Hybrid Vehicle
Opportunities, Challenges, & Viability

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Technical Presentation

AGENDA

GLOBAL MARKET OVERVIEW

TECHNOLOGICAL VIABILITY

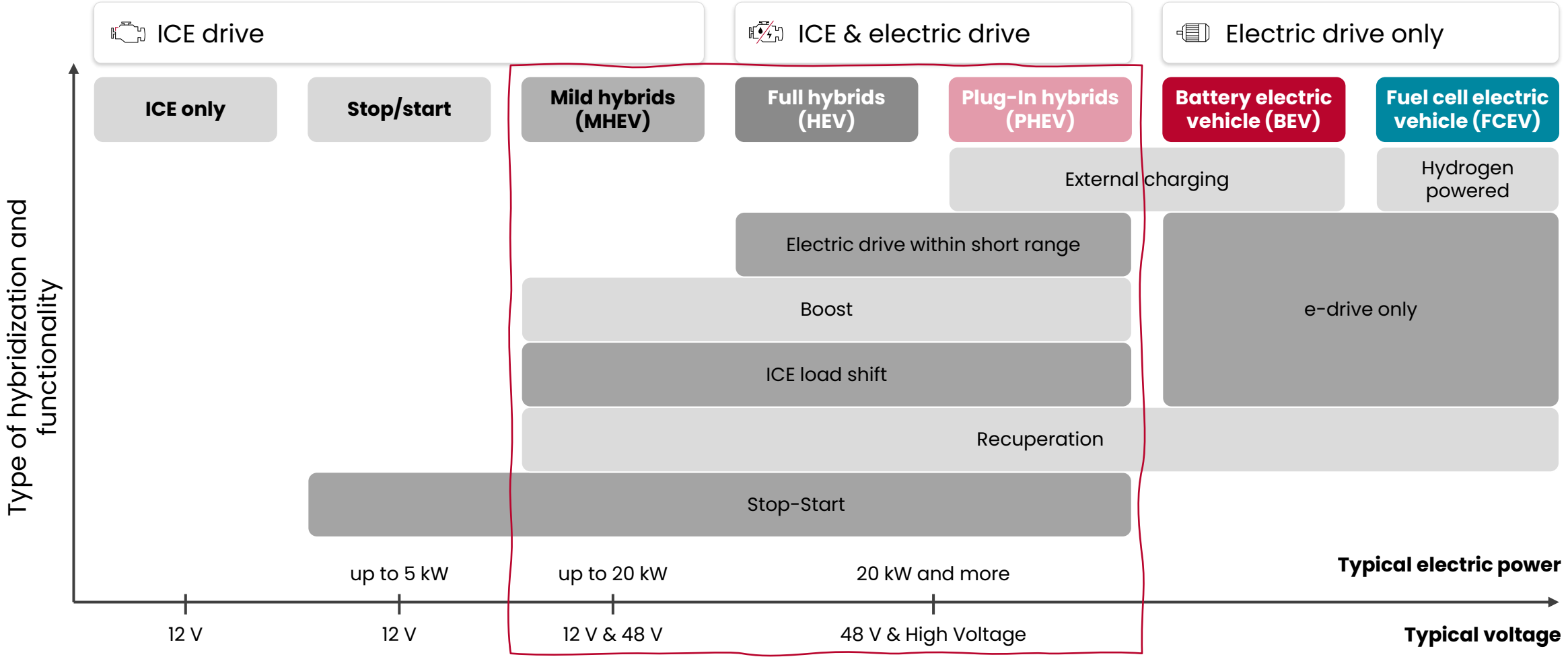
CONSUMER CENTRICITY & EMOTIONS ON HYBRID

