systems – Diesel Truck

		Tata T7 Ultra (7T)		Tata Signa (28T)		Tata Signa (48T)	
System	**Scaling Factor**	**Specifications**	**Cost (₹)**	**Specifications**	**Cost (₹)**	**Specifications**	**Cost (₹)**
Engine	4431.8 ₹ / kW	100 Kw	4,43,182	140 Kw	6,20,455	186 Kw	8,24,318
Transmission System	237.3 ₹ / Nm	300 Nm	71,186	850 Nm	2,01,695	950 Nm	2,25,424
Cabin (interior, exterior, windshield, instrument)	-	-	50,000	-	1,21,000	-	1,32,000
Ladder Frame	175.9 ₹ / kg	300 kg	52,778	1100 kg	1,93,519	1350 kg	2,37,500
Load Body	133.3 ₹ / kg	247 kg	33,043	1100 kg	1,46,667	1350 kg	1,80,000
Driveshaft	666.7 ₹ / kg	20 kg	13,333	67 kg	45000	77 kg	51,320
Braking System (incl. drum, shoe, hydraulics & ABS)	73.17 ₹ / mm	275 mm	1,20,732	410 mm	1,80,000	410 mm	3,00,000
Front Suspension	3333.3 ₹ / kg	3.1 Ton	10,333	7 Ton	23,333	7 Ton	23,333
Rear Suspension	2500 ₹ / kg	4.2 Ton	10,500	21 Ton	52,500	21 Ton	52,500
Compressor	2000 ₹ / bar	10 bar	20,000	10 bar	20,000	10 bar	20,000
Front Axle	5833 ₹ / ton	3.1 Ton	18,083	7 Ton	40,833	7 Ton	40,833
Rear Axle	5000 ₹ / ton	4.2 Ton	21,000	21 Ton	1,05,000	21 Ton	1,05,000
Steering	10833 ₹ / ton	3.1 Ton	33,583	7 Ton	75,833	7 Ton	75,833
Tires + Wheels	857.1 ₹ / inch	20 inch	54,857	20 inch	1,71429	20 inch	2,74,286
LV Wiring Harness	1000 ₹ / kg	26.12 kg	26,122	46 kg	46,000	46 kg	50,000
Accessories & Others	-	-	25,000	-	50,000	-	60,000

Source: EY-Parthenon analysis

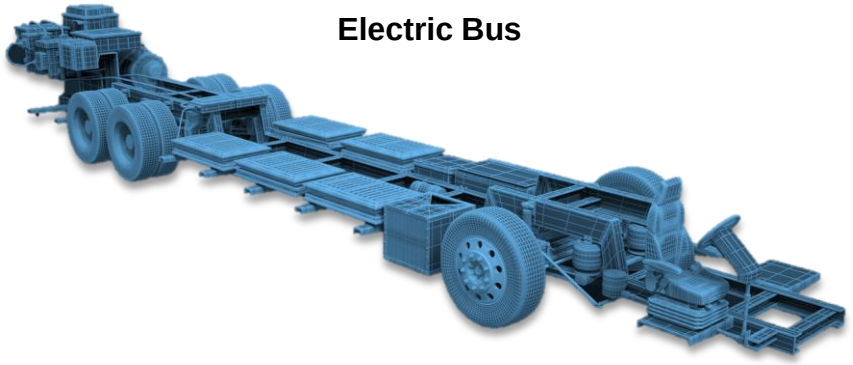
Table of Contents

- Project Summary
- WP 1: Baseline Cost & Weight estimation
- **WP 2: Cost projections for Key ZET components**
- WP 3: Evaluation of existing supply chain & localization potential
- Appendix

EY Parthenon

Battery, motor & PE currently accounts for ~60% of the BOM cost; Factors such as technology, economies of scale, raw material & policy will influence the costs till 2040

Cost Projections of Key EV Components



Electric Bus

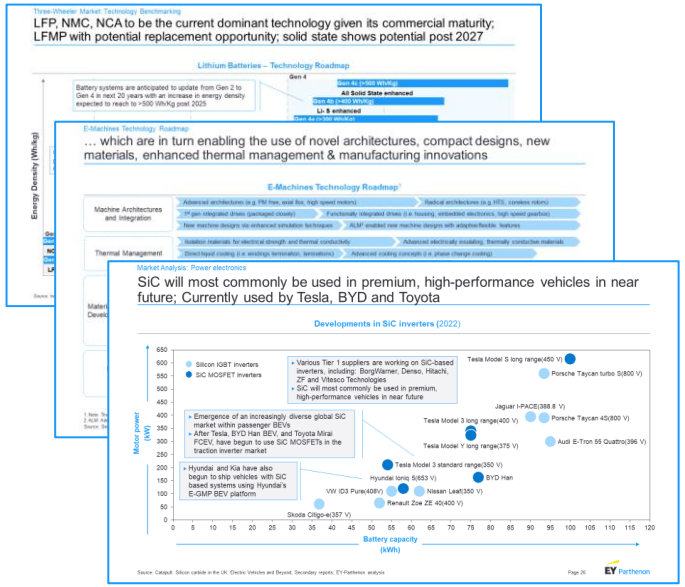
Methodology

EY-P has used a combination of factors to arrive at the cost projections till 2040 with key consideration of the following components

Battery | **Motor** | **Power Electronics**

Critical Cost Driving Factors

Technology Evolution	New technologies in Battery, Motor & Power Electronics that are likely to influence cost & efficiency
Economies of Scale	Increased volumes would impact manufacturing efficiencies, component costs and the overall supply chain
Raw Material Costs	Pricing trends of raw materials like Copper, Lithium, Magnesium, etc. would directly impact the cost of key components
Policy	Policies & incentives for component manufacturing and EV sales are likely to influence cost & availability of E-CVs in India
Productivity	Increased sales volumes & mature supply chains would increase productivity & efficiency of manufacturing and would impact costs

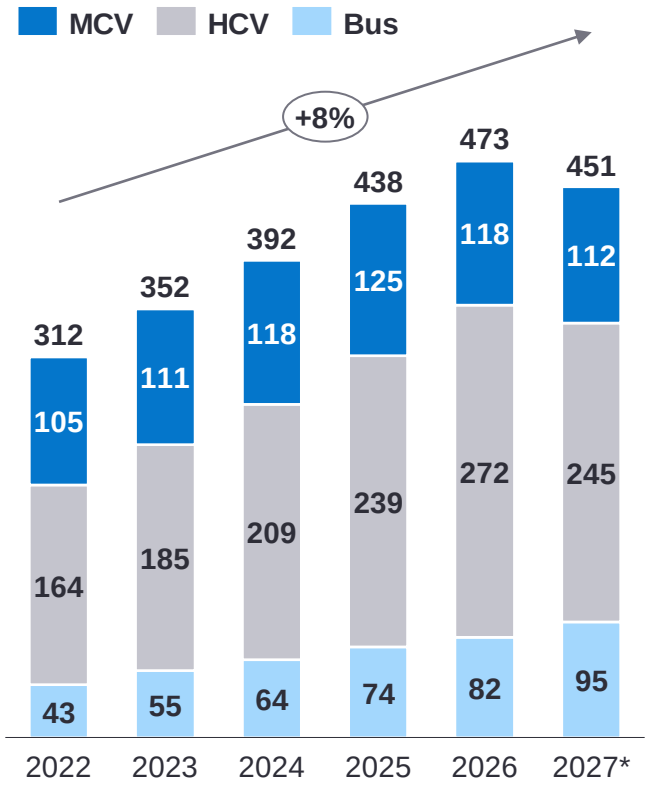


Source: EY-Parthenon analysis

EY Parthenon

CV volume projections till 2040 could be laid out in different scenarios which will impact the electrification penetration but will ensure sufficient scale to lower the component costs

Commercial Vehicles – Volume Projections (2022-2040) (in '000)



Dieselization

- Diesel dominant scenario; diesel to account for 60-70% share

MCV
- Diesel & CNG will have 50-50% share for the MCVs

HCV
- Diesel will continue to largely dominate (>75%) of HCV segment due to lack of infrastructure for hydrogen & electric
- CNG / LNG will form the remaining share but will lack performance parity compared to diesel

Bus
- Intercity buses will continue to run on diesel while CNG buses will form a large part of Intra-city buses

Hybridization

- Mix powertrain scenario but diesel to still account for ~40-45% share

MCV
- Besides diesel & CNG, MCVs will also have share of electric

HCV
- HCVs will have marginal share of LNG & Hydrogen-ICE but will still have diesel as the dominant fuel type

Bus
- Intercity buses will have share of diesel & LNG while Electric buses will form the large part of Intra-city buses while CNG will be the balance

Electrification

- Electric will be the dominant fuel type in this scenario

MCV
- MCVs will have a higher share of electric trucks, diesel & CNG will form the remaining

HCV
- HCVs will have marginal share of electric and the balance will be from LNG & Hydrogen-ICE
- Infrastructure set-up of LNG & Hydrogen will promote its use in HCV

Bus
- Intercity buses will have majority share of electric while balance will be skewed towards CNG as the infrastructure would have developed
- Intra-city buses will be 100% electric

Scenarios for 2040

Regardless of the different scenarios for 2040 for commercial vehicles, there will be sufficient volumes of electric trucks & buses spaced out between top 3-4 OEMs which will help reduce the cost of key components by 2040

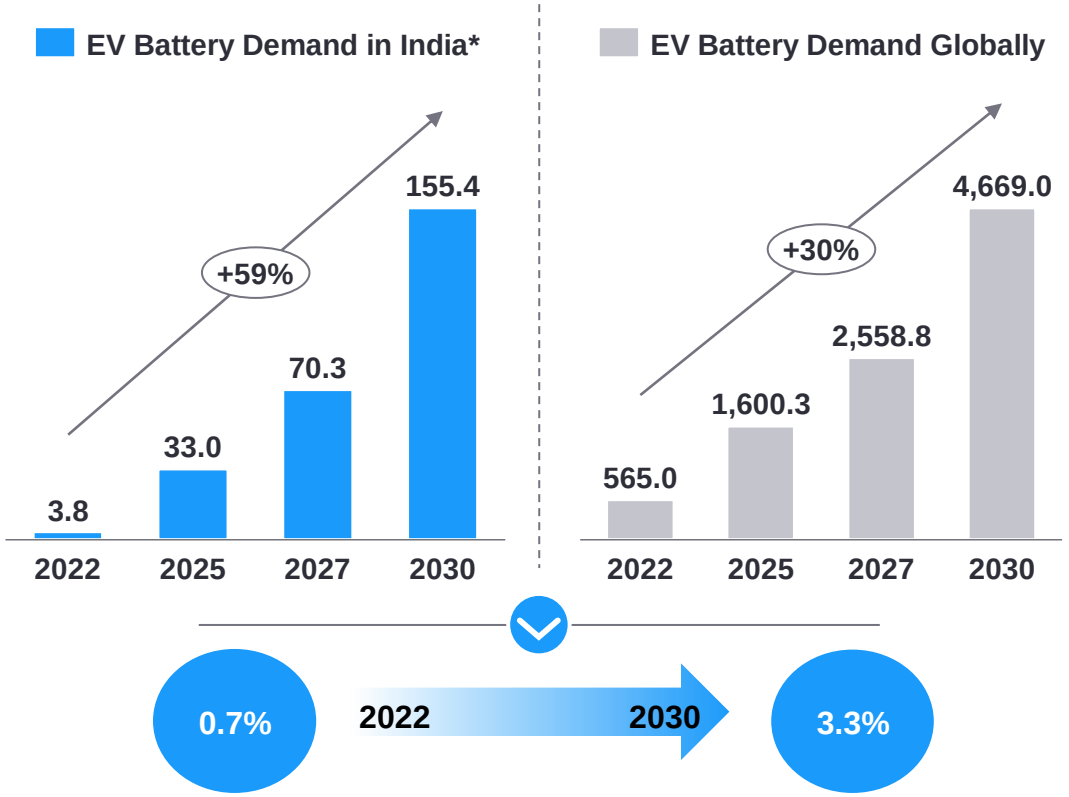
The CV Market in India has a cyclical nature and based on the same cycle data, the 2027 CV predictions are less than 2026
Source: Secondary Sources, EY-Parthenon analysis

EY Parthenon

India's battery demand by 2030 is likely to account for ~3% of the global demand; manufacturing efficiency is likely to increase cell to pack ratio by 2030

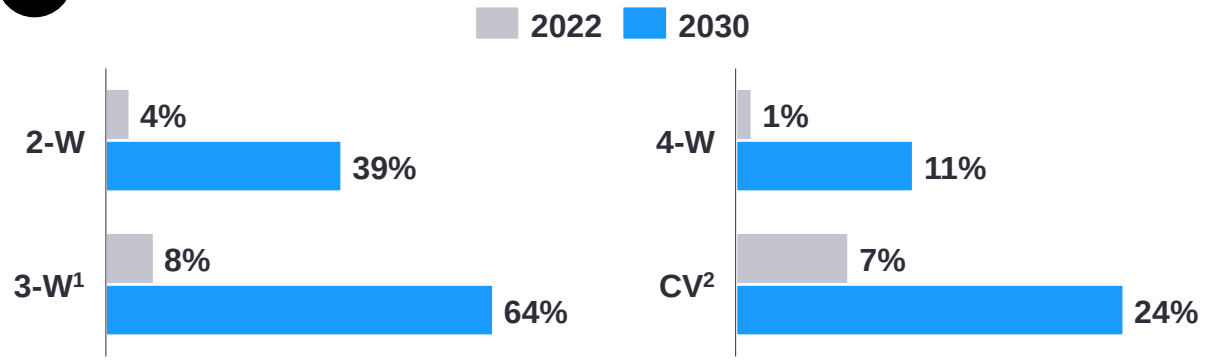
Factors impacting battery pack costs in India

1 EV Li-ion Battery Demand (in GWh, 2022-2030)



Indian EV Lithium-ion battery demand to grow from ~0.7% to ~3.3% of the global Li-ion battery demand

2 EV Penetration Rate (2022-2030)



Major battery demand to come from e-2W and e-3W having sub ~10kWh batteries

3 Cell to Pack Cost ratio

- Cell to pack cost ratio indicates the cost of cells as compared to the overall battery pack costs which may contain additional components as BMS, thermal management as well as the overall assembly costs
- The cell to pack cost ratio in India is likely to increase from ~64% in 2022 to ~80% in 2030 with pack costs decreasing in a higher gradient as in comparison to cell costs owing to manufacturing efficiencies
- At the cell level, costs will be similar for different vehicle classes which translates to similar battery pack costs for the different vehicle classes

