AUTOMOTIVE PROJECT

CRYSTAL BATCH

E-DRIVE

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Vehicle Concept & Requirements

Use Case Definition:

- **Vehicle Type**: Luxury family sedan
- **Primary Purpose**: Daily commuting with a blend of performance and fuel efficiency
- **Drive Experience**: Punchy acceleration, smooth EV drive, and refined ICE cruising
- **Passenger Capacity**: 4 adults + luggage (LWB sedan class)

Performance Targets

Power Source	Output	Drive Type	Acceleration (0–100 km/h)
Electric Motor Only	250 hp	FWD	~6.2 seconds
ICE Only (B48 Engine)	255 hp	RWD	~6.5 seconds
Combined (Hybrid Boost)	~500 hp	AWD (assumed)	~4.5 seconds

Acceleration estimates based on ~1900 kg curb weight, torque delivery curves, and drivetrain layout.

Range & Efficiency

- **EV-Only Range**: 250–263 km (WLTP estimate)
- **ICE Range**: ~450 km (based on B48 fuel efficiency and tank size)
- **Hybrid Efficiency Goal**: Maximize EV usage in urban zones; ICE for highway cruising

Design Philosophy

- **Luxury & Comfort**: Spacious cabin, premium materials, quiet ride
- **Performance**: Dual powertrain for instant torque and sustained power
- **Practicality**: EV-first architecture with ICE backup for long-distance flexibility
- **Sustainability**: LFP battery, regenerative braking, and efficient HVAC integration

Powertrain & Drivetrain Layout

ICE Engine

- **Engine Specification :** BMW's B48 inline 4-cylinder turbocharged engine.
- **Cubic centimeters :** 1998cc (2.0L)
- Inline 4, DHOC (Dual Overhead Camshaft), 16-valve
- Compression Ratio ~ 11:1
- Power : 255HP @5000-6500rpm
- Direct Injection ~ 350 bar rail pressure
- **Turbo :** Single, Twin-scroll turbo (fast spool & good low end torque)
- **Torque :** 250 – 450Nm @1550-4400rpm
- **Redline :** 6500rpm
- **Powers rear wheels**

Electric Motor (Nidec Ni200Ex)

- Motor: IPMSM (IPM) with CRM rotor cooling, liquid-cooled stator & rotor — *target peak 186 kW / 250 hp, peak torque ≈400 Nm*.
- Electrical (400 V pack): peak DC current ≈489 A (calc: 186,000 W ÷ (400 V × 0.95) = 489.47 A → spec to 520–600 A for margin).
- Phase currents: ≈283 A RMS per phase typical at peak. Inverter: ≥600 A peak, ≥320–350 A continuous, SiC, liquid-cooled.
- Wheel torque (9:1 reduction): ≈3,600 Nm; example tractive force ≈ 10.7 kN (wheel radius 0.336 m) → notable launch capability.
- Thermal: peak motor+inverter heat ≈ 9.8 kW — design coolant loop to remove 10–20 kW bursts; integrate with pack thermal system.
- Regen: pack accepts 3.2C peak (464 A) — BMS will mediate charge current; motor/inverter must support equivalent regen current & braking torque.

Battery -

- 58 kWh gross LFP pouch battery; **≈52 kWh usable** (400 V nominal, 145 Ah).
  or
- 65kWh gross LFP pouch battery; **≈58 kWh usable** (400 V nominal, 145 Ah).
- Designed to accept **3.2C peak regen (≈464 A)**; sustain **1.5–2.0C**.
- Pack mass estimate: **~320–390 kg** (depending on cell energy density).
- Architecture: **modular backbone** under rear seats; liquid cold-plate cooling; distributed CMU + Master BMS.
- Charging:
  AC Level-2 11 kW OBC (≈5.5–6 h);
  DC fast 150 kW CCS2 (0→80% ≈ 16–25 min).

