

# SUMMER PROJECT

# ANALYSING THE FUTURE OF AUTOMOBILES -

# Comparative Study of BEVs, Green Fuel Vehicles and Hybrid Vehicles –

BY TEAM YOSEMITE



# AGENDA

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- Introduction
- Environmental Impact
- Cost and Efficiency Analysis
- Market Trends and Consumer Preferences
- Strategies and Innovations
- Future Trends and Strategic Recommendations
- Conclusion

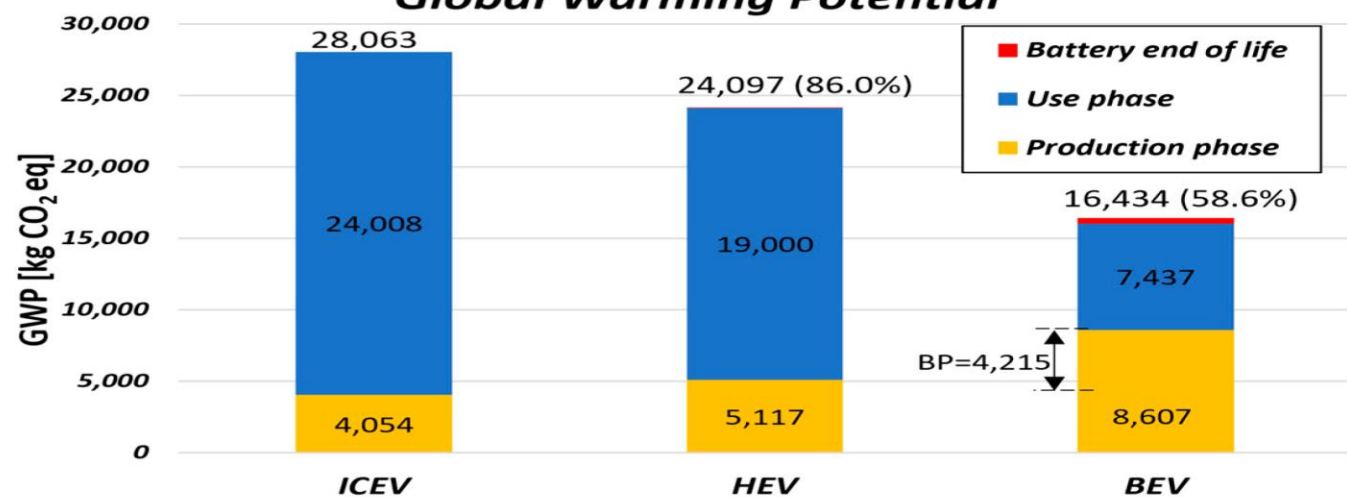
# Introduction to the Global and Indian Automobile Sectors and Importance of Sustainable Solutions

- **Global Automobile Sector:**
- **Market Size:** \$3.8 trillion (2022)
- **Key Players:** Toyota, Volkswagen, Tesla
- **Trends:** Shift to green vehicles driven by tech advancements and regulations
- **Indian Automobile Sector:**
- **Market Size:** \$100 billion (2022)
- **Key Players:** Tata Motors, Mahindra & Mahindra, Maruti Suzuki
- **Growth Rate:** 7.6% CAGR (2022-2027)
- **Initiatives:** FAME scheme for EV promotion
- **Importance of Sustainable Solutions:**
- **Environmental Impact:**
  - Auto sector = 15% of global greenhouse emissions
  - ICE vehicles = Major CO<sub>2</sub> and pollutant contributors
- **Economic Benefits:**
  - Cost savings: Less fuel and maintenance
  - Opportunities: Renewable energy and EV sectors
- **Regulatory Pressure:**
  - EU CO<sub>2</sub> standards
  - India's Bharat Stage norms
- **Consumer Demand:**
  - 40% prefer sustainable vehicles

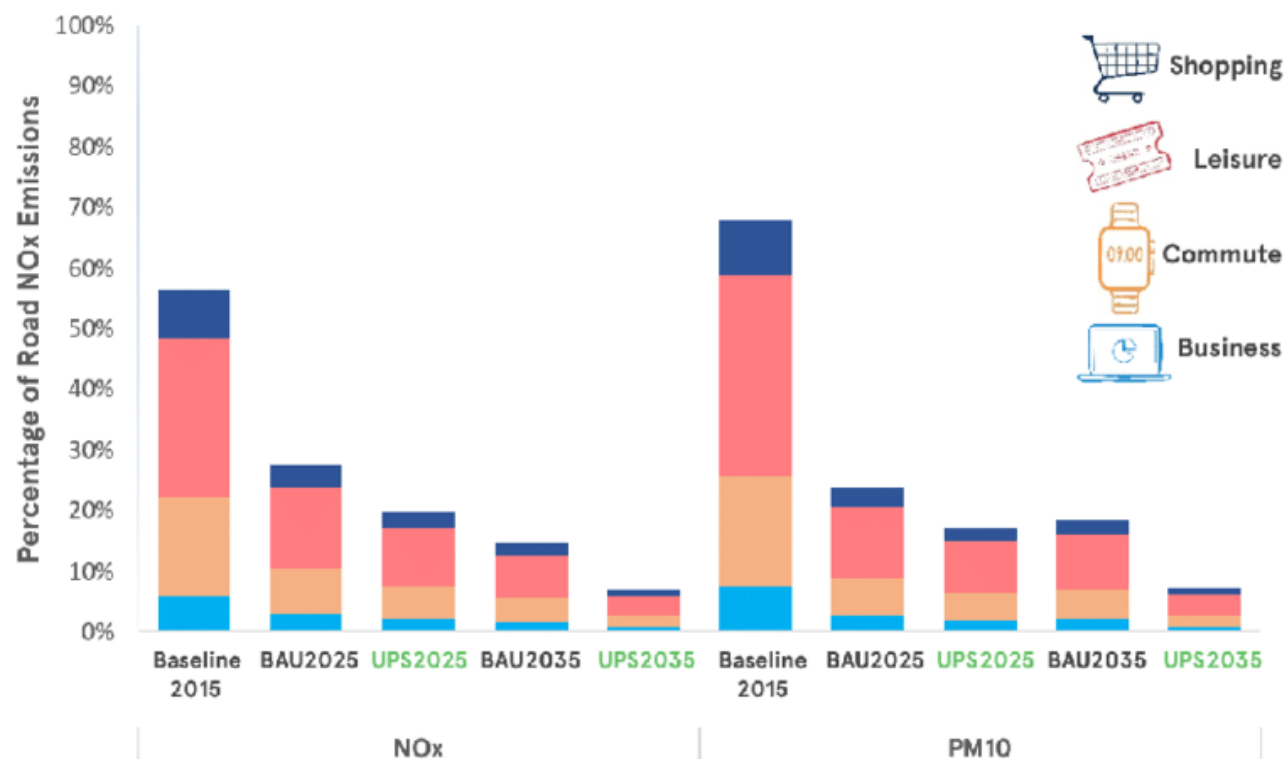
# Overview of Environmental Issues Related to Conventional Vehicles