*Li-Ion Battery demand includes the demand coming from End-of-Life EV Batteries after 2027, Battery life being assumed at 8 years. The demand does not include the demand coming from ESS and others

1: 3-W include light cargo and goods carrier vehicles

2: CV comprises of Buses only

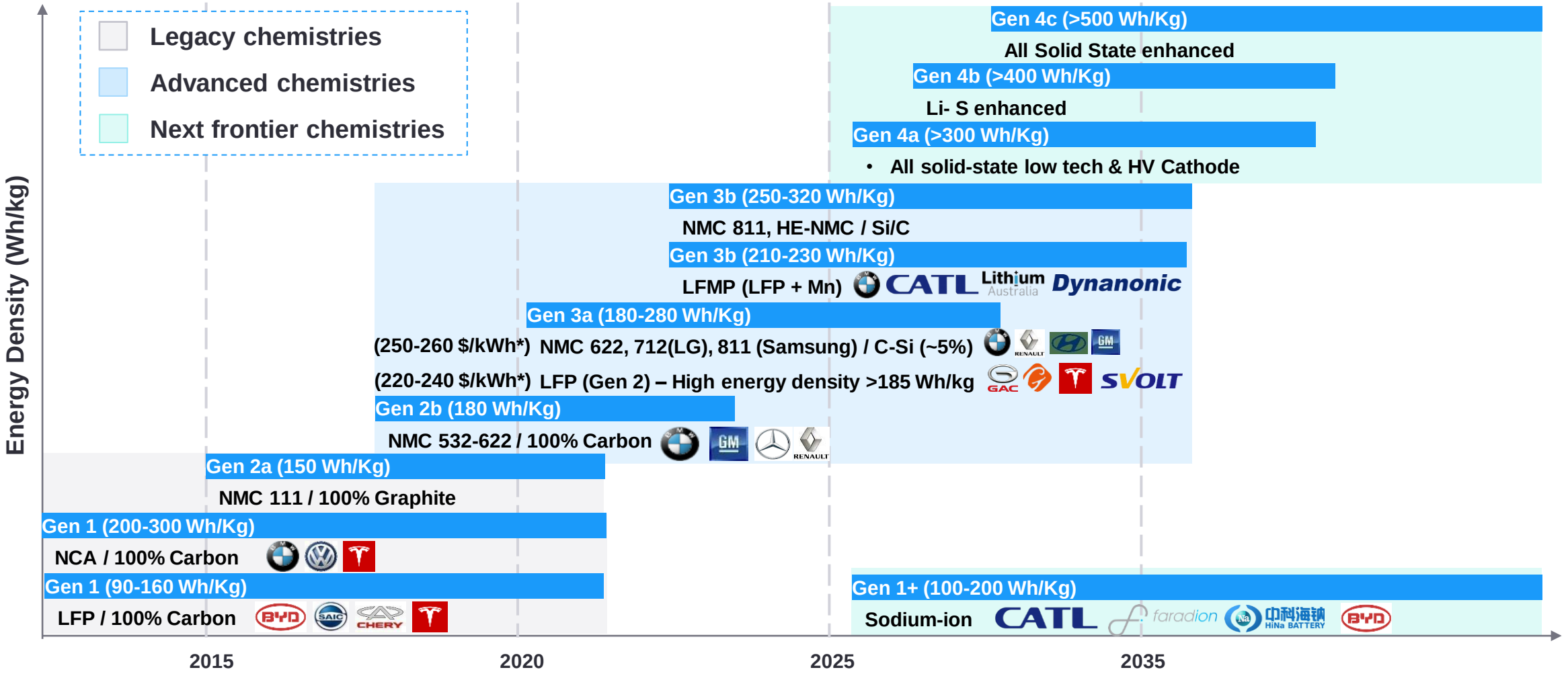
Source: Secondary Sources, EY-Parthenon analysis

Click to go to methodology for battery demand *Click to go to ACC PLI scheme-based Li-ion battery supply in India* *Click to go to Niti Aayog scenario comparison*

EY Parthenon

Li-Ion chemistry to be the dominant technology for the foreseeable future given its maturity; Next frontier technologies such as solid-state, sodium-ion shows potential post 2027

EV Batteries – Technology Roadmap



The different generation of chemistries has been developed by EYP based on secondary sources and EYP understanding to notify the battery technology development, The roadmap is applicable in general to all EVs

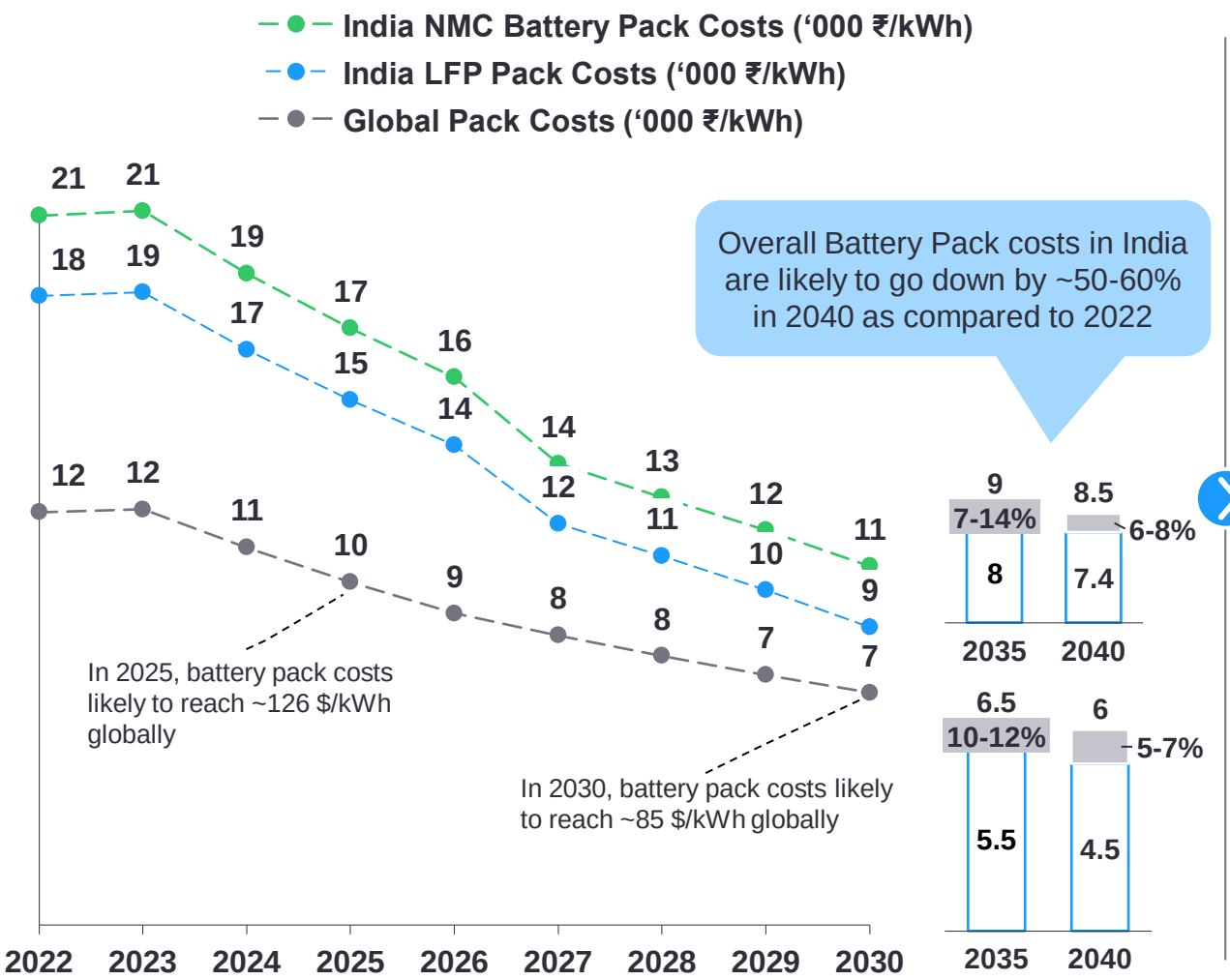
* Delivered battery pack costs in the Indian Market

Source: Secondary Sources, Public domain, EYP Database

EY Parthenon

Battery Pack costs in India are likely to fall by ~50-60% by 2040 with raw material costs, volumes & local production driving most of the cost reduction with tech improvements

Battery Pack Cost Estimates for India (2022-2040) (in '000 ₹/kWh)



- For 2022, the delivered cost of Battery Packs (incl. BMS) in India is **220-240 $/kWh for LFP and 250-260 $/kWh for NMC**
  - Cells are imported, primarily from China, and battery pack is assembled locally with BMS
- **LFP market share** forecast to double to **~70% by 2030** while **NMC market share** estimated to halve to **~30% by 2030** in India
  - By 2030, NMC battery packs will be used mainly in long range, weight sensitive applications while LFP will gain more traction in the low range space
  - LFP chemistry has higher thermal stability and hence is more suitable for Indian temperature conditions
- Geological survey of India recently found "inferred resources" of 5.9 million tonnes of lithium in Jammu and Kashmir. Since, these are inferred resources and no prior feasibility study has been done, the time taken to materialise will be a very lengthy one and hence the discovery has not been used in the battery pack cost forecasting
- **Primary factors for cost reduction -**
  - **Higher Battery Demand due to EV Penetration** – Higher production volumes resulting from higher lithium-ion battery demand will help lower cell cost and reduce the cell to pack conversion cost
  - **Localization of cell production** – In line with the ACC PLI scheme, Indian companies are likely to start indigenous cell production, major cell production capacity is expected to come online by 2027

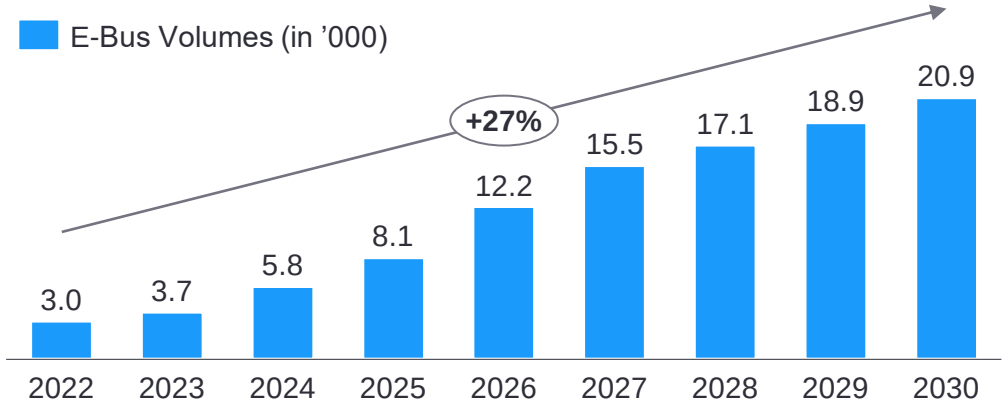
* 1 USD = 80 INR
Inflation not considered as part of forecasted costs
Source: Secondary Sources, Reports, Public Domain, BNEF Data, EY-Parthenon analysis

Click to go to Electric Bus Cost Forecast slide *Click to go to ACC PLI Scheme slide* *Click to go to Electric Truck Cost Forecast slide*

Reduction in motor costs in India are likely to be attributed to the surge in volumes; BoM cost of motor suggests scope for import duty reduction due to localization

Factors impacting motor costs in India

1 India E-Bus Volume (2022-2030)



- Several Factors are likely to contribute to growth of e-buses which will generate demand for motors till 2030
  - Govt. subsidies which aid STUs to procure e-buses via OPEX model by lowering the high upfront cost
  - State Govt electrification targets which will drive the demand in metro cities initially followed by Tier IIs
  - New product availability for both inter & intra city which will garner interest from private sector as well
  - Auto Expo 2023 also witnessed launch / showcase of new products indicating OEM readiness

2 Import Duty Reduction

Importing the components currently accounts for 10% duty (import tax) which can be saved if Stator Core, windings, housings & rotor are manufactured locally

3 Motor Supplier Feedback

Leading motor suppliers have quoted 20% reduction on delivered prices in the next 3-4 years as the volumes are likely to increase by 3x-4x

Source: Secondary Sources, Supplier Interviews, EY-Parthenon analysis

EY Parthenon

Compact designs requirement are driving greater functional integration of components; Advanced cooling methods, materials and manufacturing to enhance performance

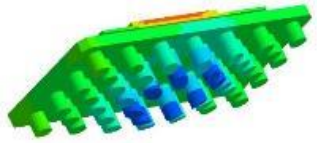
Evolution of e-Motors

Motor Architecture & Integration


Size

- Innovations in motor design & their integration in wider powertrain to deliver more compact design -
- Axial flux being commercialized for power dense applications; radial architecture possible post 2035 using HTS[1], coreless rotors, etc.