- Safety: UN38.3, IEC62619, ISO26262 & ISO6469 compliance roadmap.
- Nominal voltage: **~400 V** | Pack Ah: **≈145 Ah**
- DC fast current @150 kW: **~375 A** | Pack peak regen current: **~464 A**
- Peak battery heat to manage (regen): **~10–15 kW** → coolant flow **~16–30 L/min**
- Inverter: **SiC (**, rating ≥**600 A peak / 320–350 A continuous**
- **CONSIDERATION OF BRAND FOR BATTERY**
  ~ High ambient temperatures (up to ~50-55 °C), dust, moisture → pack should have excellent sealing (IP67 or similar), good thermal insulation, effective cooling channels.
  ~ Thermal runaway risk, so pouch cell swelling must be managed; monitor cell temp in hot zones.
  ~ Cold mornings at some locations → pack preconditioning / good performance at ~5-10 °C. LFP cold performance is weaker; brands with good cold soak design are better.
  -> **Exide Energy Solutions** — local LFP cell production
  -> **Tata AutoComp + Gotion** — pack + BMS

BMS (Battery Management System)

- **Recommended Platform:** Tata AutoComp-Gotion (India), LFP pouch pack + integrated BMS
- **Key BMS Capabilities Needed:**
- Peak regen current support: **≈464 A** (3.2C), sustainable 1.5-2.0 C for discharge
- Series cell count ≈125-130 S, cell voltage cut-offs per LFP specs
- Per-module temperature sensors; module-level active/passive balancing
- Communication: CAN FD with overcurrent cutoff, SOC/SOH reporting, thermal derate
- Safety: Isolation monitoring, redundant contactors, compliance to IEC, ISO26262, UN38.3
- **Alternatives / Backup Suppliers:** Pricol + BMS PowerSafe platform (if needing different power level or backup in case Tata/Gotion lead time is long)
- **Why Tata/Gotion:** Localised manufacturing, existing LFP and pouch experience, modular pack/BMS already in passenger vehicle domain in India, better cost & service support

Parameter	**Value / Requirement**
Cell chemistry	LFP pouch
Cell counts	Series ≈125-130 S (to get ~400 V nominal) + parallel count such that pack Ah ≈145 Ah (or as per module cell Ah)
Peak charge (regen) current limit	≈464 A (3.2 C)
Sustained discharge current limit	≈218–290 A (1.5–2.0 C)

Parameter	Value / Requirement
Continous charge / discharge duty cycle	e.g. 30 minutes at sustained current, with thermal limits
Voltage limits per cell	Max/Min cell voltage cut-offs (e.g., ~3.60 V / ~2.50 V or as LFP spec)
Temperature monitoring	Per module & hot spot temp sensors (≥2 temp sensors per module)
Thermal derating	BMS must reduce regen/discharge when cell temp > threshold (≥45-50 °C) or cold < ~5-10 °C
Active/passive balancing	At least passive balancing; active balancing preferred for your size and regen stress
Communication interface	CAN FD, necessary messages (SOC, SOH, temperature, current, voltage) with latency <50 ms for critical limits
Safety & isolation	Isolation monitoring (to chassis), overcurrent and short-circuit protection, redundant contactors
Safety standards	UN38.3, IEC62619, ISO26262 compliance (or roadmap), local homologation rules

HVAC System:

Component	Spec / Value	Notes (packaging & India)
Electric compressor	400 V electric scroll, 5–7 kW cooling capacity	Subframe-mounted to save hood space (compact footprint)
Refrigerant	R1234yf	Low-GWP, OEM standard
Condenser / radiator	Combined multi-core stack with active grille shutters	Front nose — staged shutters to improve aero
HVAC box (evaporator)	Under-dash compact module with heater core + expansion valve	Standard placement — minimal hood intrusion
Battery chiller	Refrigerant-to-liquid plate heat exchanger, ~15–20 kW peak capacity	Mounted near battery entry manifold under rear seats
Battery coolant pump	Variable speed, 25–30 L/min peak	Pump mounted close to battery; ~200–400 W motor
Motor/Inverter cooler	Dedicated cold plate, separate pump	High-temp loop; keep separate for best control
PTC backup heater	2–3 kW	Small, for extreme cold or defrost
Fans	Front electric fans (2) with PWM control	Packaged with condenser/radiator stack
Valve pack	4-way valves + bypass valves	Located in engine bay subframe or under-tray valve module
Thermal ECU	Automotive ECU (CAN FD); redundant watchdog	Controls all loops; rated for ASIL B/C functions
Coolant	Propylene glycol based, corrosion inhibitor	Automotive OEM-spec

Component	Spec / Value	Notes (packaging & India)
Hoses & fittings	Quick-disconnect HV-rated, insulated	Routing to avoid HV harness interference

*Picture generated with the help of AI, with Customized specification

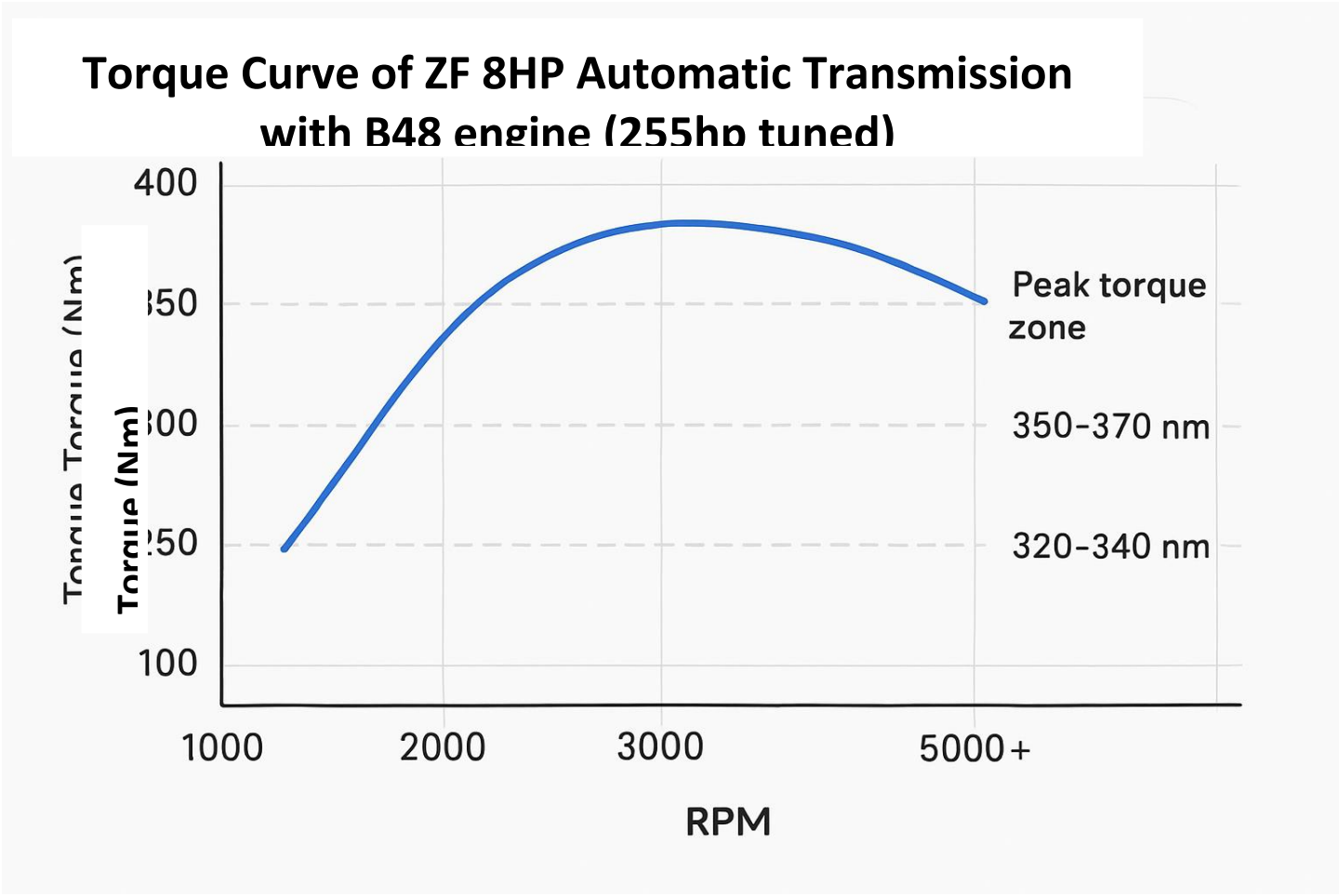
Transmission System (ZF 8HP Automatic)