SUSTAINABILITY & LIFECYCLE VIABILITY

AREAS TO BE ADDRESSED FOR A SUCCESSFUL TRANSITION

FEV defines the hybridization level according to the vehicle's functionality

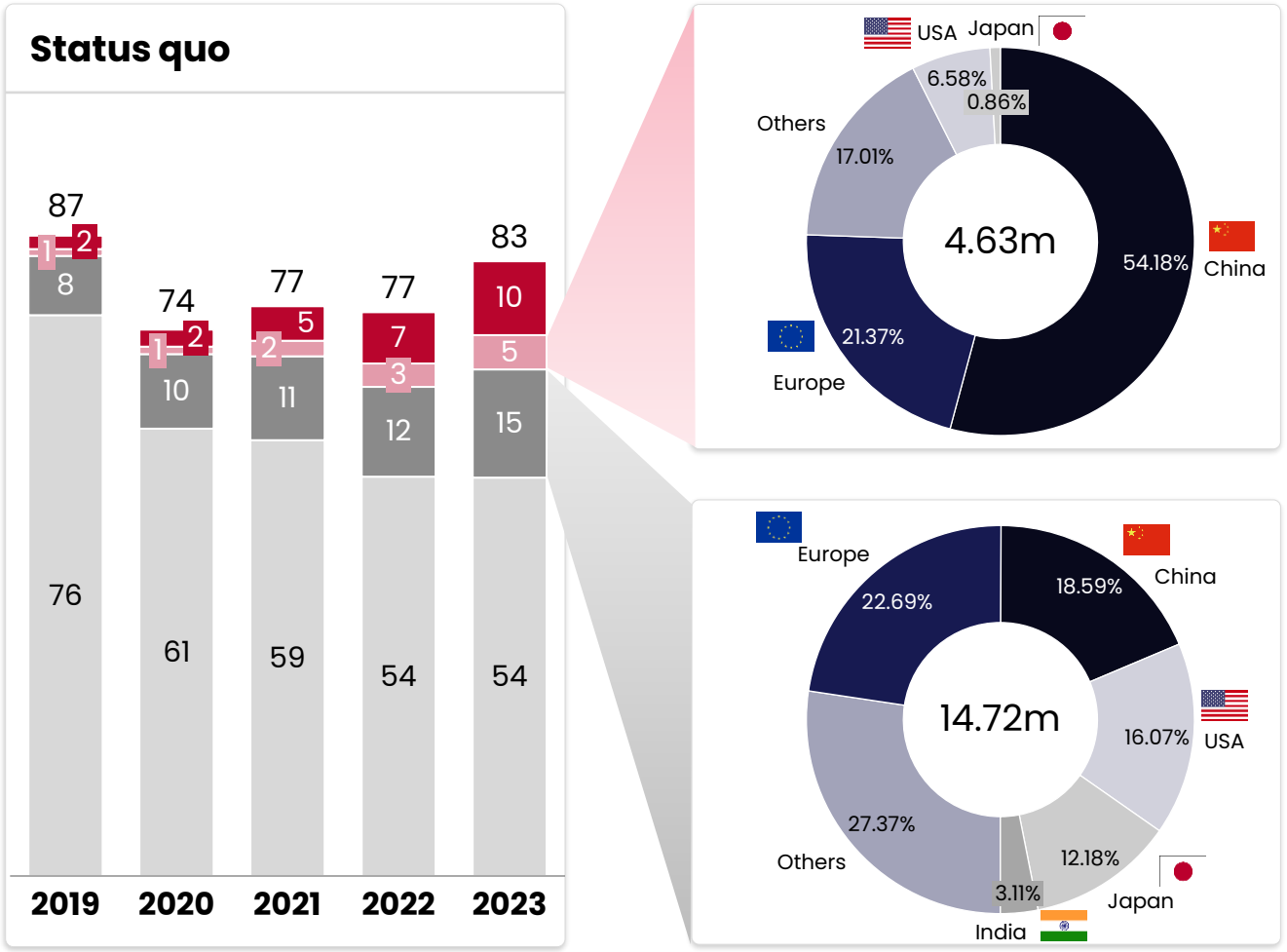
POWERTRAIN LANDSCAPE



Source: FEV

Sales of HEV & PHEV are picking up pace along with the sales of EV globally, China contributes ~54% sales of PHEV globally followed by Europe Union