Thermal Management



Performance

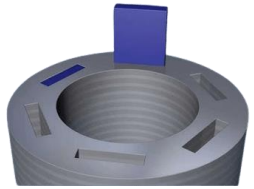
- Choosing the ideal motor cooling solution for high-speed & power dense motors
- Active cooling options for EVs – liquid or air cooling
- Converging thermal management solution for integrated drives

Winding Material Development

Cost

- Focussing on winding material that improves performance for ex. Square wires instead of round
- Use of low cost winding solutions such as aluminium
- Change in manufacturing process to ALM

Hard Magnetics



Cost

- Alternative approaches to reduce traditional dependence on rare earths to reduce cost & supply risks – for ex. Use of recycled permanent magnets
- Iron ferrite magnets and polymer-bonded NdFeB magnets present cost effective alternatives

Soft Magnetics


- Soft magnetic composites allows more complex 3D shapes to be manufactured as near-net shapes
- Next-generation electrical steels have potential to drive higher performance due to advancements in magnetic & chemical properties of electrical steels

Manufacturing Innovations


Cost & Manufacturing Complexity

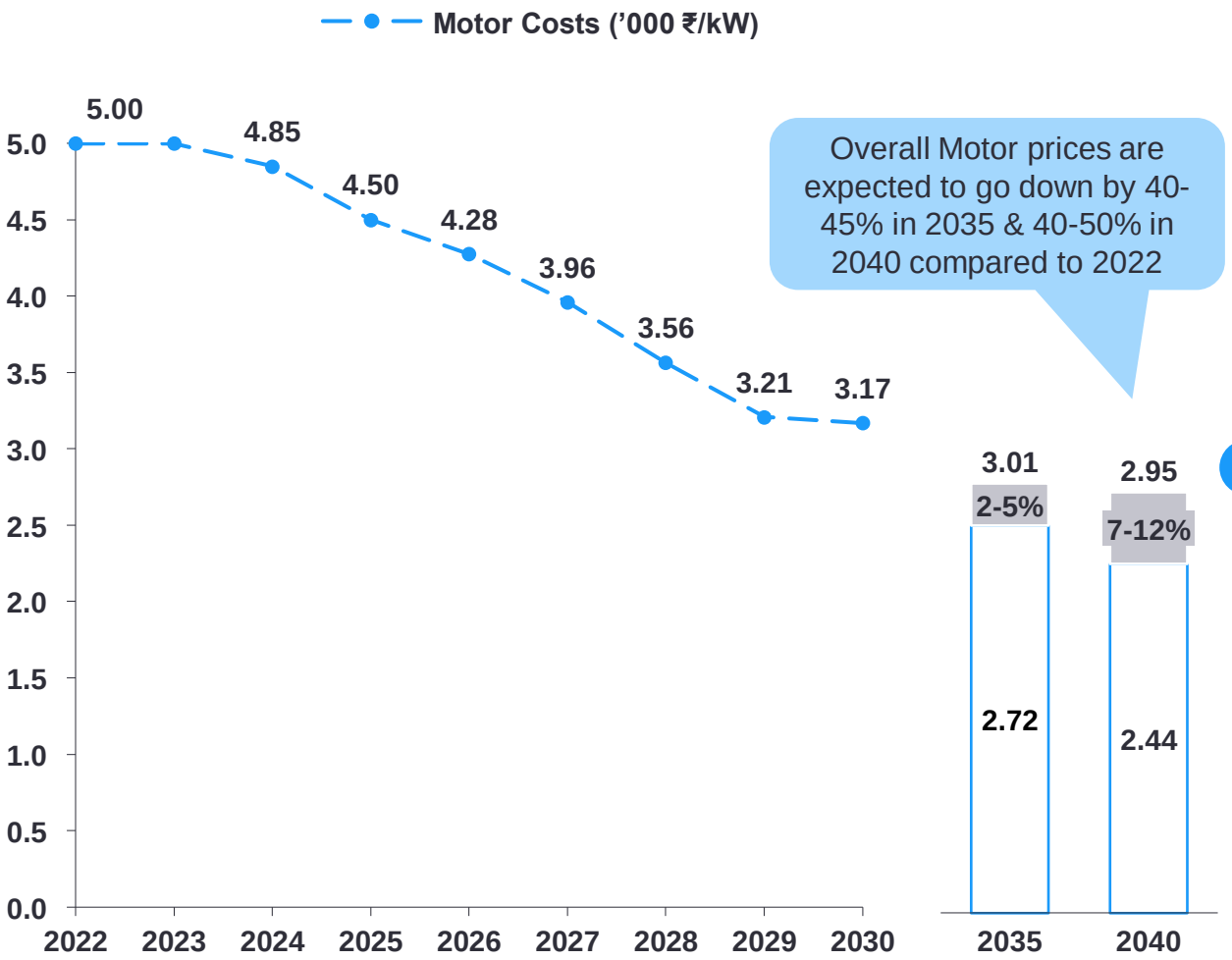
- New production methods are needed to deliver higher material yields for stators, rotors, PM[1] & windings
- Removing resins, greases & bonding material would improve motor production speeds

1. HTS: High temperature superconductors

Source: Secondary research, Public Domain, EYP analysis

Motor costs in India are likely to fall by 40-50% by 2040 with volumes & local production driving majority of the cost reduction followed by technological improvements

Motor Cost Projections for India (2022-2040) (in '000 ₹/kW)



- The delivered cost for Motors (incl. inverter) in India is 5000 ₹/kW in 2022 with only a few suppliers like Dana manufacturing it locally for CVs (primarily buses now)
- **Primary factors for cost reduction**
  - **Increase in CV volumes** (primarily by buses till 2030)
  - **Technology Change** – Different materials & recycled magnets will also help in cost reduction
  - Other technology changes would include more efficient thermal management solutions & increase of power density
- With the increase in volumes by 2027, motor costs are projected to fall by ~20% to 3,960 ₹/kW
- Motors that use lesser rare earth metals & with aluminum windings would be introduced around 2030 & technology realization would happen by 2035
  - Technology R&D costs would be amortized over the increased volumes post 2030 & this would lower the fall in motor costs in 2035 & 2040
- Overall motor prices are expected to fall by 40-45% by 2035 & 40-50% by 2040 compared to 2022

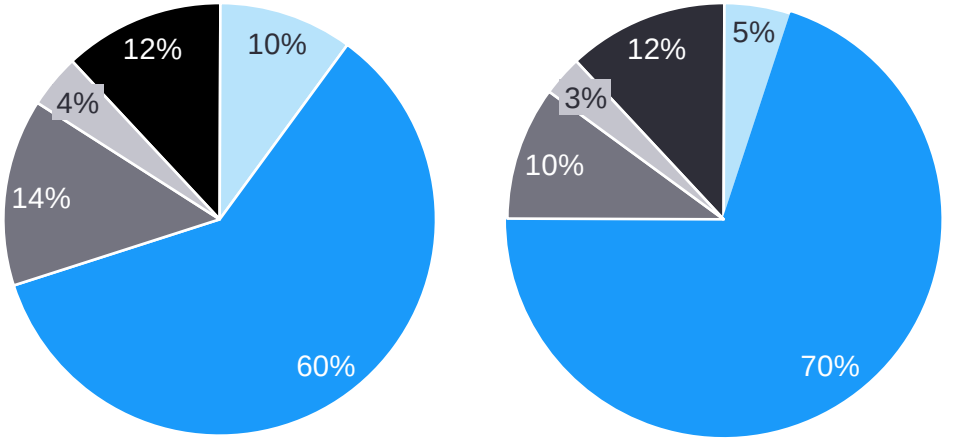
Click to go to Electric Bus Cost Forecast slide

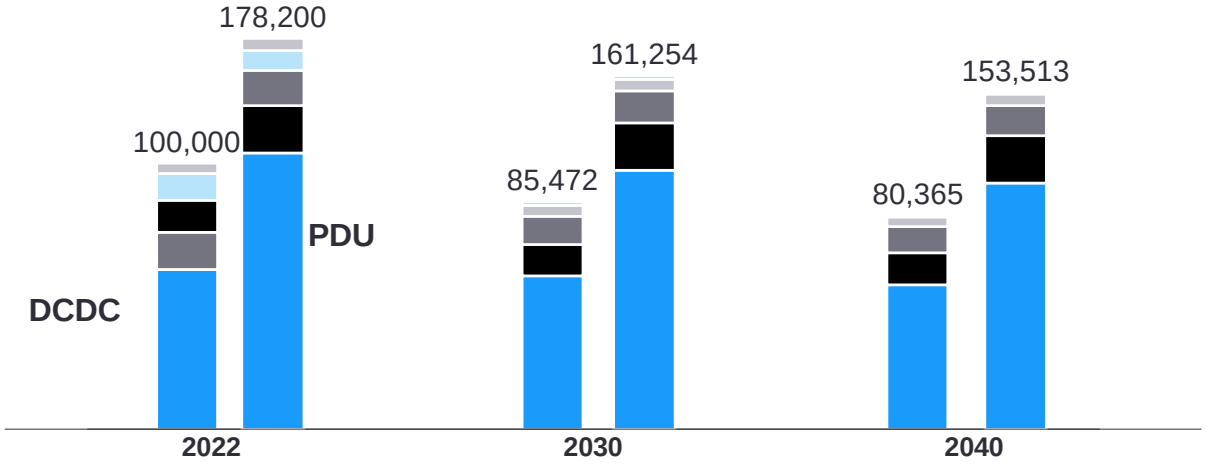
Click to go to Electric Truck Cost Forecast slide

Source: Secondary Sources, EY-Parthenon analysis

For forecasting PE costs, impact of volume, localization & technology was taken into consideration; The largest cost driver was the material cost for both PE components

Power Electronics Cost Breakdown





1: Sales, Goods and Admin Costs
2: Other costs include import duties, amortized labor, equipment, facility and maintenance costs
Source: Secondary Sources, EY-Parthenon analysis

- **DCDC converters**
  - Power converters require higher R&D due to their reliance on semiconductor components. Majority (~66.6%) of R&D cost for DCDC is attributed to software development
  - **Hardware costs** are expected to have an YoY decrease at 2-4% in the initial years, settling down to 1-2% for the consecutive years
  - **R&D costs** are increasing in absolute terms over 2030 and 2040, however they're being amortized over higher volumes sold
  - As a result**,** R&D contributes to 10% of the total cost in 2022, 2% in 2030, and 1% in 2040
  - **Impact of localization** for HV DCDC converters for CVs has been kept relatively low (up to 3%) by 2040
- **PDU**
  - Primary purpose of a PDU is to safely distribute power to multiple high voltage components, such as the DCDC converter, AC Compressor, Battery Chiller, etc.
  - **Hardware components contribute more (~70%)** to the overall costs due to the nature of the product
  - Majority of hardware costs (~90%) in PDU comprise of passive and electrical components (fuses, bus bars and connectors)
  - PDUs don't utilize semiconductor components (<5% of BOM cost) within the device and hence a **higher impact of localization (up to 4% in 2040)** has been taken into consideration of PDUs

The future trend in the power electronics components is the use of Wide Band Gap Semiconductors with deep integration of components as DCDC and Inverter together

Power Electronics Technological Trends

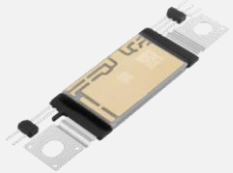
Semiconductor Improvements

Performance

Optimization of existing Si Semiconductors

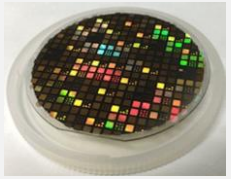
- Improvements in thermal management, chip sizes, & switch design (higher switching frequency, reverse-blocking, etc) resulting in power efficient and smaller devices

Rise of SiC & GaN Semiconductors



- SiC provides faster switching, higher power tolerance & better thermal efficiency
- Reduction in manufacturing cost by 2035

Ultra WBG Materials



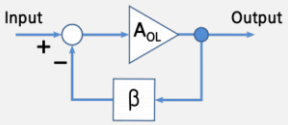
- Next-gen materials (Aluminium Nitride, Gallium Oxide, Diamond) can provide a significant performance boost compared to GaN and SiC devices

System Improvements

Cost

Complexity

Control



- Sophisticated control strategies, with tailored outputs based on drive cycle and user behaviour
- Better integration with overall vehicle software

Design

- Improved circuit and packaging design to accommodate WBG semiconductors, resulting in smaller packages with higher volumetric & gravimetric densities

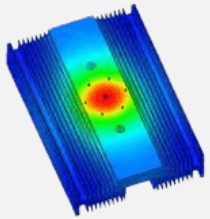
Integration

- Combined DCDC converters & inverters to minimize packaging space, reduce weight and achieve higher volumetric efficiencies

Passive Improvements

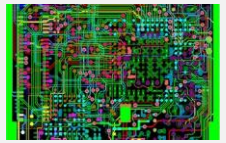
Performance

Thermal Improvements



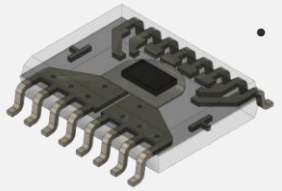
- Improvements in thermal management as WBG semiconductors operate at higher temperatures

PCB Designs



- Improved PCBs designed to tolerate higher switching frequencies and higher currents by hybrid use of ceramic materials

Sensors & Device Management

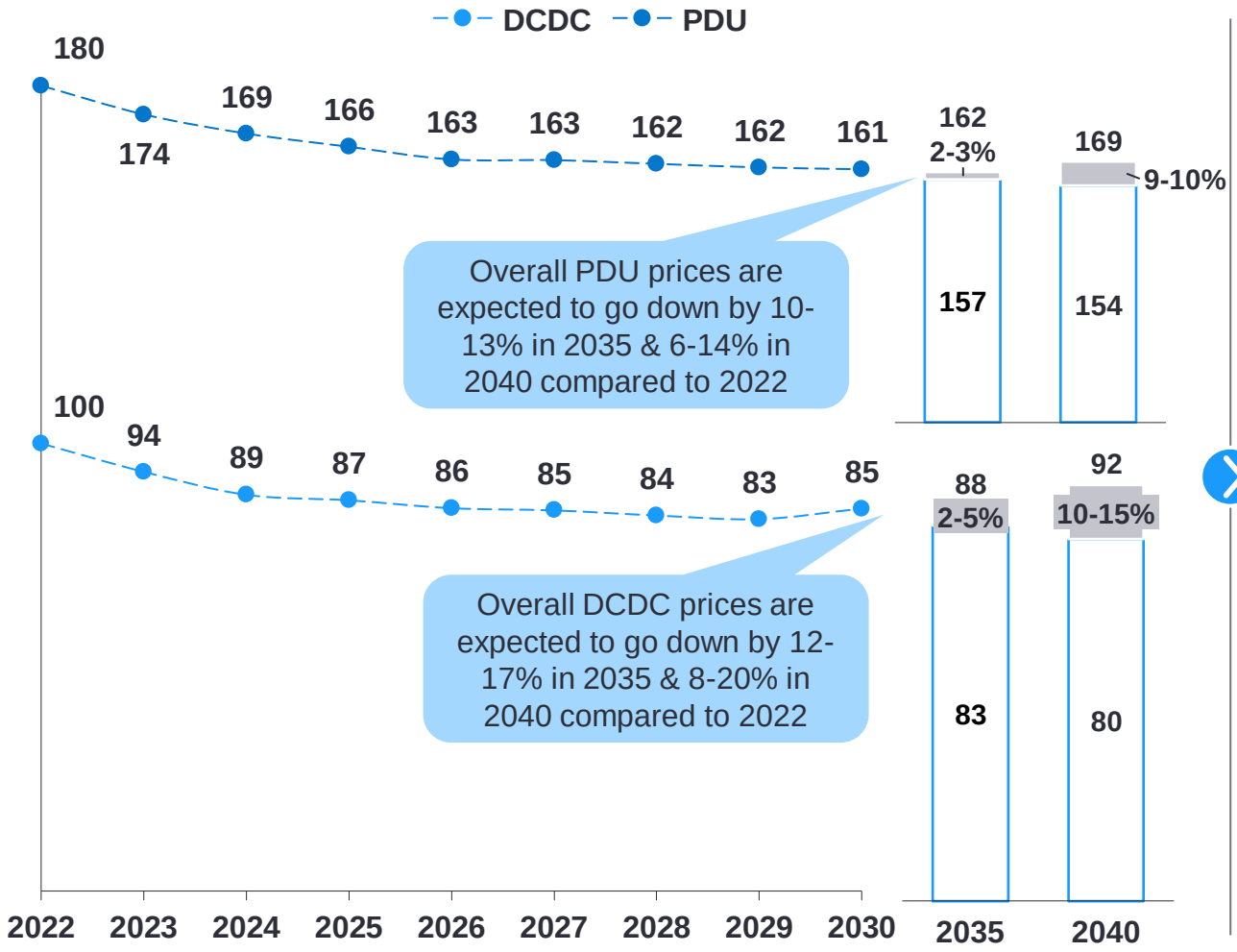


- Higher temperature tolerant sensors, designed to work with connected vehicle platforms to deliver real time diagnostics in smaller packages