- **Proven with B48**: OEM-proven combos with BMW engines and PHEV variants exist — engine maps, ECU logic and hybrid controls are established.
- **Torque capacity**: ZF 8HP variants handle high torque (~500–700 Nm depending on variant), matching B48 outputs and hybrid loads.
- **Torque converter**: Twin tortional dampers (gives smooth low-speed drivability) — important when the front motor and rear ICE swap driving roles.
- **Vane cell pump**: Creates more hydraulic pressure

- **Mechatronic units**: Combines sensors, actuators and transmission control module (TCM) to manage gear shifts precisely
- **Hydraulic Control:** Uses pressurized fluid to engage/ disengage clutches & change gears seamlessly.
- **Hybrid compatibility**: easier integration for PHEV control (torque fill, launch strategies), and good thermal robustness for sustained highway.
- **For improvements :** Multistage l;ockup, dual-mass flywheel, recalibrated shift maps for hybrid torque fill.

Driveshaft

- **Type**: two-piece with center support bearing (for LWB)
- **Material**: **Chromoly steel (SAE 4130 / 35CrMo)** or high-strength steel tube
- **Outer diameter:** ~ **45–60 mm OD**, wall thickness 3–6 mm depending on torque
- **Joints:** Tripod or Rzeppa CV joints at ends
- **Weight target: ~8–12 kg**
- **NVH (Noise, Vibration, Harshness)** Rubber center bearing (if 2-piece), thermally isolated from battery enclosure
- **Manufacturer:** Bharat Forge, JTEKT India, TVS-Srichakra(Bearing & joints)
- **E-axle**: Nidec, YASA



Suspension Setup

- **1) Front Setup:** Double-pivot MacPherson spring-strut + subframe-mounted e-axle cradle
- Front spring (static start) : ~45 N/mm per corner, Heavier front (motor+engine)
- Front damping (starting) : **c ≈ 2,600 N·s/m per corner** (adaptive valving)
- Subframe: **Aluminium or high-strength steel**
- **Anti-roll bars: 31–34 mm (hollow)**
- Torque-reaction arm: Steel torque arm + hard primary mount + hydraulic secondary mount
- NVH measures: Isolate e-motor via subframe mounts
- Usage of **equal or nearly equal half-shaft lengths**.
- Usage of **electronic traction & torque-vectoring** to limit front wheel torque on launch.

- 2) **Rear Setup: *5-link independent, driven axle* (multi-link driven setup) with reinforced subframe and anti-squat tuned geometry.**
- Rear spring (static start): ~33–36 N/mm per corner
- Rear damping (starting): Rear **~2,300 N·s/m** (adaptive valving)
- Anti-roll bars: Rear **24–26 mm (hollow)**