GLOBAL SALES LANDSCAPE OF PASSENGER VEHICLE

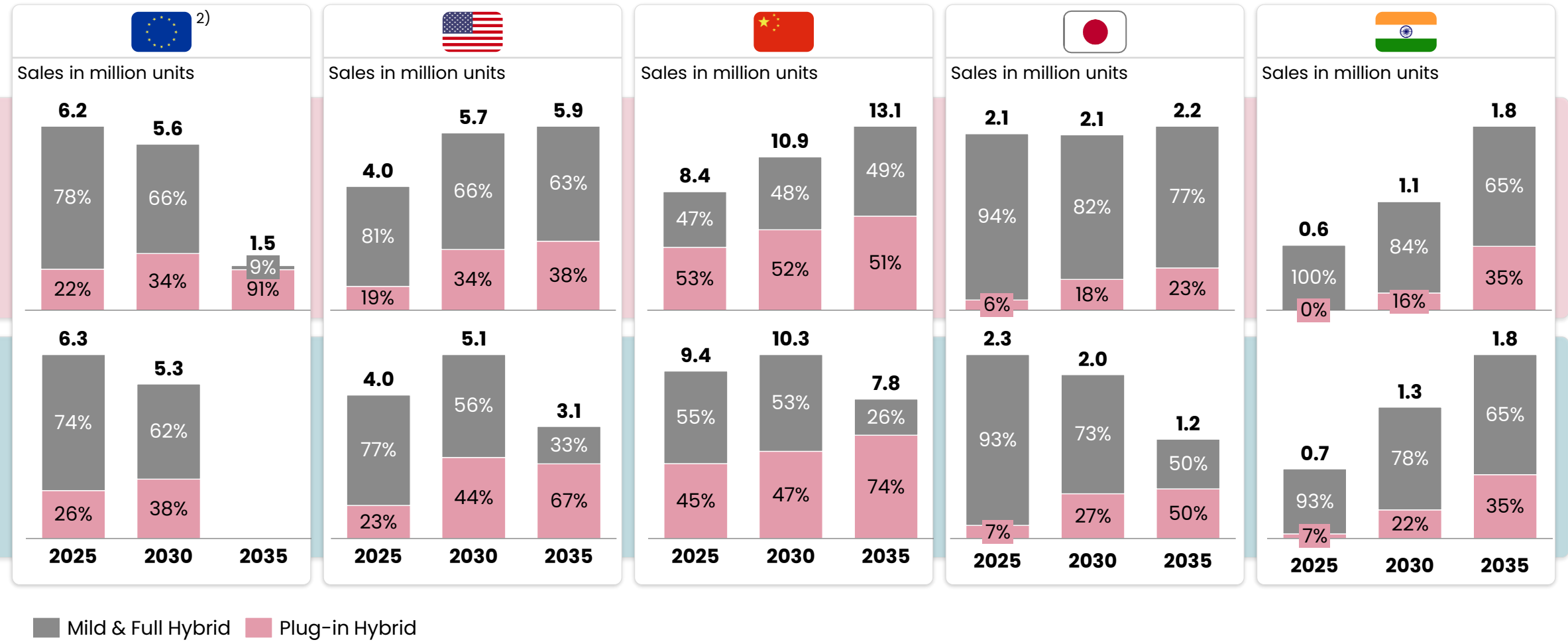


Key Take Aways

- **It is evident from the sales data that there is decline in sales of ICE vehicle**
- **Mild & full hybrid vehicles are picking up pace with 14.72 m units sold globally in 2023**
  - **22.69%** from Europe
  - **18.59%** from China
  - **India** also contributing around **~3.2%,** that's just the start of a transition from ICE to other PWT
- **PHEV vehicle sales are also growing at a ~ 38% CAGR globally**
  - **54%** of the sales coming from China
  - There are no evident sales in Indian market but according to the recent article published by AutoCar India *"PHEVs especially those resulting from partnerships with Chinese OEMs, are gaining traction in India and could replicate the success seen in China, where PHEVs have experienced rapid growth"*

Sales Forecast:
PHEV & HEV Exhibits a Robust Growth in Chinese & Indian market

PASSENGER CAR[1)] – PHEV & HEV MARKET FORECAST FOR EU, US, CN, JP & IN



1) Europe, China & Japan: passenger cars, USA: light-duty vehicles up to 3.5 t gross vehicle weight; 2) EU+EFTA+UK
Source: FEV