- **1. Air Pollution:**
  - **Emissions:** Conventional vehicles emit harmful pollutants including CO<sub>2</sub>, NO<sub>x</sub>, and particulate matter (PM).
  - **Statistics:**
    - **CO<sub>2</sub> Emissions:** Road transport contributes approximately 13% of India's total CO<sub>2</sub> emissions.
    - **NO<sub>x</sub> Emissions:** Vehicles contribute about 30% of total NO<sub>x</sub> emissions in Indian cities.
- **2. Greenhouse Gas Emissions:**
  - **Climate Change:** Conventional vehicles significantly contribute to global warming due to high CO<sub>2</sub> emissions.
  - **Statistics:**
    - **Global Impact:** Transportation accounts for approximately 24% of global CO<sub>2</sub> emissions from fuel combustion.
    - **India Data:** In India, the transport sector is responsible for around 14% of the country's total greenhouse gas emissions.
- **3. Resource Depletion:**
  - **Fossil Fuels:** Heavy reliance on non-renewable fossil fuels like oil.
  - **Statistics:**
    - **Oil Consumption:** The transportation sector consumes about 20% of India's total oil consumption.
- **4. Health Impacts:**
  - **Public Health:** Emissions from conventional vehicles are linked to respiratory diseases, cardiovascular problems, and premature deaths.
  - **Statistics:**
    - **Premature Deaths:** Air pollution from road traffic contributes to approximately 1.67 million premature deaths annually in India.

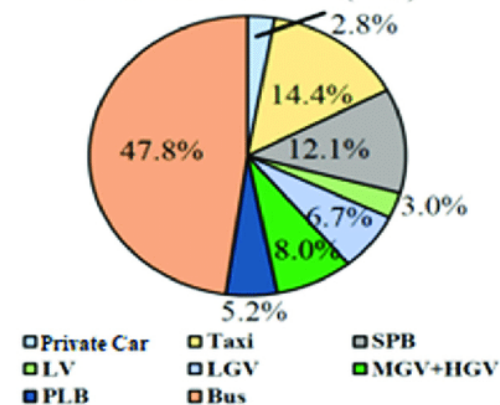
## Global Warming Potential



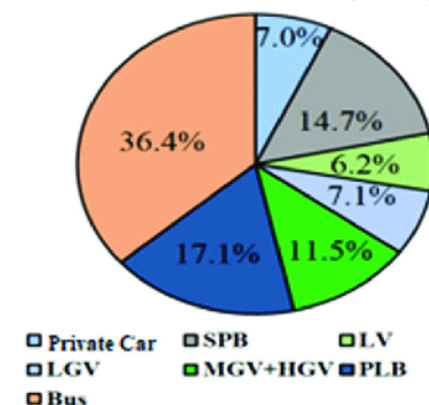
## BAU and UPS for Road Transport NOx and PM10 Emissions by Motive



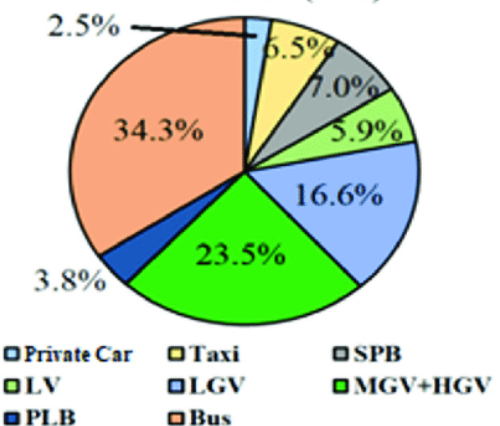
## Central and Western (NOx)



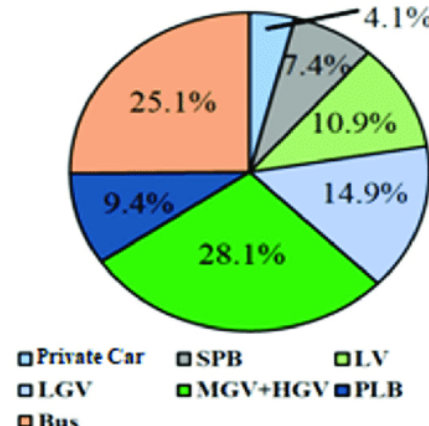
## Central and Western (PM2.5)



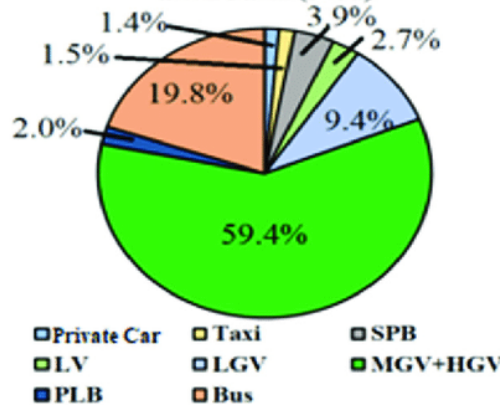
## Sham Shui Po (NOx)



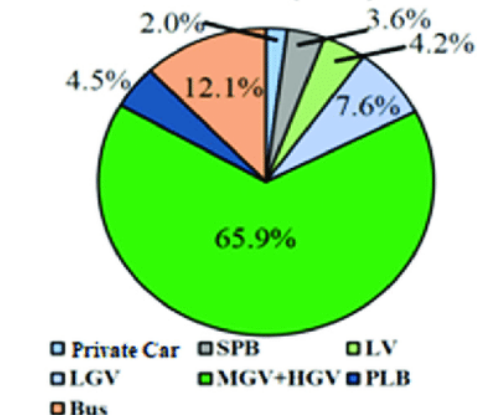
## Sham Shui Po (PM2.5)