Source: Secondary research, Public Domain, EYP analysis

PE costs comprising of a DCDC converter and PDU are expected to fall by ~15%, driven by increase in volume of e-CVs and decrease in hardware costs

PE Cost Projection for India (2022-2040) (in '000 ₹)



- The power electronics costs comprise of a DCDC converter and a Power Distribution Unit (PDU)
- Primary impact of use materials such as SiC, GaN, and other WBG[1] semiconductors will be observed in DCDC converters and inverters
- Cost reductions are primarily driven by reduction in YoY hardware costs and amortization of development costs over higher volumes
- For a **DCDC converter**, costs may rise in 2035 and 2040, **driven primarily by ~20% increase in hardware costs** depending on adoption of WBG materials by OEMs for CVs in India
- **Key Assumptions**
  - Indian OEMs are expected **to start adopting SiC technologies by 2030** for HV systems, once the technology has reached maturity in global markets
  - **Impact of PLI scheme on electronic components observed will be minimum for DCDC converter** used in high voltage systems
  - This is **due to the lower volumes of HV systems** that will be sold & therefore semiconductor components for these systems will continue to be imported
  - Junction box, currently priced at INR 70,000 is not considered a part of forecasting exercise as costs are expected to remain largely constant against increase in inflation

Click to go to Electric Bus Cost Forecast slide

Click to go to Electric Truck Cost Forecast slide

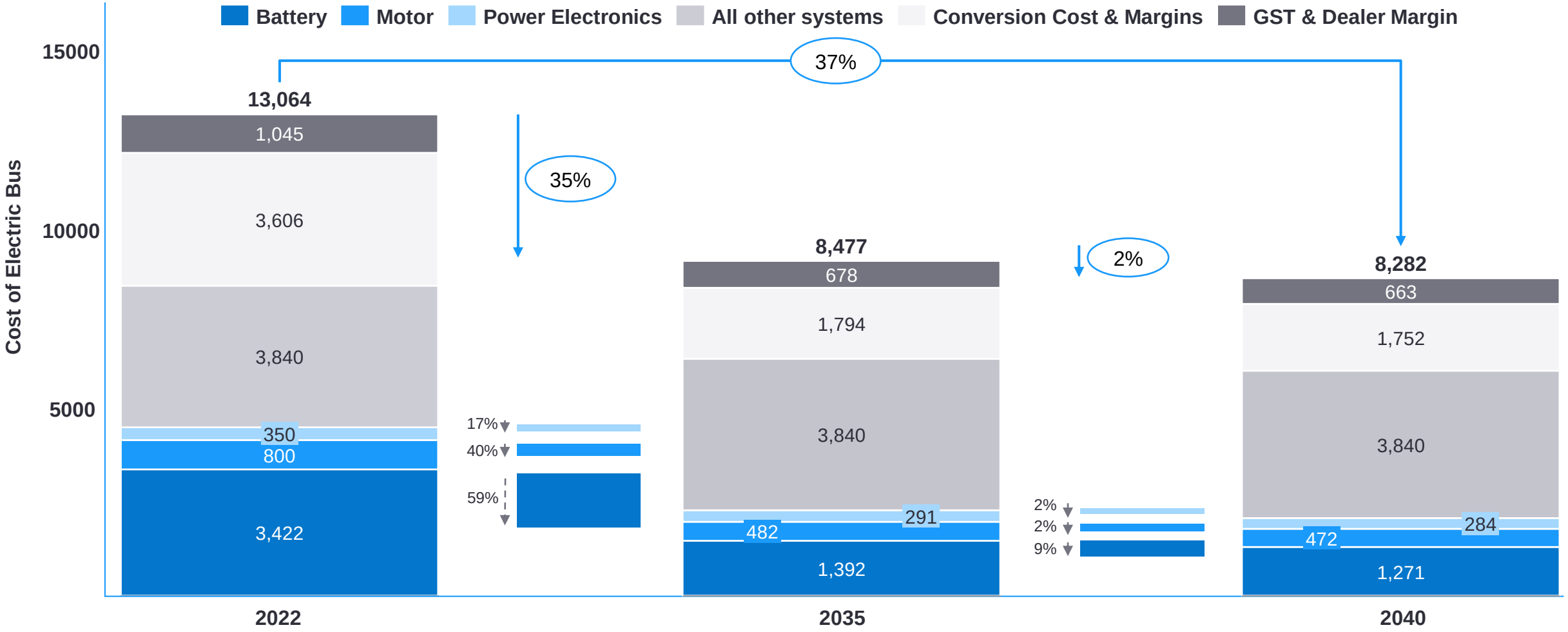
1. WBG: Wide Band Gap

Source: Secondary Sources, EY-Parthenon analysis

Electric Bus Cost likely to decrease by ~37% by 2040 as compared to 2022; Battery Pack, Motor and Power Electronics to the key areas of cost reduction

Electric Bus Cost (000'INR, 2022-2040)

12M Bus



Click to go to Battery Cost Forecast Slide

Click to go to Motor Cost Forecast Slide

Click to go to Power Electronics Cost Forecast Slide

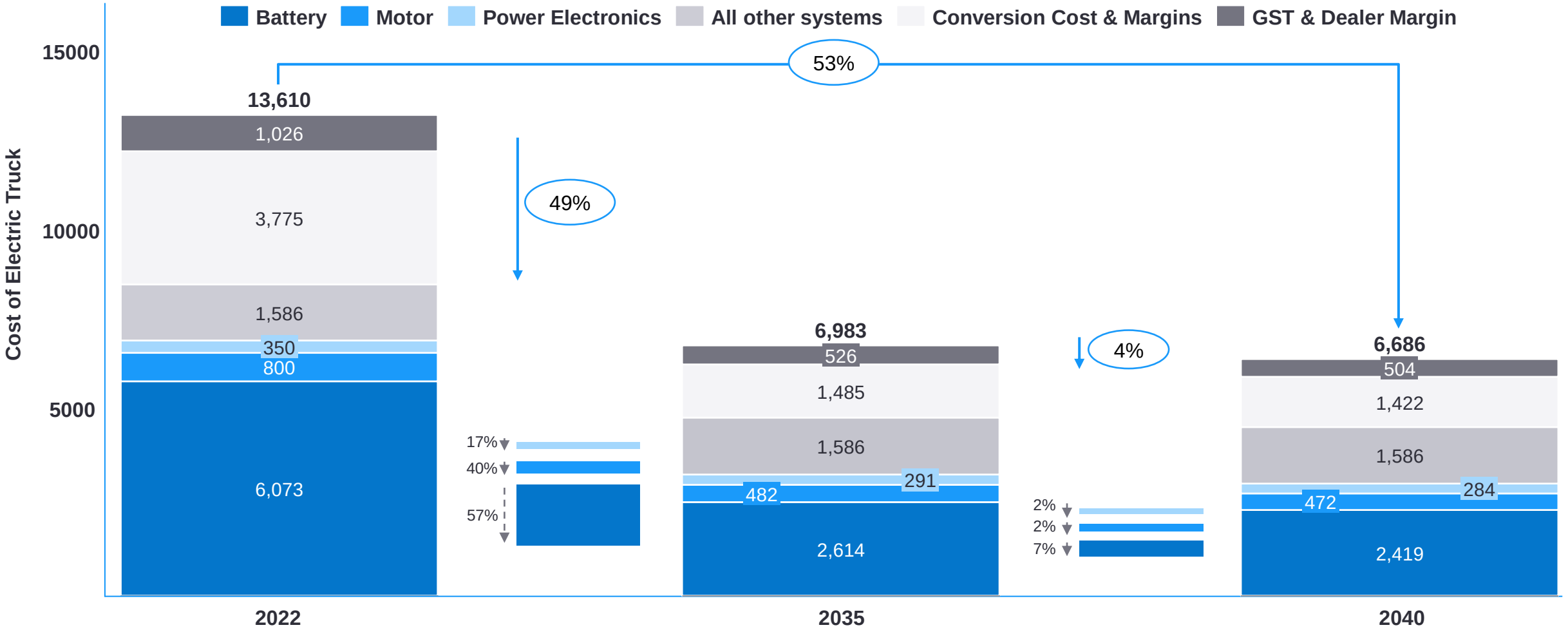
Source: EY-Parthenon analysis

EY Parthenon

Electric Truck Cost likely to decrease by ~53% by 2040 as compared to 2022; Battery Pack, Motor and Power Electronics to be the key areas of cost reduction

Electric Truck Cost (000'INR, 2022-2040)

16T GVW



Click to go to Battery Cost Forecast Slide

Click to go to Motor Cost Forecast Slide

Click to go to Power Electronics Cost Forecast Slide

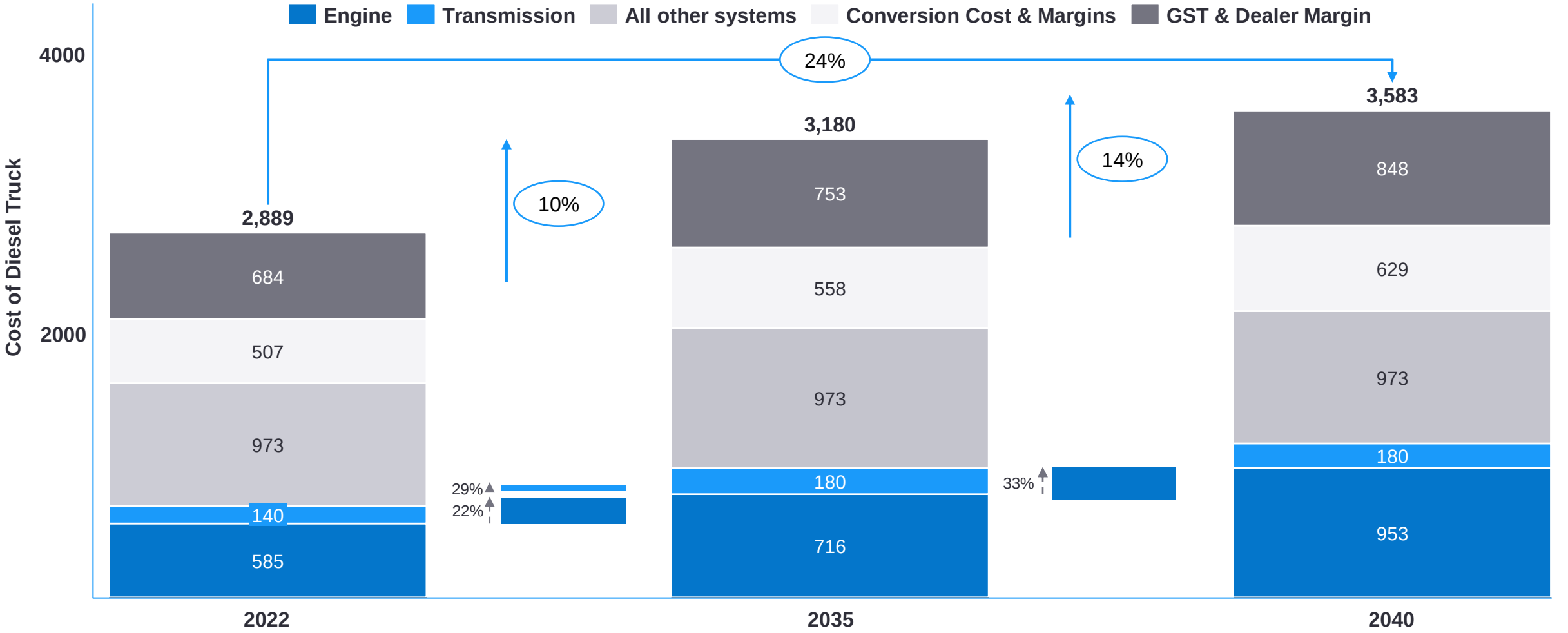
Source: EY-Parthenon analysis

EY Parthenon

Diesel Truck Cost likely to increase by ~24% in 2040 as compared to 2022; Engine and transmission upgrades, to meet stricter emissions norms, are the primary cost drivers

Diesel Truck Cost (000'INR, 2022-2040)

16T GVW



Click for detailed view of derivation of costs

Source: EY-Parthenon analysis

EY Parthenon

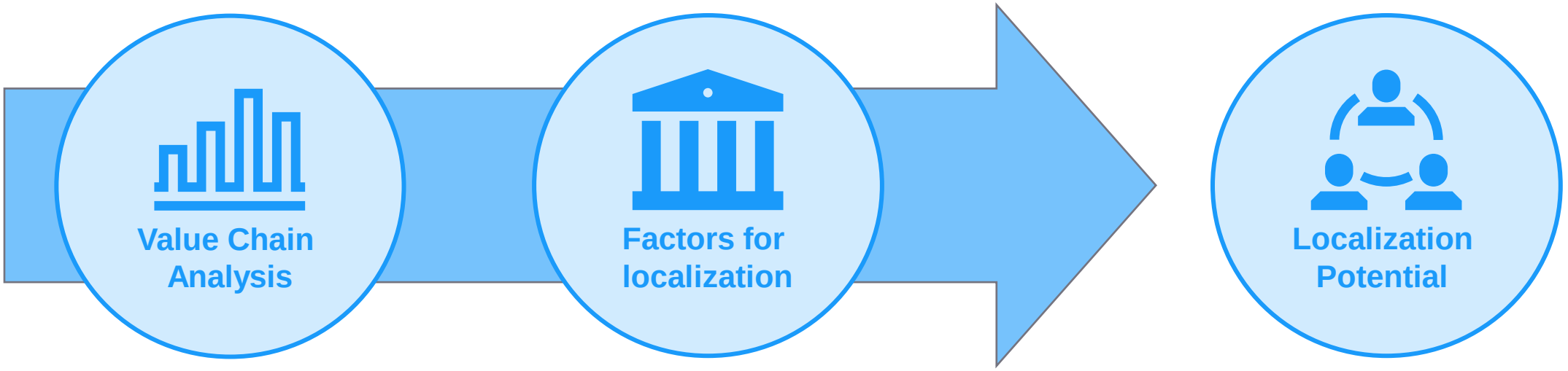
Table of Contents

- Project Summary
- WP 1: Baseline Cost & Weight estimation
- WP 2: Cost projections for Key ZET components
- **WP 3: Evaluation of existing supply chain & localization potential**
- Appendix

EY Parthenon

EYP has laid out the value chain of the Battery, Motor & PE to indicate current status of localization & then use external factors to determine the localization potential

Methodology



Analyze the value chain of Battery, Motor & PE to understand current localization status, cost contribution of each step, key players etc.