Differential

- **Electronic torque-vectoring differential**: An actively controlled differential that uses sensors, an ECU and clutch packs or electric actuators to vary torque left/right.
- **ADAS & hybrid integration**: Integrates with ESC/BMS/Powertrain ECU for coordinated torque blending (front motor + rear ICE).
- Design rating: **wheel torque capacity ≥ 4,500 – 6,000 Nm**
- Pros: highest performance, ADAS integration, tunable.
- Cons: cost & complexity; need full ECU integration and software tuning.
- Suppliers - **ZF** — torque-vectoring differentials / electronic differential modules
- **GKN Automotive** — eTwinster / eDifferential family

Tyres

- **Front: 245/35 R19 or 225/40 R19**
- **Rear: 275/35 R19 or 255/35 R19**
- **Michelin, Pirelli, and Continental**

Brake Setup

- **Front rotors: 360–374 mm ventilated, 2-piece (aluminum hat, iron ring)**
- Rear rotors: **345–350 mm** ventilated (2-piece optional)
- Front calipers: **4-piston fixed monoblock** (OEM M340i style)
- Rear calipers: **2-piston floating** (or 4-piston for sport trim)

- Brake pads: High-performance ceramic-organic compound (street/sport)
- Parking brake: **Electric parking brake (EPB)** (caliper integrated)
- Booster / Assist: E-booster (electro-hydraulic) + hydraulic backup
- Master cylinder: Dual-circuit tandem master, bore sized with e-booster
- Brake cooling: Ducts to front rotors + directional airflow channels
- ABS/ESC unit: Bosch 8.0 platform or similar (CAN FD capable)
- Brake lines: Stainless braided lines / OEM braided hose
- Brake fluid: DOT 4 / DOT 5.1 high-temp
- **Regen Blending:** The car first uses **regen** up to the battery's acceptance limit
- **E-booster helps** because the engine may be off (no vacuum) — pushing hydraulic pressure quickly when regen is not available.
- **FLOW:**
- Pedal Input: Driver presses brake → BCU reads pedal position.
- Light braking: Regen only (front motor) up to MaxChargeTorque allowed by BMS.
- Medium braking: Regen first, add hydraulic braking until requested decel is met.
- Hard braking: Regen mostly off → rely on full hydraulic braking for safety.
- ABS active: ABS takes priority → regen cut/reduced to avoid torque conflicts.
- Communication: BMS ↔ BCU via CAN (Max charge current, thermal & SOC limits).
- Suppliers - Brembo, AP Racing

Aerodynamics & Styling

- Basic Shape Design: The vehicle adopts a sporty-luxury sedan body style with a long wheelbase for family comfort and a low-slung roofline for aerodynamic efficiency. The proportions are inspired by the BMW 3 series (G20 series), but optimized to achieve a target drag coefficient of ~0.22–0.23.
- Aero Aids:
    - Front: Active grille shutters to reduce drag at cruising speeds.
    - Underbody: Smooth undertray panels to reduce turbulence.
    - Rear: Subtle integrated diffuser + lip spoiler to manage wake flow.
    - Wheels: Aero-optimized 19/20-inch wheel designs.

- Simulate Airflow Using CFD: In absence of in-house CFD tools, the aerodynamic concept is validated against published coefficients of comparable sedans (BMW 340i, Tesla Model 3, Mercedes C-Class EQ). Our design references these benchmarks to target a drag coefficient of ~0.22, which is realistic for a premium sedan with aero aids

Electronics & ADAS

ADAS LEVEL 3: Level-3 ADAS uses a fused sensor suite: 1× lidar, 6× radars, 5× cameras, 12× ultrasonics, and a Bosch SMI130 IMU centrally mounted. Cameras and lidar stream high-bandwidth data over Automotive Ethernet to the ADAS ECU; safety-critical control and vehicle state messages use CAN FD. This layout provides redundant, 360° perception and robust motion reference required for conditional automation and safe handovers.