## Tuen Mun (NOx)



## Tuen Mun (PM2.5)

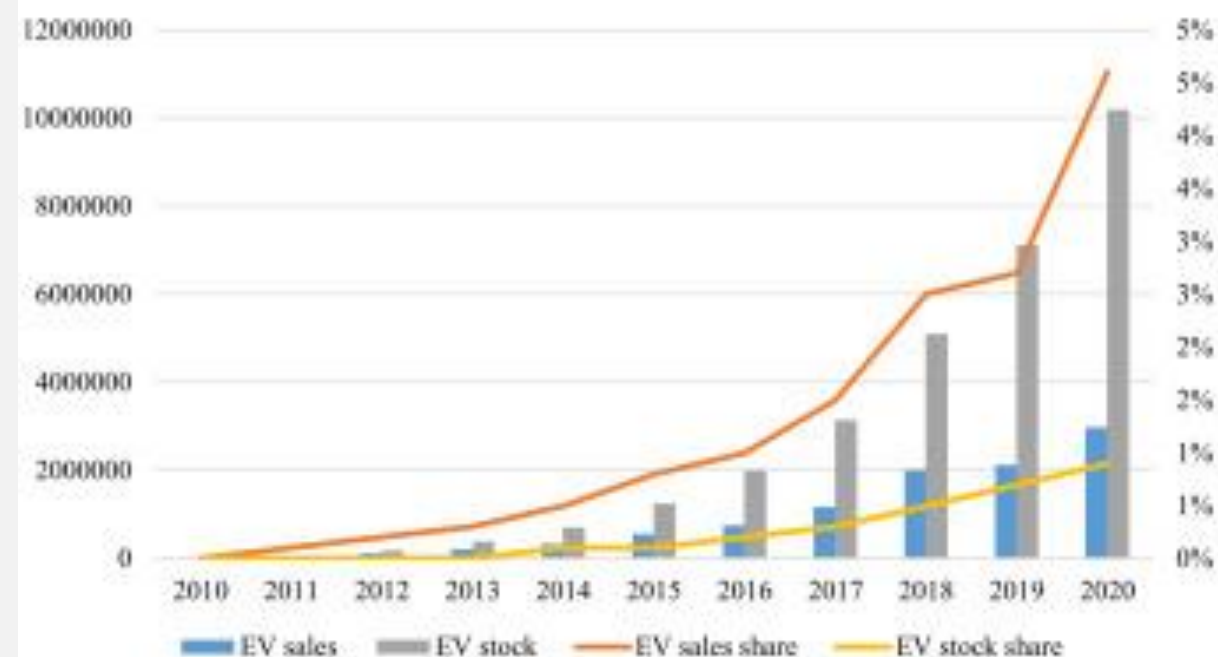




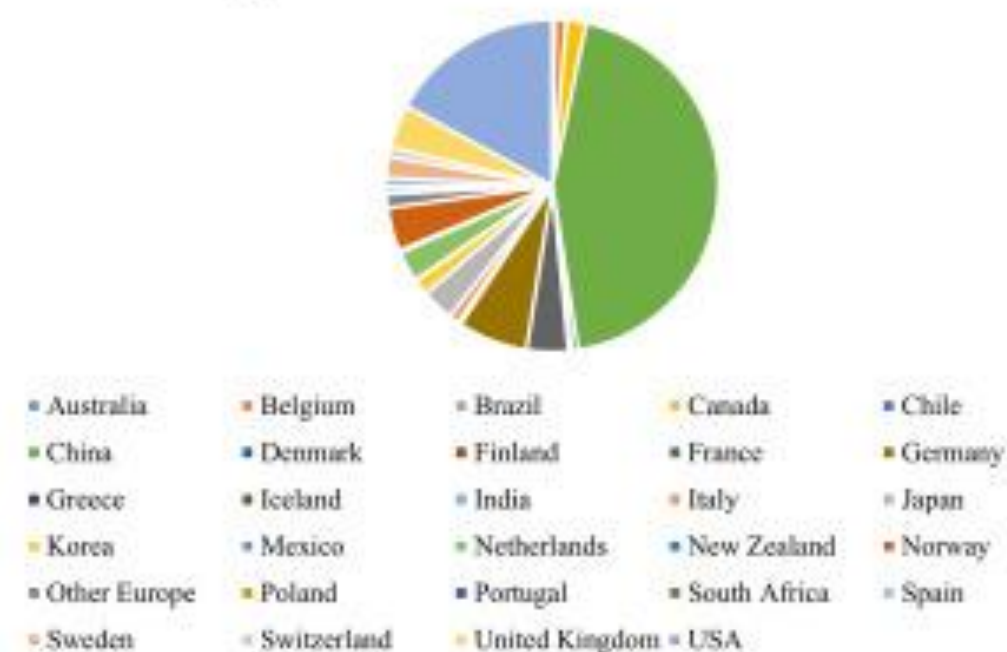
# Lifecycle Emissions and Pros and Cons of BEVs

- **Manufacturing Phase:**
  - **Battery Production:** Producing a lithium-ion battery emits around 150-200 kg CO<sub>2</sub> per kWh.
- **Usage Phase:**
  - **Zero Tailpipe Emissions:** BEVs produce no exhaust emissions.
  - **Energy Source Impact:** Emissions vary based on electricity mix. In India, coal-based electricity can result in higher indirect emissions.
- **End-of-Life Phase:**
  - **Recycling:** Up to 95% of lithium, cobalt, and nickel can be recovered from batteries.
- **Manufacturing Emissions:** 150-200 kg CO<sub>2</sub> per kWh for batteries.
- **Charging Stations in India:** ~1,800 (2022).
- **Range Example:** Tesla Model 3 - 350+ miles per charge.
- **Cost Comparison:** BEVs 20-30% more expensive than conventional cars in India.
- **Cons:**
  - **Purchase Price:** Higher upfront cost due to expensive batteries.
  - **Example:** Average BEV price in India is 20-30% higher than conventional vehicles.
  - **Charging Network:** Limited availability, especially in rural areas.
  - **Example:** India has about 1,800 public charging stations as of 2022.
  - **Grid Emissions:** Dependent on electricity mix; higher in coal-reliant countries like India.
- **Pros:**
  - **Zero Tailpipe Emissions:** Reduces air pollution and greenhouse gases.
  - **Renewable Energy Potential:** Can utilize renewable energy, reducing overall emissions.
  - **Lower Operating Costs:** Electricity costs less than gasoline/diesel.
  - **Maintenance:** Fewer moving parts lead to lower maintenance costs.
  - **Range Improvements:** Example: Tesla Model 3 offers over 350 miles per charge.