Volumes, Technology, Raw material availability and Govt. Policy that will impact the localization

Localization potential for components / sub-components of battery, motor & PE

Source: EY-Parthenon analysis

EY Parthenon

Indian local battery manufacturing value chain is very new and key areas such as materials extraction, cell manufacturing, R&D are still under development

Battery manufacturing value chain - India

	Material Sourcing	Cell Component Manufacturing	Cell Manufacturing	Battery Pack Assembly	Battery Reuse	After life/ Recycling
Description	*Raw material obtained from mining*	*Manufacture of anode, cathode, electrode, separator, casing, etc.*	*Manufacture of cells from materials*	*Cell to battery pack assembly along with BMS[1]*	*Automotive EoL[2] batteries repurposed for second-life usage*	*Recycling of Li-ion batteries to obtain key battery minerals for reuse*
Value Map	*~42% of total pack cost is contributed by raw material sourcing and manufacturing of battery materials*		*~22% of total pack cost is attributed to cell manufacturing*	*~36% of total pack cost is attributed to battery pack assembly and BMS[1]*	-	
Key Players	KABIL, TIANQI LITHIUM, GLENCORE	Epsilon carbon, Himadri	EXIDE, Leclanché Energy Storage Solutions, TDSG, TELEMAX	nexcharge, Exide Leclanche Energy Private Limited, cygni, TATA AUTOCOMP SYSTEMS, octillion Power Systems	LOHUM, nunam	ATTERO, GRAVITA INDIA LIMITED
Key Insights	▸ Currently, India has to import all the raw materials for cell manufacturing ▸ India will likely continue to import >50% of the raw materials (primarily China) in the next 4-5 years ▸ Government has been scouting lithium deposits in India and South America to ensure consistent supply of critical raw material for batteries		▸ Currently, cells are imported in India due to import dependence on raw material & lack of tech know-how ▸ TDSG, Exide have started small scale production	▸ Market is fragmented with numerous players incl legacy players and startups ▸ Players have developed capabilities in battery pack assy. using imported cells	▸ Currently the market is not developed in India and many automotive 1st gen EoL[2] Li-ion batteries expected to enter the market post 2030 ▸ The market is largely organized with few big players having pan India presence; players managing e-waste business have plans to enter the Li-battery recylcing business	
Current Scenario	**Yet to be started**	**Started** *Synthetic graphite anode by Epsilon*	**Started** *Small scale production by some companies*	**Started** *Market is fragmented with many players mushrooming*	**Started** *Market not developed & 1st gen automotive Li-batteries yet to enter market*	

1. BMS: Battery Management Systems
2. EoL: End of life

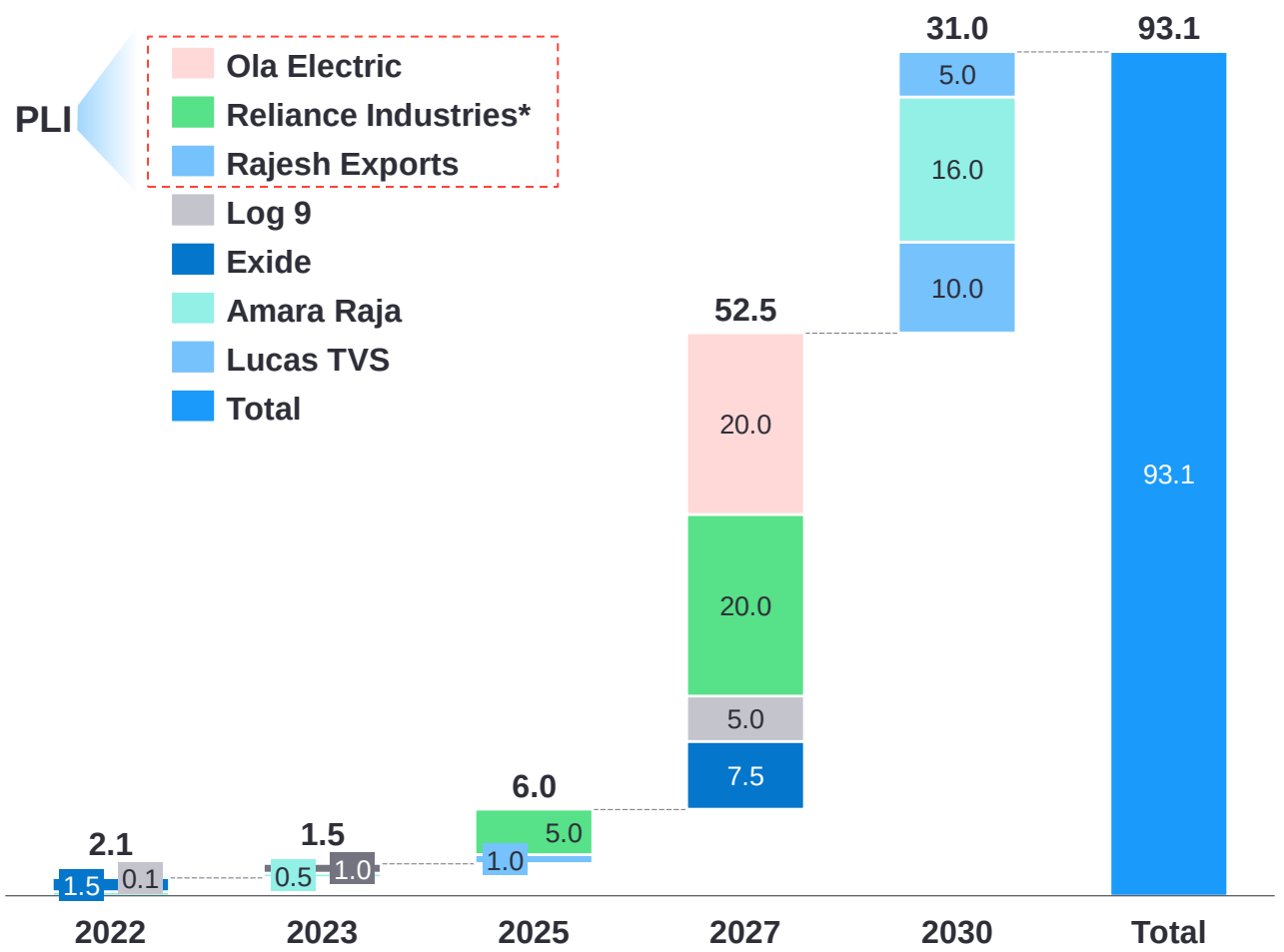
Source: Secondary Sources, Company websites, EY-Parthenon analysis

EY Parthenon

Given the challenges in China's supply chain, battery manufacturers are setting up local supply chains; India to have a total cell manufacturing capacity of ~93 GWh by 2030

Battery Capacity Expansion Plans - India

Capacity plans[1] – India (GWh)



ACC PLI[2] Scheme

- The Government approved the Production Linked Incentive (PLI) Scheme 'National Programme on Advanced Chemistry Cell (ACC) Battery Storage' for achieving manufacturing capacity of Fifty Giga Watt Hour (GWh) of ACC for enhancing India's Manufacturing Capabilities with a budgetary outlay of ₹ 18,100 crore
- A total of 4 companies are selected for the incentive under PLI which includes Reliance New Energy Solar Limited; Ola Electric Mobility Private Limited; Hyundai Global Motors Company Limited and Rajesh Exports Limited
- Most of the companies are investing heavily in LFP and NMC based battery chemistries, with some investing in LTO and Na-ion chemistries

Cumulative Capacity awarded under PLI Scheme

Company	Capacity Awarded (GWh)
OLA	20
Reliance Industries Limited	20 (5 awarded, 15 waitlisted)
RAJESH EXPORTS	5

1. Non-exhaustive list
2. PLI – Production Linked Incentive

* Reliance investing majorly in Sodium-Ion Batteries with the acquisition of Faradion

Source: Secondary reports, Public domain, EY-Parthenon analysis

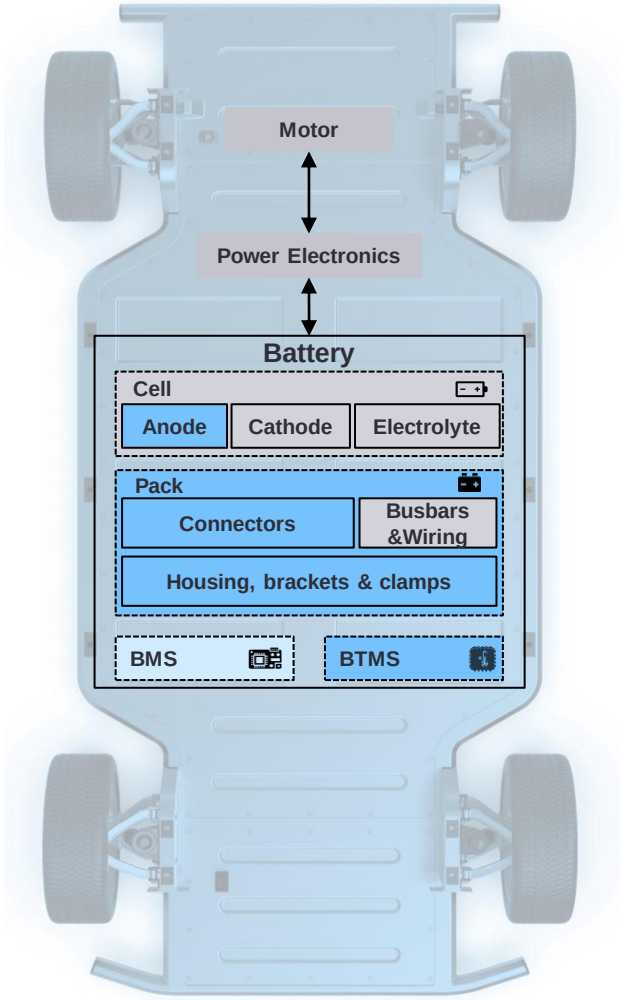
Click to go back to Battery Pack Cost Forecasting slide

Click to go back to Li-ion battery demand slide

EY Parthenon

Currently, cells for batteries are imported, with packs being assembled locally; Efforts are being made to locally manufacture cells with results expected to mature after 2027

Battery – Localization Potential in India



Import Dependent → Localization Potential

Localization of Battery Pack Manufacturing

- **Anode, cathode and electrolyte** development is heavily dependent on raw materials. India to continue importing raw materials globally with an aim to localize the manufacturing of anode and cathode materials
  - Players like Himadri, Epsilon and HEG have started investments in the anode space
  - Cathode and electrolyte development initiatives are lacking, and India is likely to continue importing these materials in the long term
- **Cells** for the battery pack are majorly being imported, however, local manufacturing plans have been announced and is likely to be localised under the ACC PLI scheme. India to have a ~93 GWh cell manufacturing capacity by 2030 with major investments coming in from OLA, Reliance and Exide Industries
- **Battery pack assembly** has started in India and has been localized to some extent with new players mushrooming in this space. While cell making is heavy on investment & technology, battery pack manufacturing is relatively lighter on both these parameters, thereby lowering the entry barrier and attracting non-traditional battery manufacturers & start-ups.
  - Emerging companies like Octillion, Tata Autocomp, Exicom, Lohum, are building up capacities by importing cells globally and assembling them with the integrated BMS and BTMS in India
  - **BMS** has a high potential for localization. BMS is currently fragmented with a few large and emerging players and competition from Chinese imports. Semiconductor components will continue to be imported in the long term
  - **Battery thermal management system (BTMS)** is another sub-system which has a high potential for localization. Currently, the heat exchanger, pipes, valves and compressor are components that are being locally manufactured with e-pumps being imported

Source: Secondary Sources, Public Domain, EY-Parthenon analysis

Relative Localization Scale: High, Medium, Low

EY Parthenon

For the electric motors, component casing & system integration is done locally while the inverter & control systems manufacturing is yet to be started

Motor Value Chain - India

	Material Sourcing	Component Manufacturing	Inverter Manufacturing*	Controls Manufacturing*	System Integration
	Raw material to be used for sub-systems	***Manufacturing of casing, rotor & stator***	***Manufacturing of power electonics***	***Manufacturing of control systems, circuit boards***	***Assembly of Motor, drive & controls***
Value Map	*RM is ~62% of delivered cost (NdFeB is 70% of RM, Copper 17% & Steel 13%)*	*Assembly & Integration accounts for ~38% the delivered cost (including the margin)*			
Key Players	aramco, thyssenkrupp, ArcelorMittal, ZHAOBAO Permanent Magnet Solutions, ALCOA, TENGYE Magnetic Technologies	TLC Thomson Lamination Company Inc., Magnetic Metals, Prestolite electric, Windtech Inc. Motor Windings and Assembly, Lamination Specialties powered by UPG	Continental The Future in Motion, DELPHI, BOSCH, Nidec All for dreams, SEVCON Electrification Partner, DANA, TM4, SIEMENS	STERLING GTAKE E-MOBILITY, NXP, embitel A CARIAD GROUP COMPANY, Infineon, NexusPCB TECHNOLOGIES	Ford, gm, VOLVO, BOSCH, Nidec All for dreams, SIEMENS, Prestolite electric, STERLING GTAKE E-MOBILITY, DANA, TM4
Key Insights	Key raw material like permanent magnets, copper wire for windings etc. is imported currently	Casing is currently done locally in India, but rotor & stator are imported	Drives (inverter) is currently imported with some of the software done locally	Circuit boards, sensors, diodes, relays used are currently imported	Some OEMs / Tier 1 suppliers are assembling these motors in India while it largely remains an import
Current Scenario	**Started** *Al & copper for windings are available locally*	**Started** *Casing production by some companies*	**Yet to be started**	**Yet to be started**	**Started** *Local assembly of motor*