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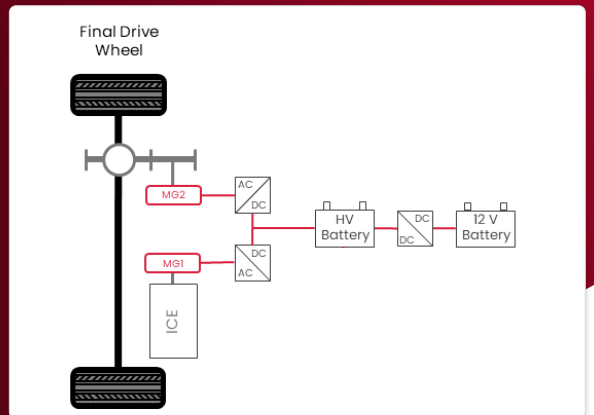
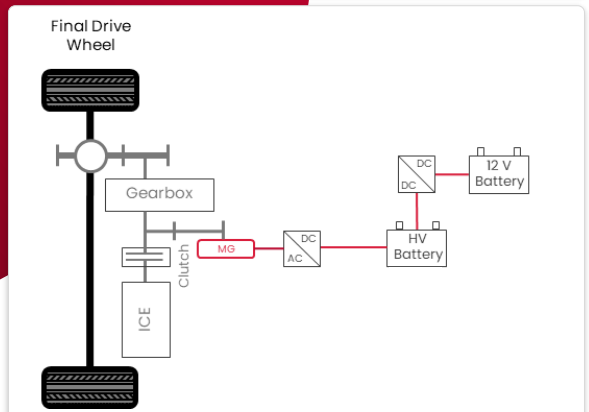
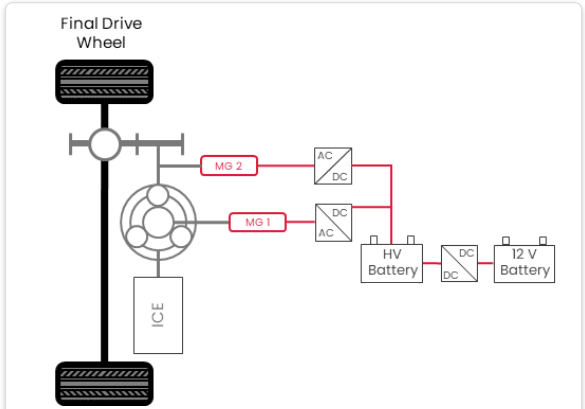
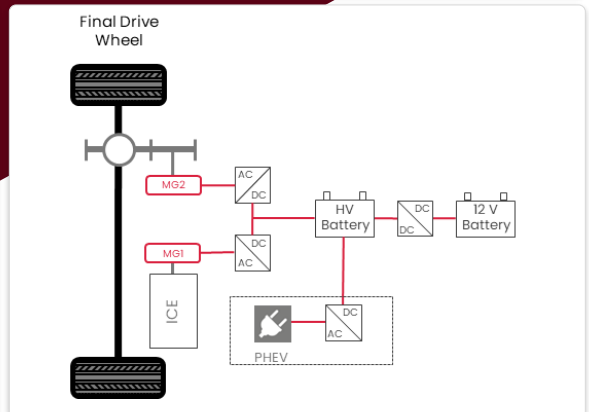
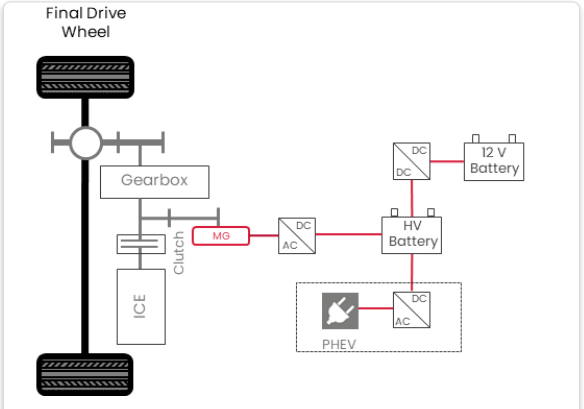
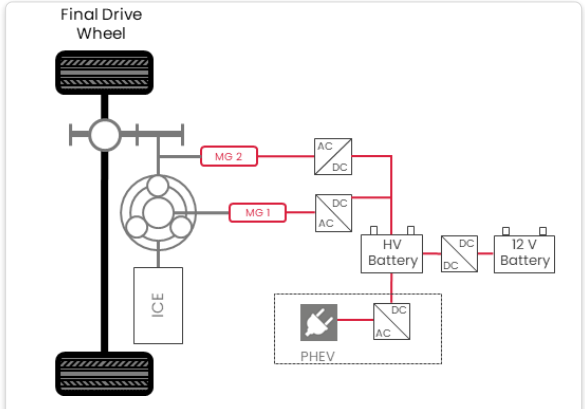
Engineering Challenges in the Transition: ICE to Hybrid