Cameras - (5)

1. Front central (windshield, behind rearview mirror) — forward scene, lane markings, traffic sign recognition.
2. Left mirror — side traffic, lane-change assist, blind-spot.
3. Right mirror — side traffic, lane-change assist, blind-spot.
4. Rear (top of tailgate / rear windshield) — rear object detection, reversing, cross-traffic.
5. Front bumper / low wide-angle — close-range forward detection, small obstacle/pedestrian at near field and parking assist.

Reasons: A 5-camera layout gives robust forward vision + side coverage with redundancy for Level 3 perception and driver-monitoring tasks (driver camera could be added internally if needed).

Radars - (6)

- 1 × Long-range front radar (center front grille): high-speed object detection and adaptive cruise (detects vehicles at 150–250 m).
- 2 × Front-side medium-range radars (left/right in bumper corners): detection of approaching vehicles from oblique angles, lane change assistance.
- 2 × Rear-side medium-range radars (left/right rear bumper): blind-spot detection, cross-traffic alert.
- 1 × Rear long/med-range radar (center rear bumper): rear closure detection and assist for reversing at speed.
- Bosch – Long range radar (LRR) or (SRR) 77Ghz frequency, Supports adaptive cruise, up to 250m range, AEB & blind spot

Reasons: This mix ensures full 360° radar coverage with both long-range forward sensing for highway Level-3 maneuvers and medium-range side/rear sensing for blind-spot and cross-traffic — important when the system must make safe takeover or emergency maneuvers.

Ultrasonic sensors - (12)

- Placement: Evenly distributed around front and rear bumpers — typically 6 front + 6 rear
- Use: Low-speed parking, curb detection, close-range obstacle avoidance and low-speed maneuvering.
- Bosch – Range 0.2 – 5 meters, CAN & LIN bus compatibility.

Reasons: Ample short-range coverage for parking and urban low-speed safety redundancy (required for automatic parking and close-quarters ADAS behaviors).

Lidar - (1)

- Placement: Roof-center (low-profile housing) or high front grille if roof packaging not possible.
- Use: High-resolution 3D point-cloud for object classification, lane/edge detection and robust perception in mixed lighting where cameras struggle.
- Valeo SCALA LIDAR – Horizontal view 120-150 degrees, Vertical view 20-30 degrees, Range – up to 200 meters

Reasons: A single, centrally placed lidar provides dense forward 3D data needed to meet Level-3 object permanence and to act as a redundancy source alongside cameras and radars.

IMU — Bosch SMI130

- Placement: Rigidly mounted near vehicle center (floor tunnel or under center console) — low vibration location, near vehicle center of gravity.
- Use: The Bosch SMI130 (6-axis IMU) provides high-quality yaw, pitch, roll and linear acceleration data for sensor fusion, dead-reckoning when GNSS is degraded, and precise motion reference for the ADAS fusion stack. Mounting it close to vehicle center reduces lever-arm errors and improves fusion stability.

Networking & integration

- Automotive Ethernet (1 Gbit or higher): transports camera and lidar data to the ADAS domain controller (sensor fusion, perception & planning).
- CAN FD: used for deterministic, safety-critical messages to/from powertrain, brakes (ABS/ESC), BMS and body controllers (low-latency control and status).
- Fusion controller: central ADAS ECU performs real-time sensor fusion, trajectory planning, and issues actuation commands to steering, throttle/brake and to the vehicle safety stack.

ELECTRONICS:

1. Power Electronics (High Voltage)

- Inverter: Converts 400 V DC → AC for the e-motor, bi-directional (also handles regen).
- DC–DC Converter: Steps down 400 V → 12 V to keep the auxiliary battery charged.
- Onboard Charger (OBC): Manages 11 kW AC and up to 150 kW DC fast charging.
- Battery Management System (BMS): Monitors 60 kWh LFP pack, regen currents, balancing, safety.
- Thermal Control Electronics: Sensors + actuators for HVAC, battery cooling, motor cooling.