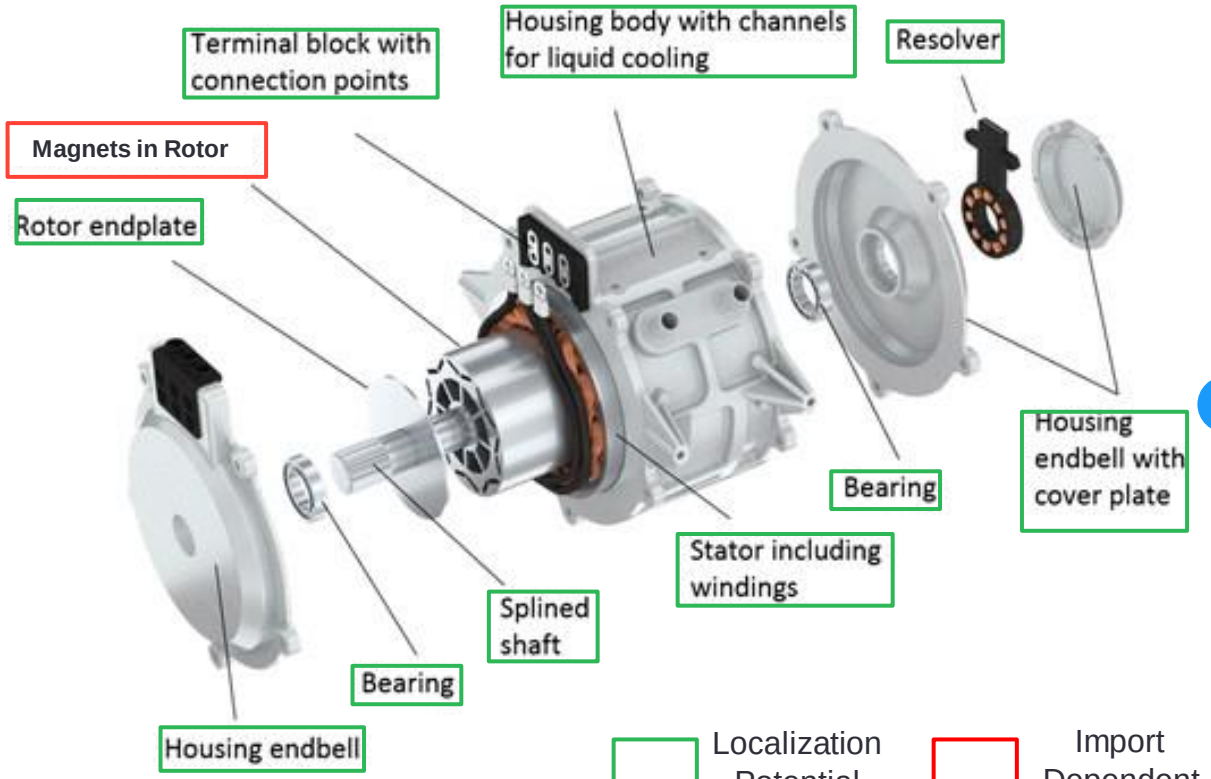
Source: Secondary reports, Public domain, EY-Parthenon analysis, *Detailed Value Chain covered in Power Electronics slide

EY Parthenon

Raw Material Availability and Design & development capabilities will influence the localization of rotors, stators, brackets / end plates etc. in India in the next 2-3 years

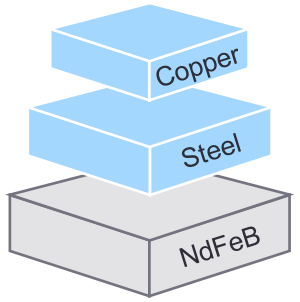
Motor* – Localization Potential in India

Components in a motor for Localization



Localization of Motors will be influenced by volume, capital requirements, raw material availability, design & development capabilities

Raw Material Availability



Motor RM Composition

- India will continue to import the magnets due to lack of raw material & higher price of extraction & refining of the materials
- Locally manufactured Copper & Steel could be used in motors
- India leads the consumption of copper & uses both domestic production & imports to meet the demand

Design & Development Capabilities

- India has potential to localize all other sub-components as Tier-I & II suppliers have following capabilities:
  - Die Casting
  - Lamination
  - Stacking
  - Winding
  - Rotor Balancing
- Assembly & Testing capabilities already exist within the Tier-I suppliers
- These capabilities have relatively low capital requirements

*Inverter Localization potential is covered in Power Electronics
Source: Secondary Sources, EY-Parthenon analysis

With the introduction of the PLI scheme, local players are investing in to capabilities across the Power Electronics value chain to locally manufacture modules

Power Electronics Value Chain - India

	Material Sourcing	Wafer Manufacturing	Sub Component Manufacturing	Component Manufacturing	PE Device
	Raw material to be used for manufacturing wafers	***Design & Fabrication of semiconductor wafers***	***Assembly, Testing & Packaging (ATP)***	***Assembled sub components***	***Assembled PE Devices***
Value Map	*~37% of total cost of PE devices comes from semiconductor components included in the device. This includes designing, fabricating and assembling the wafers in to sub components for use in PCBs*			*~28% of final PE device* cost from passive & electrical components; ~65% of the total cost at this stage*	*~35% of the final cost of PE devices from final integration and assembly*
Key Players	LG Chem, KYOCERA, SHOWA DENKO, INDIUM CORPORATION	vedanta transforming for good, tsmc, RIR, SAMSUNG, FOXCONN	VISICON POWER, TEXAS INSTRUMENTS, CDIL, Infineon	NVIDIA, intel, Qualcomm, SAMSUNG	VISICON POWER, EATON, BorgWarner, BOSCH, TATA, TATA AUTOCOMP SYSTEMS LIMITED
Key Insights	• Suppliers of metals (copper, nickel, aluminum, etc.), silica and other raw materials • Currently no major Indian player is involved in supplying semiconductor raw materials	• Also known as fabs, used for manufacturing integrated circuits (ICs) • Local fabs are being locally set up and expected to be online by end of the decade	• Layered chips, assembled into packages that can be mounted on circuit boards (IGBTS, diodes, transistors) • Currently manufactured in India but not automotive grade quality yet	• Assembled electronic circuit boards containing passive, electronic & semiconductor components • Currently players in India are limited due to stiff global competition	• Assembled and integrated power modules such as DCDC converters, PDUs, traction and aux. inverters • As demand for EVs grows, local players are emerging
Current Scenario	**Yet to be started**	**Yet to be started** *Initial investments, local partnerships formed to set up manufacturing in India*	**Started** *,Indian govt. wants to increase local manufacturing of EV power electronics*	**Started** *Majority of assembled circuit boards are still imported due to advanced design and testing capabilities required*	**Started** *Local assembly of power devices has begun as EVs become more popular*

* Applicable to PE devices that rely heavily on usage of semiconductor components (Inverters, Power Converters, Control Units)

Source: Secondary reports, Public domain, EY-Parthenon analysis

EY Parthenon

With strong support from PLI, Vedanta and Tamil Nadu Guidance Bureau have made announcements that relate to cumulative production capacity of ~80k wafers/ month

PLI scheme for semiconductor manufacturing

Semiconductor PLI Scheme (2021)

- In 2021, Indian Givernment announced a Production Linked Incentive (PLI) of $10 billon (INR 76k Crore) to encourage semiconductor & display manufacturing in India
- Incentives for semiconductor fabs/ project cost are based on the size of nodes:

Size of Node (nm)	Fiscal Support/Incentive
45-65	30% of project cost
28-45	40% of project cost
<28	50% of project cost

Tweakings to the PLI Scheme

- The scheme allows a uniform fiscal support of **50% of the project cost** for semiconductor fabs across technology nodes and display manuacturing
- The modified scheme also emphasizes on the production of 45 nm chips which are fairly less time consuming and economical in terms of production
  - These chips have a high demand, with demand primarily driven by sectors such as power, automotive & telecom
- Despite push from local and central governments, local manufacturing of HV semiconductor components, such as those required for e-CVs, is unlikely to begin soon due to significanly lower demands and higher investments needed

Recent Announcements in Semiconductor landscape in India

vedanta transforming for good  FOXCONN

- Vedanta & Taiwanese chipmaker Foxconn have signed a Memorandum of Understanding (MoU) to set up a ₹1,54,000 crore semiconductor plant in Gujarat
  - The project is likely to get subsidies & incentives like zero stamp duty on land purchase & subsidized water & electricity under the 'Gujarat Semiconductor Policy 2022-27'

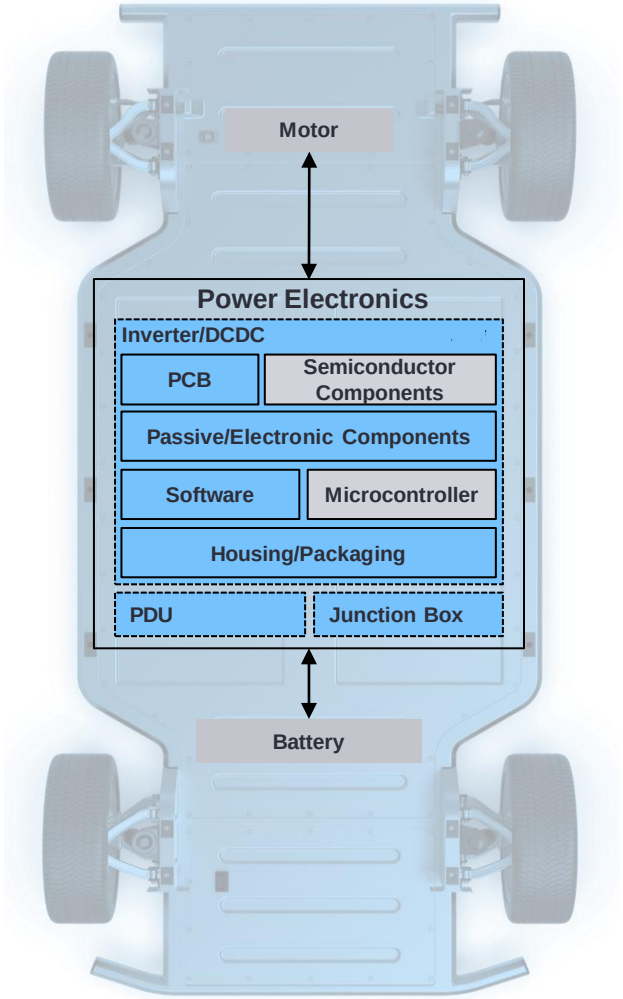
IGSS VENTURES  **Tamil Nadu Guidance Bureau**

- In July 2022, An MoU has been signed between IGSS Ventures & Tamil Nadu Guidance Bureau for setting up a semiconductor plant in Tamil Nadu with a capacity to develop 40,000 wafers per month – roughlly 2,000 to 2,200 chips per wafer

PLI – Production Linked Incentive
Source: Secondary research, EY-Parthenon Analysis

Majority of PE components have high potential for localisation, however, despite introduction of favourable policy, semiconductor components will not be fully localised

Power Electronics – Localization Potential in India



Import Dependent Localization Potential

Localized vs. imported components	Current localisation	Potential for localisation
• **Semiconductor Components/Microcontroller:** Majority of automotive grade semiconductor components and microcontrollers for CVs are expected to be imported	Low	Low
• **Passive/Electronic Components:** Passive components (capacitors, inductors, etc) & electronic components (fuse, wiring, connectors, etc) are currently manufactured locally and are expected to have high potential for localisation for use in high voltage systems	Medium	High
• **Software:** With a large talent pool available locally, software development for power electronics has high potential for localisation	Medium	High
• **PDU/Junction Box:** Largely comprised of passive/electronic components, potential for localisation for this component is high	Medium	High
• **PCB:** With WBG materials increasing market penetration, PCB capable of withstanding higher temperatures would be required, and have a high potential for localisation	Low	High