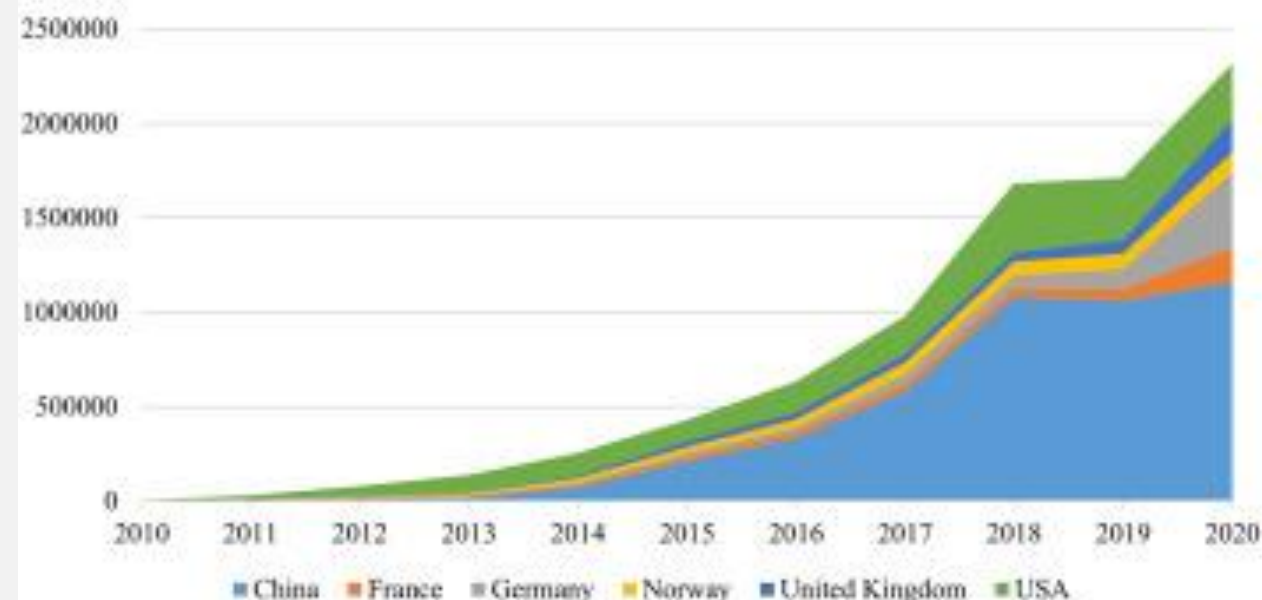
Global electric vehicle sales and stock from 2010 to 2020



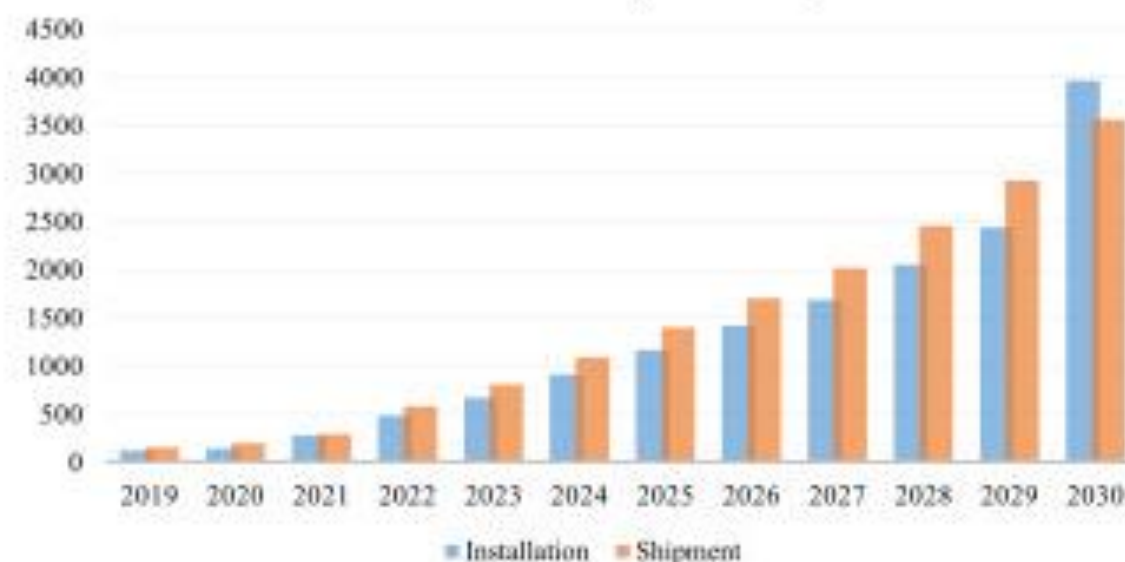
Total global sales of electric vehicles from 2010 to 2020



Top six countries for electric vehicle sales from 2010 to 2020



Installed capacity and shipment of global power batteries from 2019 to 2030 (Unit: GWh)



# Environmental Impact Comparison: BEVs vs. Green Fuel vs. Hybrid Vehicles

## 1. Battery Electric Vehicles (BEVs):

- Zero Tailpipe Emissions:** No direct emissions during operation.

- Lifecycle Emissions:** Higher emissions during manufacturing (battery production: 150-200 kg CO<sub>2</sub> per kWh).

- Energy Source Impact:** Emissions depend on electricity mix; lower if renewable energy is used.

## 2. Green Fuel Vehicles (CNG):

- Tailpipe Emissions:** Lower CO<sub>2</sub> and NO<sub>x</sub> emissions compared to petrol/diesel.

- Lifecycle Emissions:** Producing and transporting CNG results in some emissions.

- Pollutants:** Emits fewer particulate matter and other pollutants.

## 3. Hybrid Vehicles:

- Tailpipe Emissions:** Lower than conventional vehicles; combines internal combustion engine with electric motor.

- Lifecycle Emissions:** Moderate emissions during manufacturing; lower emissions in operation compared to conventional vehicles.