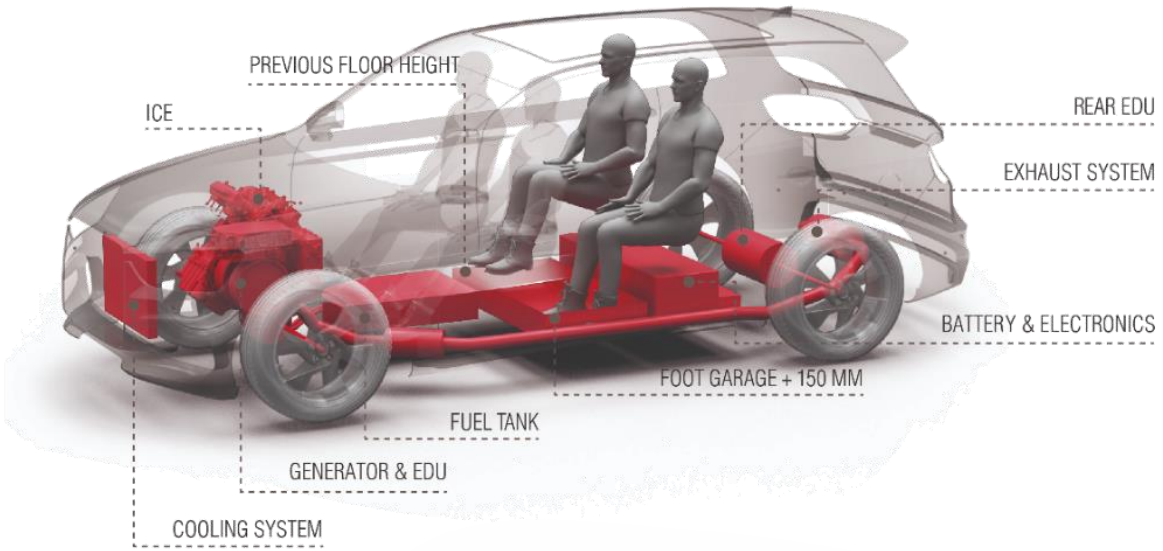
POWERTRAIN INTEGRATION COMPLEXITY

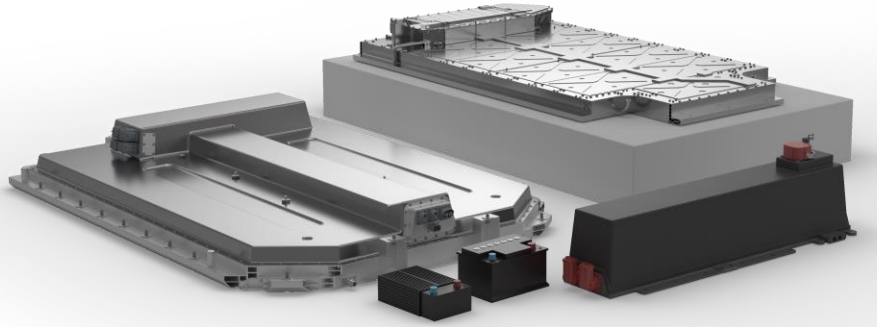
	Series Hybrid *(Motor Drives the wheels while the ICE charges the battery)*	**Parallel Hybrid** *(Motor & ICE both drives the vehicle one at a time)*	**Series- Parallel Hybrid** *(Motor & ICE both drives the vehicle based on the driving inputs)*
Hybrid Electric vehicle (HEV)			
Plug In Hybrid Electric vehicle (PHEV)			

- One of the primary challenges in converting an ICE to a PHEV is the integration of two distinct power sources: the internal combustion engine and the electric motor.
- This dual-system architecture necessitates sophisticated powertrain control strategies to seamlessly switch between electric and combustion modes.
- Balancing these systems to optimize fuel efficiency, emissions reduction, and vehicle performance requires precise engineering and advanced control algorithms.