Low Medium High

Source: Secondary Sources, EY-Parthenon analysis

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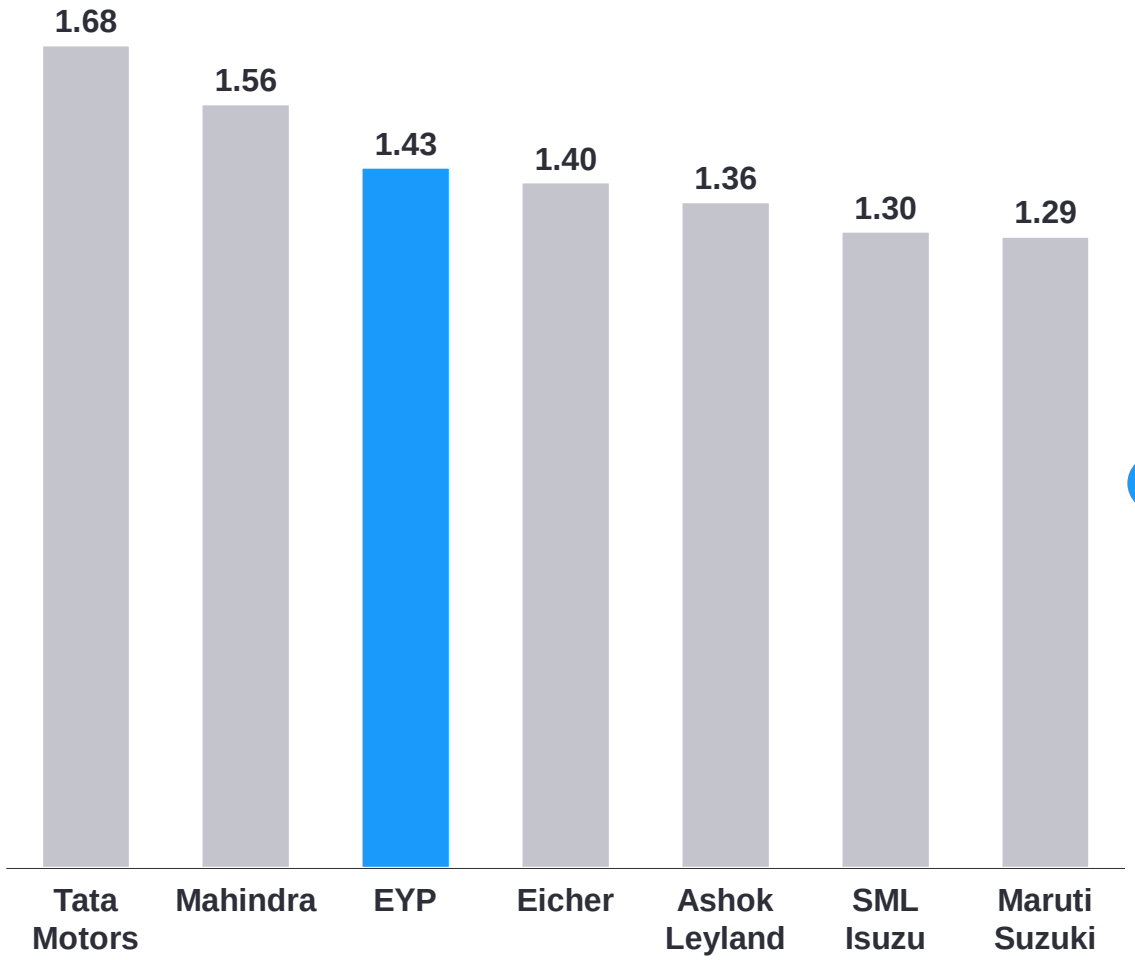
- Project Summary
- WP 1: Baseline Cost & Weight estimation
- WP 2: Cost projections for Key ZET components
- WP 3: Evaluation of existing supply chain & localization potential
- **Appendix**

Ratio of the total costs to the direct costs across the industry ranges from ~1.3 to ~1.68 – sub-optimal for comparison across the OEMs

Cost Ratio Comparison



Methodology

Cost Ratio Calculation = **Total Costs (Direct + Indirect)** ÷ **Direct Costs**

- Direct costs include the Cost of goods sold
- Indirect costs include the SG&A, R&D Expense, D&A and other operating expenses incurred

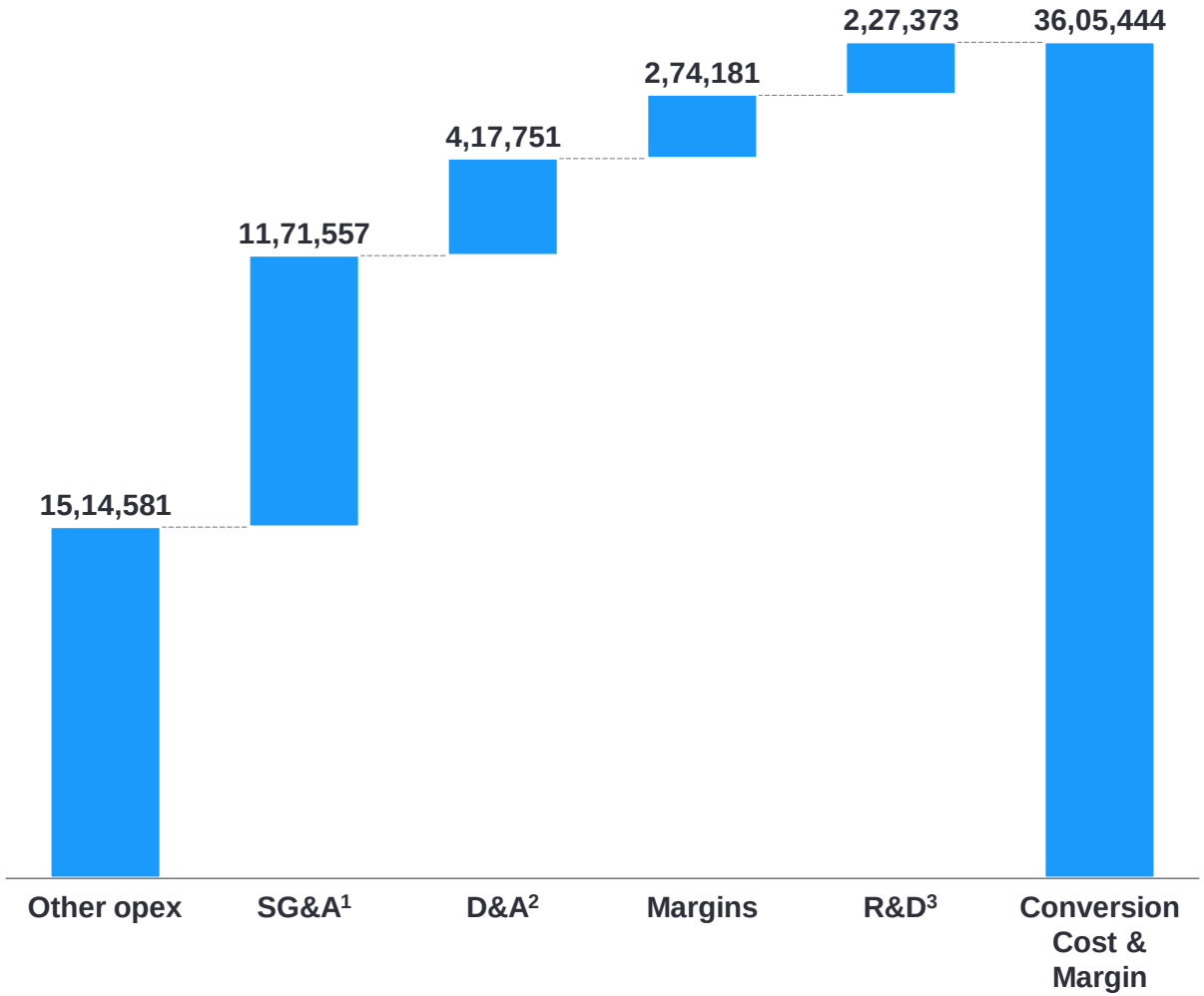
- Maruti Suzuki is the leader in PV space with ~50% share & volumes of ~1.5 Million, hence the indirect costs get amortized over the higher volumes resulting in a lower ratio (1.29)
- In case of Mahindra, the company has a diversified portfolio ranging from two wheelers to heavy duty trucks & off-highway equipment which skews the overall ratio (1.56)
- GST is not a part of the direct / indirect costs

SG&A: Selling, General and Administrative Expense, D&A: Depreciation and Amortization, R&D: Research and Development Expense
Source: Secondary Sources, EY-Parthenon analysis

The operating expenses and other expenses contribute to ~42% of the Conversion and Margins cost; SG&A and D&A contribute to ~44% of the cost

Electric Bus – Conversion and Margins Cost in (₹)

12M Bus



- **Operating Expenses** include the money that a company spends on the day-to-day basis. It includes-
  - Equipment maintenance costs
  - Service and product warranty costs
  - Rent and Insurance costs, etc.
- **SG&A costs** generally include the following
  - Marketing costs
  - Human resource costs
- **D&A** costs include the periodized cost of using long term assets over the specified time period
- **R&D** costs include
  - These are direct expenditures relating to a company's efforts to develop, design, and enhance its products, services, technologies, or processes
  - Additional R&D expenses are also attributed to development of dedicated EV platforms for future products

1: Selling, General and Administrative Expense

2: Depreciation and Amortization

3: Research and Development Expense

Source: EY-Parthenon analysis, Supplier Quotations, Expert Interviews

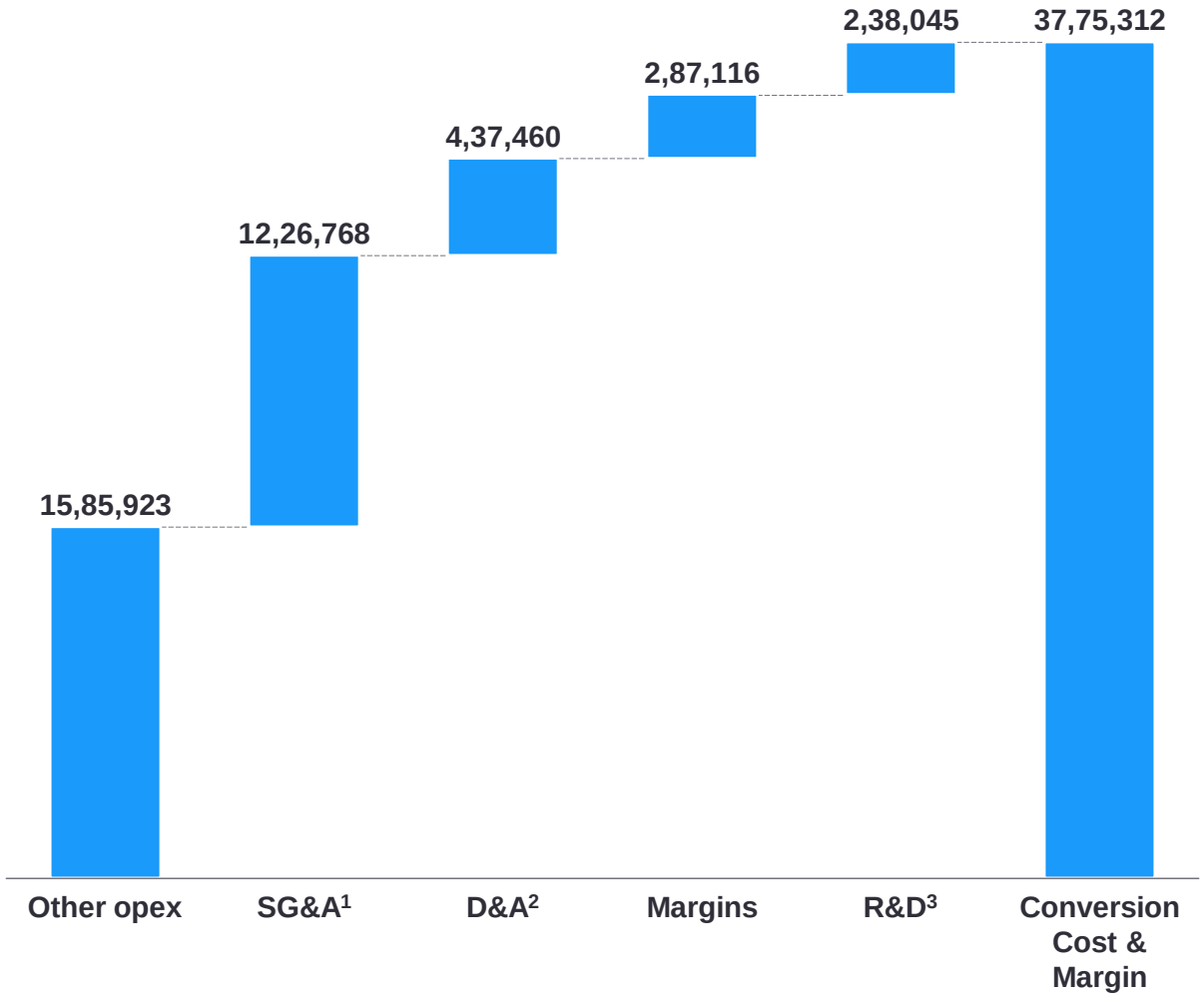
Click to go back to BOM cost buildup

EY Parthenon

The operating expenses and other expenses contribute to ~42% of the Conversion and Margins cost; SG&A and D&A contribute to ~44% of the cost

Electric Truck – Conversion and Margins Cost in (₹)

16T GVW



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1: Selling, General and Administrative Expense

2: Depreciation and Amortization

3: Research and Development Expense

Source: EY-Parthenon analysis, Supplier Quotations, Expert Interviews

Click to go back to BOM cost buildup

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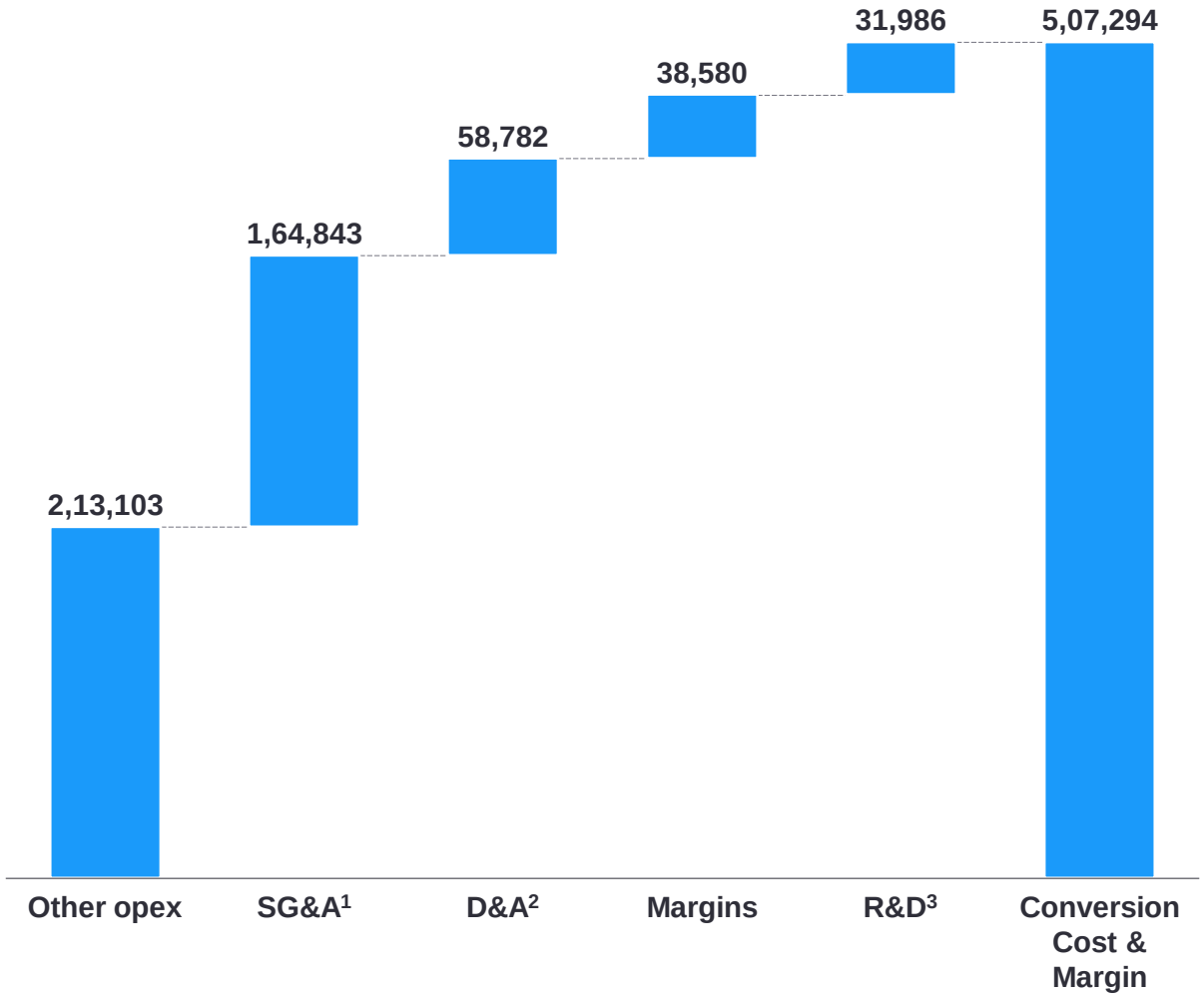
The operating expenses and other expenses contribute to ~42% of the Conversion and Margins cost; SG&A and D&A contribute to ~44% of the cost