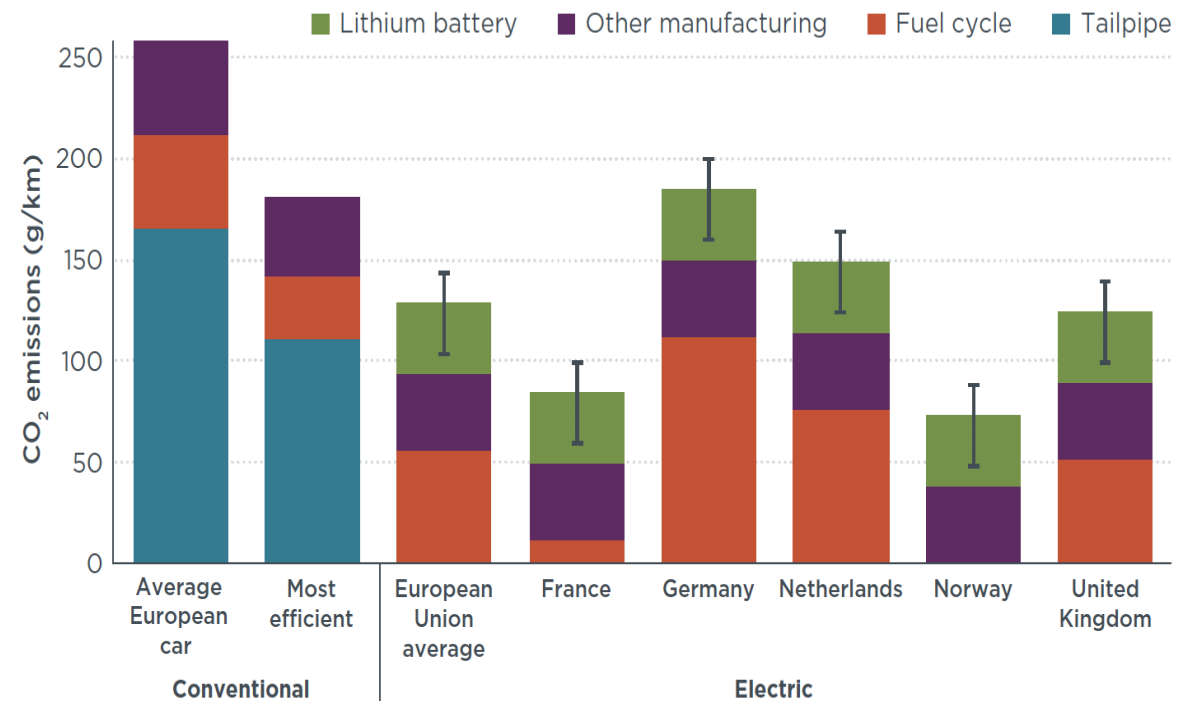
- Energy Efficiency:** Higher fuel efficiency reduces overall emissions.

### Data Highlights:

- BEV Battery Production:** 150-200 kg CO<sub>2</sub> per kWh.

- CNG Vehicles:** ~20% reduction in CO<sub>2</sub> emissions compared to petrol.

- Hybrid Vehicles:** ~30-40% reduction in fuel consumption and emissions compared to conventional vehicles.