Engineering Challenges in the Transition: ICE to Hybrid

BATTERY TECHNOLOGY AND PACKAGING





The heart of any HEV is its battery pack, which must be integrated into a vehicle originally designed for an ICE. This integration poses several challenges:

Space Constraints: HEV batteries are typically larger than those in traditional ICE vehicles, requiring careful consideration of vehicle packaging to maintain interior space and vehicle dynamics.

Thermal Management: Batteries generate significant heat, especially during charging and discharging cycles. Effective thermal management systems are crucial to ensure the longevity and safety of the battery pack. This involves integrating cooling systems that can handle the thermal load without compromising vehicle performance.

Weight Distribution: Adjustment in the vehicle's suspension and chassis design must be made to accommodate the added weight of the battery pack, altering the vehicle's weight distribution and impacting handling and stability.

Engineering Challenges in the Transition: ICE to Hybrid

ELECTRICAL ARCHITECTURE MODIFICATIONS

Converting an ICE vehicle to HEV requires significant modifications to the vehicle's electrical architecture. The electrical system must be upgraded to support the higher voltage and current demands of the electric motor and battery pack. This involves:

Wiring and Connectors: High-voltage components necessitate the use of specialized wiring and connectors that can safely handle increased electrical loads.

Onboard Charging System: Integrating an onboard charger to enable plug-in functionality is another key challenge in PHEV. This system must be designed to work seamlessly with the vehicle's existing electrical infrastructure while ensuring efficient energy transfer and safety.

Control Systems: The addition of an electric motor and battery pack requires the development of new control systems to manage energy flow, regenerative braking, and the interaction between the electric and combustion power sources.

Engineering Challenges in the Transition: ICE to Hybrid

EMISSIONS AND REGULATORY COMPLIANCE

HEVs offer the potential for reduced emissions compared to ICE, but achieving these reductions involves several challenges:

- **Exhaust Aftertreatment Systems:** The aftertreatment system must function efficiently even during intermittent engine operation, which occurs frequently in HEVs. Ensuring optimal performance during cold starts and electric-only driving periods requires advanced catalysts and particulate filters that are effective under variable operating conditions.

- **Emission Testing Cycles:** HEVs must comply with stringent emissions regulations across various testing cycles, such as WLTP and EPA protocols. These cycles may not fully reflect real-world usage, where drivers alternate between electric and combustion power. Effective calibration of hybrid control systems is crucial to minimize emissions in diverse driving scenarios.

- **Onboard Diagnostics (OBD) Compliance:** HEVs are required to have OBD systems that monitor and report the performance of emission control systems. These systems must be reliable and tamper-resistant to ensure ongoing compliance with emission standards.

- **Global Regulatory Variations:** HEVs must meet different emission standards in various regions, necessitating adaptable powertrain and aftertreatment technologies. This complexity requires manufacturers to develop flexible solutions to satisfy the specific regulatory demands of each market.

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Consumer Centricity & Emotions on Hybrid Vehicles

UNDERSTANDING CONSUMER PREFERENCES, EMOTIONAL APPEAL, AND SUCCESS STORIES

Why Indian Consumer Preferring HEV?

Indian consumers are increasingly opting for hybrids due to their **balance of fuel efficiency** and **lower emissions** compared to traditional ICE vehicles

According to Clean Mobility Shift[1], hybrids are seen as a transitional technology, **offering familiarity & practicality while reducing environmental impact**

No long wating time for charging, leading to more **peaceful long drives**

What's the Emotional Appeal of the HEV?

Hybrids resonate with consumers' values of **sustainability** and **cost-effectiveness**

Marketing strategies that highlight the **benefits of hybrids**, such as **lower emissions** and **fuel savings**, have been effective in attracting **environmentally conscious buyers**

Brands like **Toyota & Maruti Suzuki** have successfully positioned their hybrid models as **eco-friendly & economical choices**.