Diesel Truck – Conversion and Margins Cost in (₹)

16T GVW



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1: Selling, General and Administrative Expense

2: Depreciation and Amortization

3: Research and Development Expense

Source: EY-Parthenon analysis, Supplier Quotations, Expert Interviews

Click to go back to BOM cost buildup

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Differences in scaling factors for similar systems across trucks and buses stem primarily from differences in requirements, regulations and engineering specifications

Comparison of Scaling factors for various systems

System	Electric Bus Scaling Parameter	Electric Truck Scaling Parameter	Comments
Body Structure	INR 178.1/kg	INR 133.3/kg	▸ Materials used in bus bodies such as steel, aluminium, and composites can are more expensive than those used in truck bodies resulting in a higher cost per kg for bus body structures
Braking System	INR 100/mm	INR 73.2/mm	▸ The brakes considered for the bus are disc brakes whereas the brakes considered for the truck are s-cam drum brakes, resulting in a higher cost/mm for the braking system in buses
Front Axle	INR 5,844.2/ton	INR 5,833.3/ton	▸ Due to usage of air suspension in the bus, the material cost of the front axle is higher than the one in the truck since axles supporting air suspension need to house additional components contain additional complexity, resulting in higher cost/GVW supported for axles in the bus
Rear Axle	INR 5,882.4/ton	INR 5,000/ton	
Front Suspension	INR 11,039/ton	INR 3,333.3/ton	▸ The suspension system considered for buses are air suspensions, whereas the ones considered for trucks are variations of leaf spring suspensions, resulting in a higher cost/ton supported for bus suspensions
Rear Suspension	INR 16,666.7/ton	INR 2,500/ton	
Front Tires + Wheels	INR 1,000/inch	INR 857.1/inch	▸ Tires for buses are engineered to higher specification as they have are required to meet more stringent safety & performance requirements while also providing a smoother ride, leading to a higher cost/inch for bus tires and wheels
Rear Tires + Wheels			
LV Wiring Harness	INR 1,250/kg	INR 1,000/kg	▸ Due to a higher number of terminal connections and electrical loads in the bus, the HV wiring harness for an electric bus has more variety in connectors and is engineered to higher tolerances, resulting in a marginally higher cost per kg for a bus

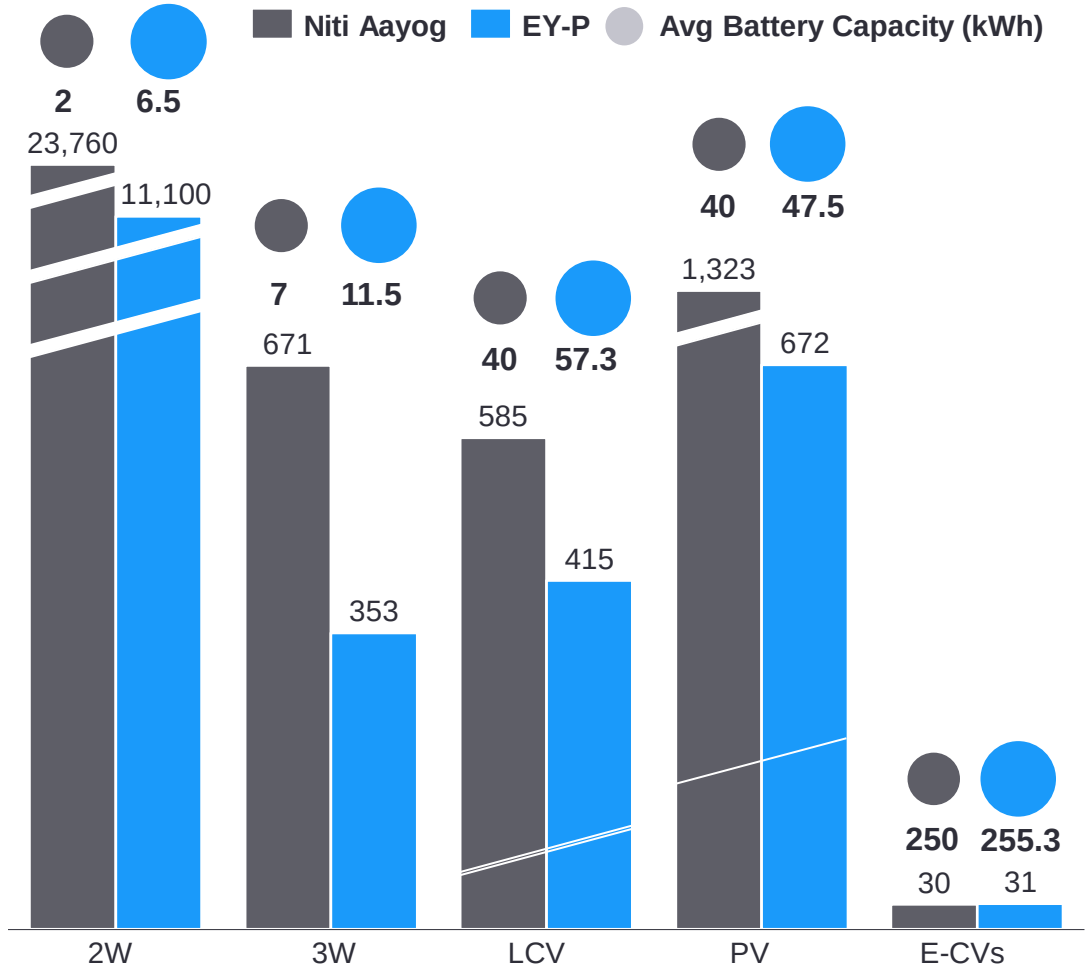
Click to go back to Electric Bus Scaling Factor slide

Source: EY-Parthenon analysis, Supplier Quotations, Expert Interviews

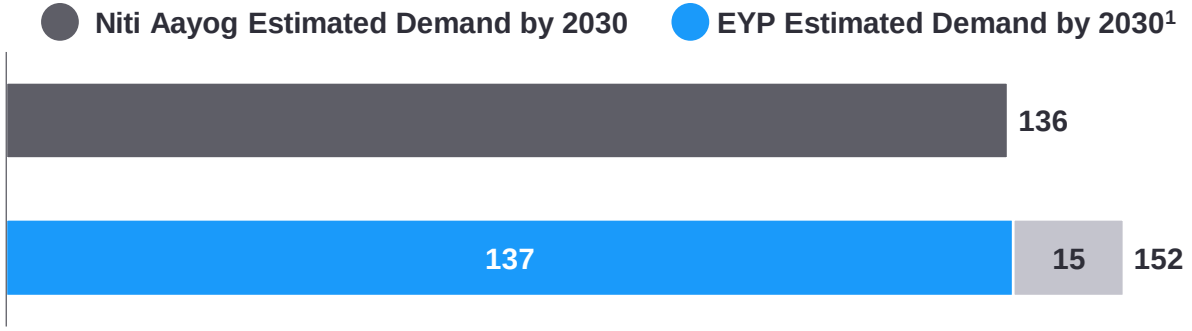
EYP has taken lower volumes & larger average battery capacities, relative to Niti Aayog, resulting in identical demands and no impact on the forecasted battery pack costs

Niti Aayog Scenario Comparison

India Segment-Wise Volume & Avg Capacity Breakdown ('000's 2030)



India Segment-Wise Demand Breakdown (GWh, 2030)



- When forecasting battery capacity demand for 2030, both EY-P and Niti Aayog considered segment-wise volumes and average battery capacity (kWh)
- EY-P has considered higher average capacities, based on an understanding that LFP's will be the dominant battery chemistry in India, and will therefore have lower power densities
- Niti Aayog has assumed higher segment-wise volumes based on their optimistic scenario, whereas EY-P has considered lower volumes based on internal analysis
- As a result, EY-P and Niti Aayog have arrived at approximately the same figure for demand at ~136 GWh in 2030
- Due to this, relative to the global demand and local supply considerations used in the forecasting of battery costs, the cell costs forecasted over the period 2022-2040 would remain same in both the Niti Aayog and EY-P scenario

EYP demand comprises only of batteries considered for usage in EVs and not ESS, Others
1: EYP demand comprises of 137 GWh as base case, with 15GWh as total if battery replacement occurs after every 8 years
Source: EY-Parthenon analysis, Advanced Chemistry Cell Battery Reuse and Recycling Market in India - Niti Aayog

Click to go back to battery demand in India

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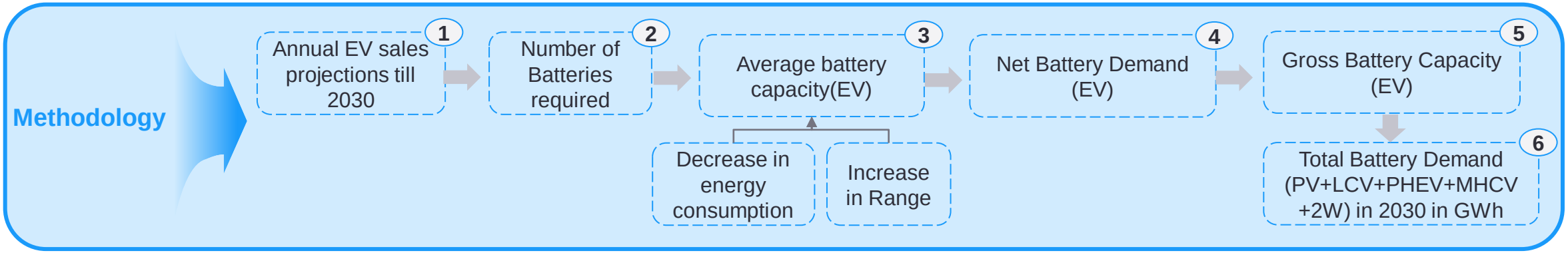
Methodology and Assumptions for Battery Demand estimation

Methodology and Assumptions for Battery Demand Estimation

- **Battery demand in India**
  - Lithium-Ion battery demand in India has been calculated based on the below mentioned methodology and it only includes EV based battery demand and excludes the battery demand based out of ESS and others
- **Vehicle Category-wise assumptions**
  - e-2W's will likely have a mixture of motorcycles and scooters with motorcycles growing their market share at a faster pace till 2030 as compared to scooters
  - e-4W's will likely grow at a CAGR of ~57% owing to population growth and incentives for consumers
  - e-MHCV will likely have a lower growth rate but owing to the higher battery capacity associated with these, they will add considerably to the battery demand
- **Government incentives** as in FAME-2,etc. will continue to have an impact on increasing the EV penetration rates in India along with the high GDP growth rate and population growth which will likely again aid the growth rate of EV's in India
- Total no. of batteries in the market will increase considerably after 2028 owing to the **End-of-Life** batteries coming into the market from the first gen. of EV's sold
- **Average Battery Capacity** for every segment is likely to increase because more EV's will try to reach the ranges offered by ICE vehicles. The increase in range in kms and decrease in energy consumption for EV's will result in a net increase in battery capacity and it will be the same story for every vehicle category
- In India, **battery chemistry** will continue to dominated by LFP as compared to NMC owing to its low cost and thermal stability. e-2W, e-3W and the e-4W market is likely to be dominated by LFP with NMC taking major share in e-MHCV and high performing applications



Source: EY-Parthenon analysis

Click to go back to battery demand in India

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For consideration of diesel truck cost forecasts, EY-P analyzed upgrades in line with requirements of stricter fuel emission norms

Cost Estimation of FE Improvement Technologies for Diesel Engine

	2022	2030	2035	Increase from 2022	2040	Increase from 2035	Total Increase
Engine Costs (Baseline = BSVI)	**5,85,000**	**6,63,000**	**7,32,300**	1,47,300	**9,54,405**	2,22,105	**3,69,405**
Level 1 upgrades		+13.33%					78,000
Level 2 upgrades			+10.5%				69,300
Euro 7					+30%		2,22,105
Transmission Upgrades (Baseline = 6+1 Speed Manual)	**1,40,000**	**1,40,000**	**1,80,000**	40,000	**1,80,000**	0	**40,000**
6 speed AMT			40000.00				

Level 1 Engine Upgrades	
OBD Updates	78,000

Level 2 Engine Upgrades	
VGT[1]	15,000
Start/Stop	10,800
Light weighting*	27,000

Euro 7 Upgrades	
Cylinder deactivation	10,000
48V Mild Hybrid System**	132105
Turbo Compounding	94,831

After treatment technologies not considered as a part of this study as discussions with OEMs indicate more emphasis on data recording technologies anticipated rather than upgrades to existing after-treatment technologies

1. Variable Geometry Turbo

* Light weighting takes into consideration lighter prop shaft, aluminum alloy engine block, cast pistons

** Mild-hybrid system considered with 15kW motor, 2kWh battery, software and power electronics

Source: Secondary Sources, EY-Parthenon analysis

Click to go back to Diesel Truck cost forecast slide

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