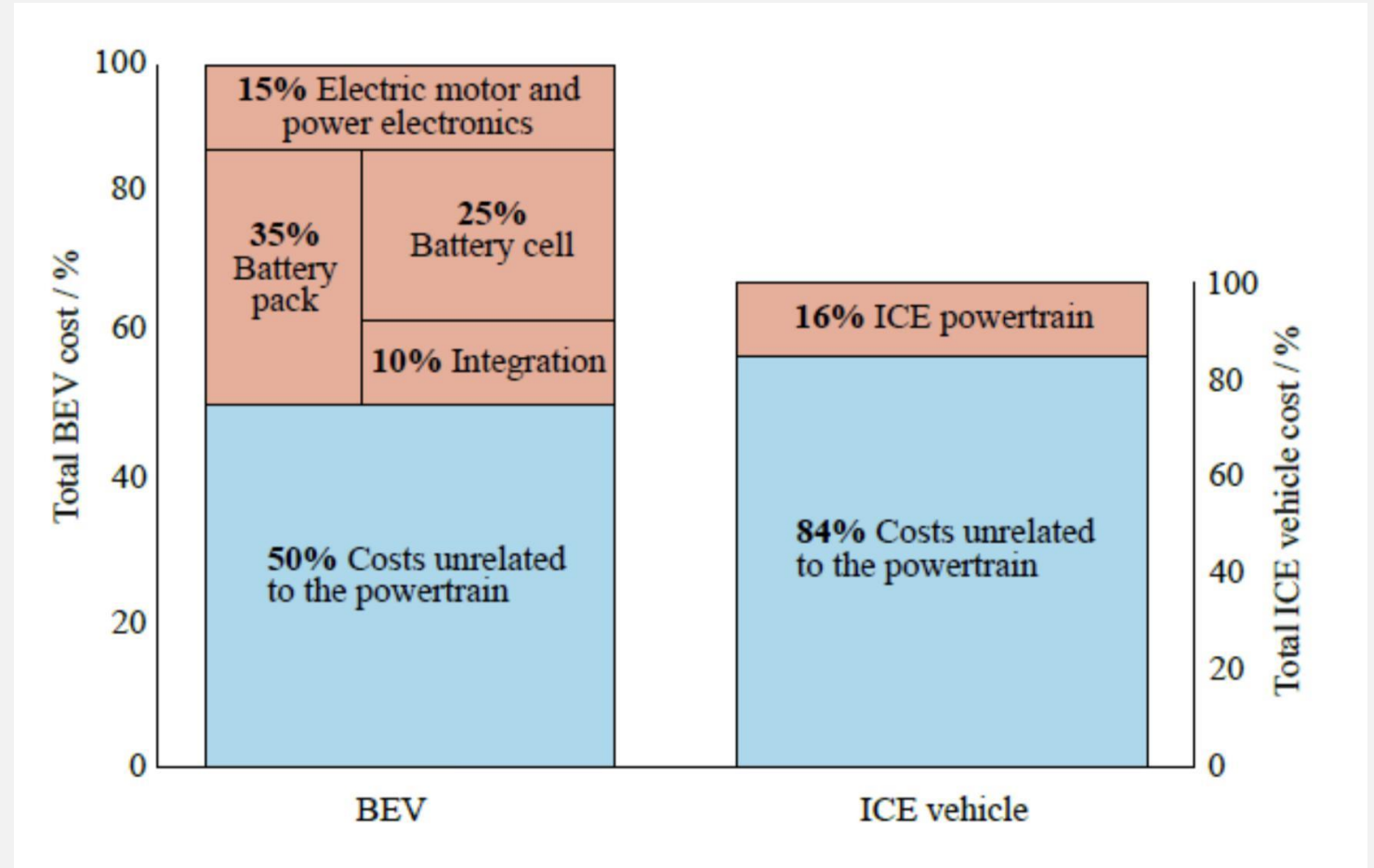


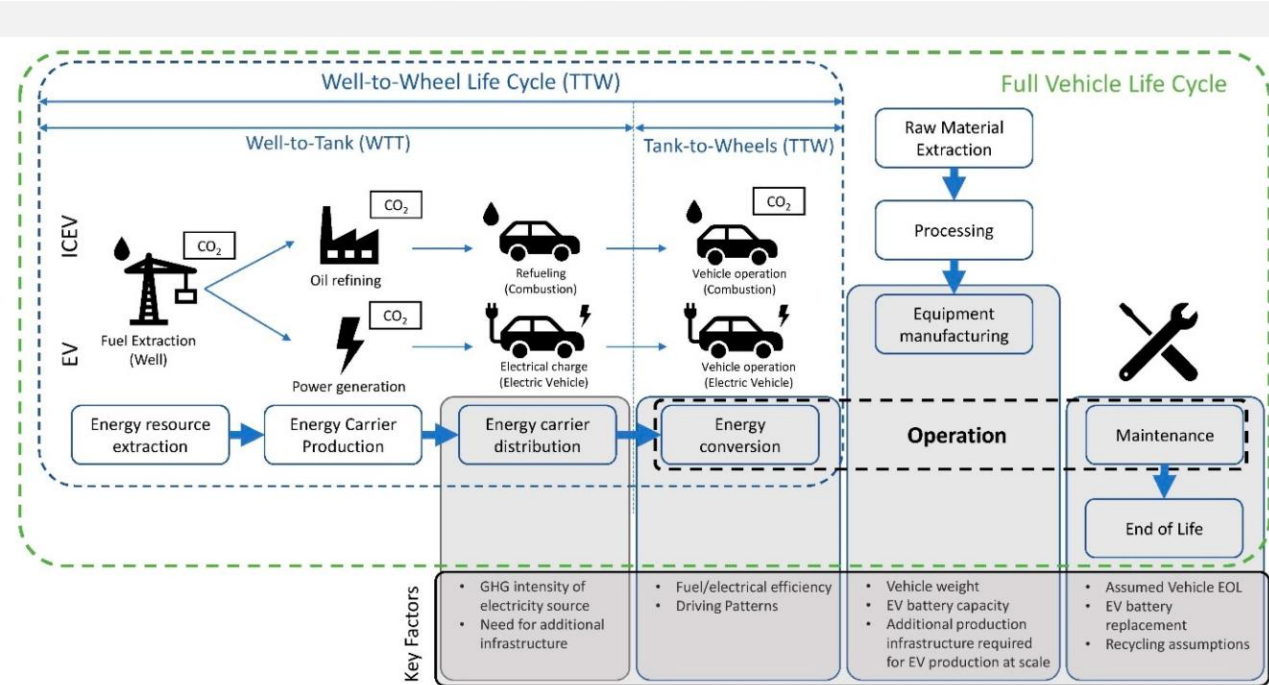
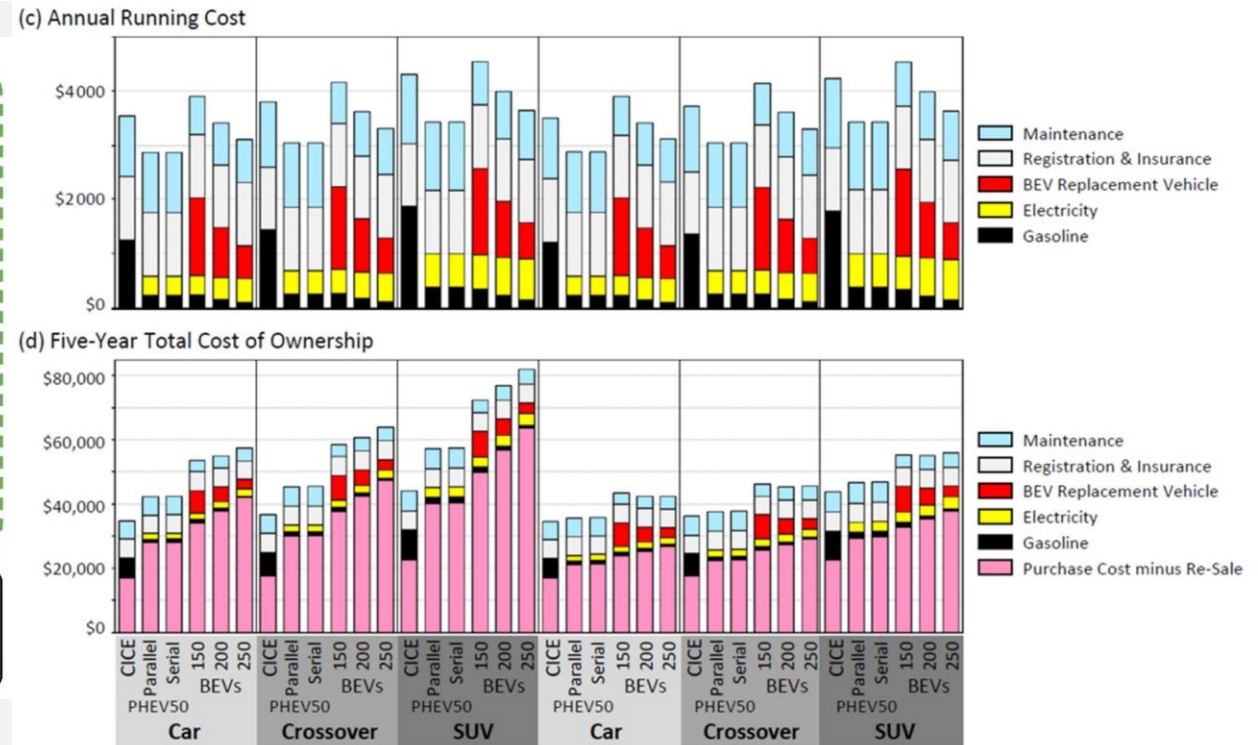
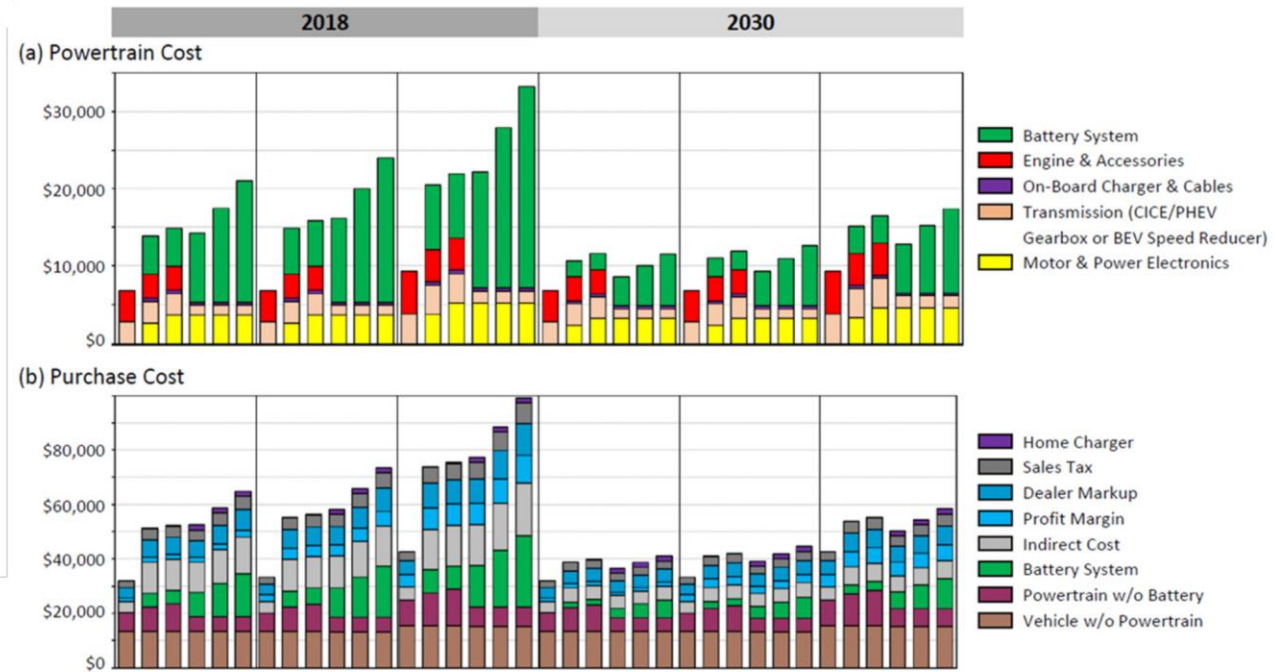