Case Studies w.r.t Indian Market

The Toyota Urban Cruiser Hyryder and Maruti Suzuki Grand Vitara have been well-received in the Indian market, with positive feedback from owners who appreciate the fuel efficiency and lower emissions

Hybrid vehicle owners have reported **high satisfaction levels**, emphasizing the **cost savings** & **environmental benefits** of their vehicles

1: Why India is starting to love hybrids - Clean Mobility Shift

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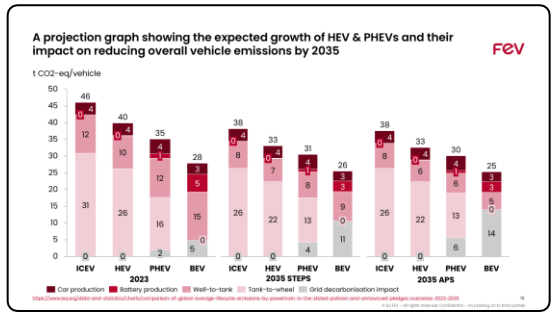
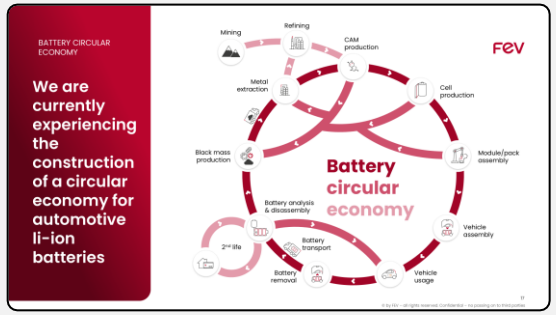
The Environmental and Economic Benefits of Hybrid Vehicles. A Comprehensive Analysis of Emissions, Costs, and Future Prospects.

Environmental Impact



- Hybrids offer significant reductions in emissions compared to traditional ICE vehicles
- According to a study by IIT Kanpur, hybrids may be more environmentally friendly than EVs in India's current energy context, where 75% of electricity is generated from coal
- This makes hybrids a practical choice for reducing carbon emissions in the short term

Lifecycle Analysis



- A detailed analysis of the total cost of ownership and lifecycle emissions shows that hybrids are a cost-effective and environmentally friendly option
- Hybrids have lower fuel consumption and maintenance costs over their lifetime, making them an attractive choice for consumers
- Additionally, the sustainability aspects of hybrid vehicle components, including battery recycling, contribute to their overall environmental benefits

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Areas to be Addressed for a Successful Transition to HEVs in the Indian Market

- **Lower the GST on HEVs:** Despite HEVs being an eco-friendlier option, the Indian government has incentivized electric cars by placing them in the lowest tax bracket of 5% GST, compared to 48% for petrol cars and 43% for HEVs. To promote faster adoption of HEVs, the GST on HEVs should be reduced to 5%, the same as for EVs.
- **Localization of Components:** Localizing the production of components can significantly reduce the acquisition cost of HEVs for consumers, thereby increasing their sales. This strategy will also boost the local economy and create jobs.
- **Increase in Number of HEV Models:** Automakers should offer a variety of HEV models to cater to different user needs and preferences. This includes Plug-in Hybrid Electric Vehicles (PHEVs), Strong HEVs, and Mild HEVs, providing options for a wide range of use cases.
- **Infrastructure Development:** Investing in the development of charging and maintenance infrastructure for HEVs will make them a more convenient and attractive option for consumers.
- **Public Awareness Campaigns:** Educating the public about the benefits of HEVs, including their environmental impact and cost savings, can drive consumer interest and adoption.

Future Outlook !!

The future of hybrid vehicles looks promising, with continued advancements in technology and increasing consumer acceptance.

Hybrids are expected to play a crucial role in the transition to full electrification, especially in Indian market where charging infrastructure is limited. As the EV infrastructure develops, hybrids can bridge the gap and provide a practical solution for reducing reliance on fossil fuels.

- Sachin Wagh

The floor is open for the questions!!