2. Vehicle Control Electronics

- Hybrid Control Unit (HCU): Supervises the B48 ICE + front e-motor blending.
- Engine ECU (DME in BMW terms): Manages turbo 2.0L B48 petrol engine.
- Transmission ECU (DCT/DSG): Coordinates with motor torque during shifts.
- VCU (Vehicle Control Unit): Top-level brain that ensures smooth torque delivery, regen blending, drive modes.

3. Body & Comfort Electronics

- BCM (Body Control Module): Windows, lights, locks, wipers, HVAC blower.
- Infotainment System: Display, navigation, connectivity.
- Cluster / HUD ECU: Driver info, hybrid power flow display.
- Seat & Climate Controllers: Memory seats, zonal HVAC control.
- ADAS-HMI Integration: Alerts, lane-keep feedback, emergency takeover requests

4. 12 V Network (Auxiliary)

- 12 V battery (AGM or $LiFePO_4$): Runs accessories & safety systems if HV is off.
- Fuse Boxes & Relays: Safety isolation, load distribution.

Sustainability & Innovation:

Recyclable Materials (Materials & Manufacturing)

1. Use high-strength steel + aluminum mix for monocoque (already 90–95% recyclable).
2. Trim & interior: bio-based polymers, soy foam, recycled PET (Polyethylene Terephthalate).
3. Battery pack casing: recycled aluminum.

Regenerative Systems:

1. Already using front e-motor regen (peak ~186 kW).
2. Adding smart regen blending modes: Eco (max regen), Comfort (balanced), Sport (reduced regen).

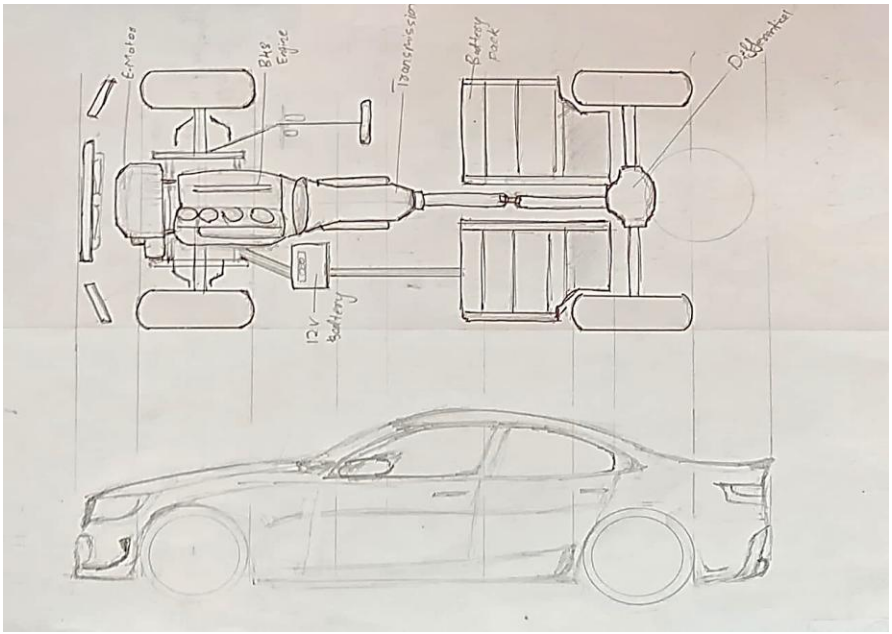
Vehicle-to-Grid (V2G):

1. The 60kWh pack could provide up to 10–15 kWh safely to grid/home.
2. Requires bi-directional CCS2 charger (Delta, Wallbox, or Tata Power prototypes).
3. Start with V2H (Vehicle-to-Home) → backup during outages, practical in Indian market.

Lifecycle CO_2 Footprint (End-of-Life):

1. Battery recycling: Attero (India) offers LFP recycling at 80–90% recovery.
2. Frame/metal recycling rate target: 95%.

Conceptual Drawing:



*The Drawing represents the aerodynamic factors, powertrain system and placement of all the parts for effective weight distribution.