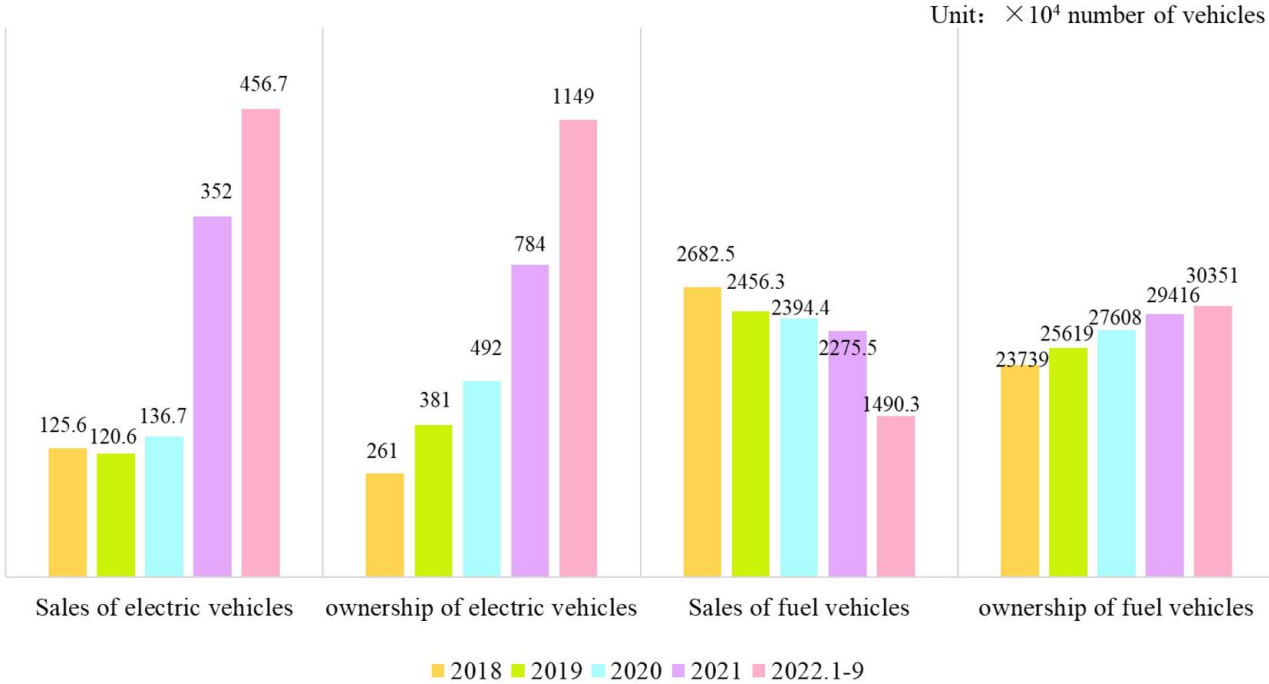
**Figure 1.** Life-cycle emissions (over 150,000 km) of electric and conventional vehicles in Europe in 2015.



# BEV COST ANALYSIS

- Battery Electric Vehicles (BEVs):
  - Purchase Price:
    - Average BEV Price: ₹15-25 lakhs
  - Incentives/Subsidies:
    - FAME II Scheme: Up to ₹1.5 lakh subsidy
    - State Incentives: Additional subsidies (e.g., Delhi offers up to ₹1.5 lakh)
  - Maintenance:
    - Lower Maintenance Costs: ~₹0.5-1 per km
    - Fewer Moving Parts: Reduced wear and tear
  - Operational Costs:
    - Electricity Cost: ₹1-2 per km
    - Total Cost per km: ₹1.5-3





# GREEN FUEL VEHICLES COST ANALYSIS -

- **Electric Vehicles (EVs)**
- The India Electric Vehicle Market size is estimated at 34.8 billion USD in 2024, and is expected to reach 120 billion USD by 2030, growing at a CAGR of 22.92% during the forecast period (2024-2030).
- **Initial Costs**
- **Purchase Price:**
  - EVs typically have a higher upfront cost compared to gasoline vehicles due to the cost of the battery.
  - Prices vary based on the model, range, and manufacturer.
- **Tax Incentives and Rebates:**
  - Many governments offer incentives to reduce the purchase price of EVs, such as tax credits, rebates, and grants.
- **Long-Term Costs**
- **Battery Replacement:**
  - EV batteries typically last 8-15 years but can be expensive to replace.
  - Many manufacturers offer warranties covering the battery for 8-10 years.
- **Resale Value:**
  - EV resale values are improving as the market for used EVs grows.
  - Depreciation rates vary based on model and battery condition
- **Operating Costs**
- **Fuel Costs:**
  - Electricity is generally cheaper than gasoline on a per-mile basis.
  - Home charging can be more cost-effective than using public charging stations.
- **Maintenance and Repairs:**
  - EVs have fewer moving parts than gasoline vehicles, leading to lower maintenance costs.
  - Key maintenance includes battery checks, tire rotations, and brake service.
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# Hybrid Vehicles Cost Analysis -

		Hybrid Vehicle Market Trends
Study Period	2019 - 2029	<ul style="list-style-type: none"><li>Initial Costs</li></ul>
Market Size (2024)	USD 231.77 Billion	<ul style="list-style-type: none"><li>1. Purchase Price:<ul style="list-style-type: none"><li>Hybrid vehicles typically cost more upfront than their gasoline counterparts due to advanced technology and more complex powertrains.</li><li>Prices can vary widely depending on the make, model, and features of the vehicle.</li></ul></li></ul>
Market Size (2029)	USD 478.33 Billion	<ul style="list-style-type: none"><li>2. Tax Incentives and Rebates:<ul style="list-style-type: none"><li>Many governments offer tax incentives, rebates, or grants for purchasing hybrid vehicles, which can significantly offset the higher initial cost.</li><li>These incentives vary by region and can change over time.</li></ul></li></ul>
CAGR (2024 - 2029)	12.83 %	<ul style="list-style-type: none"><li>Operating Costs</li></ul>
Fastest Growing Market	Asia-Pacific	<ul style="list-style-type: none"><li>1. Fuel Costs:<ul style="list-style-type: none"><li>Hybrid vehicles are more fuel-efficient than traditional gasoline vehicles, leading to lower fuel costs.</li><li>The actual savings depend on fuel prices, driving habits, and the specific hybrid mode.</li></ul></li></ul>
Largest Market	Asia-Pacific	<ul style="list-style-type: none"><li>2. Insurance:<ul style="list-style-type: none"><li>Insurance premiums for hybrids can be higher or lower than for conventional vehicles, depending on factors like the cost of repairs and the vehicle's safety features.</li></ul></li></ul>

# GLOBAL MARKET TRENDS -

- **Global headwinds make their mark** - The industry is continuing to deal with major global disruptions, not just from COVID-19, but from so many other elements of the global economy. Factors such as the tensions in Asia Pacific and the war in Ukraine have created a climate of uncertainty and hesitation. Then, of course, shortages from microchips to labour are affecting almost every touchpoint along the automotive supply chain.
- However, one of the most significant global trends continues to be the industry's focus on the development of electric vehicles (EVs), whether it is improving battery performance or expanding the charging infrastructure. These ambitions are resulting in a significant increase in research and development (R&D) by vehicle manufacturers, who seem to be charging ahead with EV technology despite the many other challenges they currently
- **Autonomous technology takes a backseat**
- The breakneck pace of development is a sign that manufacturers remain bullish on the future of EVs. In fact, it seems as though every month brings a new advancement that brings us closer to the stated promise of, 'Vehicles 2.0'. There is one ambition, however, that may have to wait a little longer to be realised.
- "The development of autonomous vehicle technology has slowed down somewhat, as manufacturers redirect and refocus on the refinement of the electric vehicle", says Keyler. "These are certainly being driven by the regulatory landscape, which at the moment is accelerating a path to wide-scale EV adoption. Governments in North America, Europe, and Asia Pacific are all implementing their own initiatives, not to mention the UN, and auto makers are under pressure to deliver". Recently, Ford Motors announced that they had put their autonomous technology production on hold. Coming from one of the world's largest auto manufacturers, this announcement sent a pretty strong signal to the entire industry.
- **Labouring through tough times**
- The staggering number of employees that recently left the workforce and never returned was yet another obstacle impacting the automotive industry. Factories were suddenly scrambling to fill shifts, and original equipment manufacturers (OEMs) were left shorthanded, at a time when the industry was eager to get its machinery back up and running. Adding to this there has also been a shift in skill sets required to serve the change from internal combustion engine (ICE) models to EV.
- **Sticker shock**
- One of the trends that seems to be part of the common discussion, especially with rising energy costs, is the concept of accelerated EV parity. The term refers to the cost of owning, operating, and producing an EV being equal to that of an internal combustion engine (ICE) vehicle. At the moment, EVs are much pricier on all fronts than their petrol-powered cousins, but that has not stopped rosier outlooks from the industry
- Recently, Volvo CEO Jim Rowan shared his projection of total EV parity by 2025. While there may be some great headwinds helping drive mass EV production, there are also rising costs and disruptions like the war in the Ukraine that are causing the costs of EVs to climb, possibly out of the average driver's reach.



# INDIAN MARKET TRENDS -

- **The Electric Fuel Type Segment is Expected to Witness Significant Growth over the Forecast Period**

- The Indian government's strict regulations in response to the rising levels of vehicular emissions and increased demand for environment-friendly automobiles are likely to drive the growth of the industry over the forecast period. Along with various schemes, the government announced a battery-swapping policy in the Union Budget 2022-2023, allowing depleted batteries to be switched out for charged ones at specific charging points, increasing the viability of electric vehicles for potential buyers.
- The Government of India has undertaken multiple initiatives to promote the manufacturing and adoption of electric vehicles in the country to reduce emissions and develop e-mobility in the wake of rapid urbanization. The National Electric Mobility Mission Plan (NEMMP) and Faster Adoption and Manufacturing of Hybrid & Electric Vehicles in India (FAME I and II) helped create the initial interest and exposure to electric mobility.

- **RISING INVESTMENT -**

- The automobile sector received a cumulative equity FDI inflow of about US\$ 35.40 billion between April 2000 - September 2023. \* India is on track to become the largest EV market by 2030, with a total investment opportunity of more than US\$ 200 billion over the next 8-10 years. \* The automobile sector received a cumulative equity FDI inflow of about US\$ 35.65 billion between April 2000 - December 2023.

- **GROWING DEMAND -**

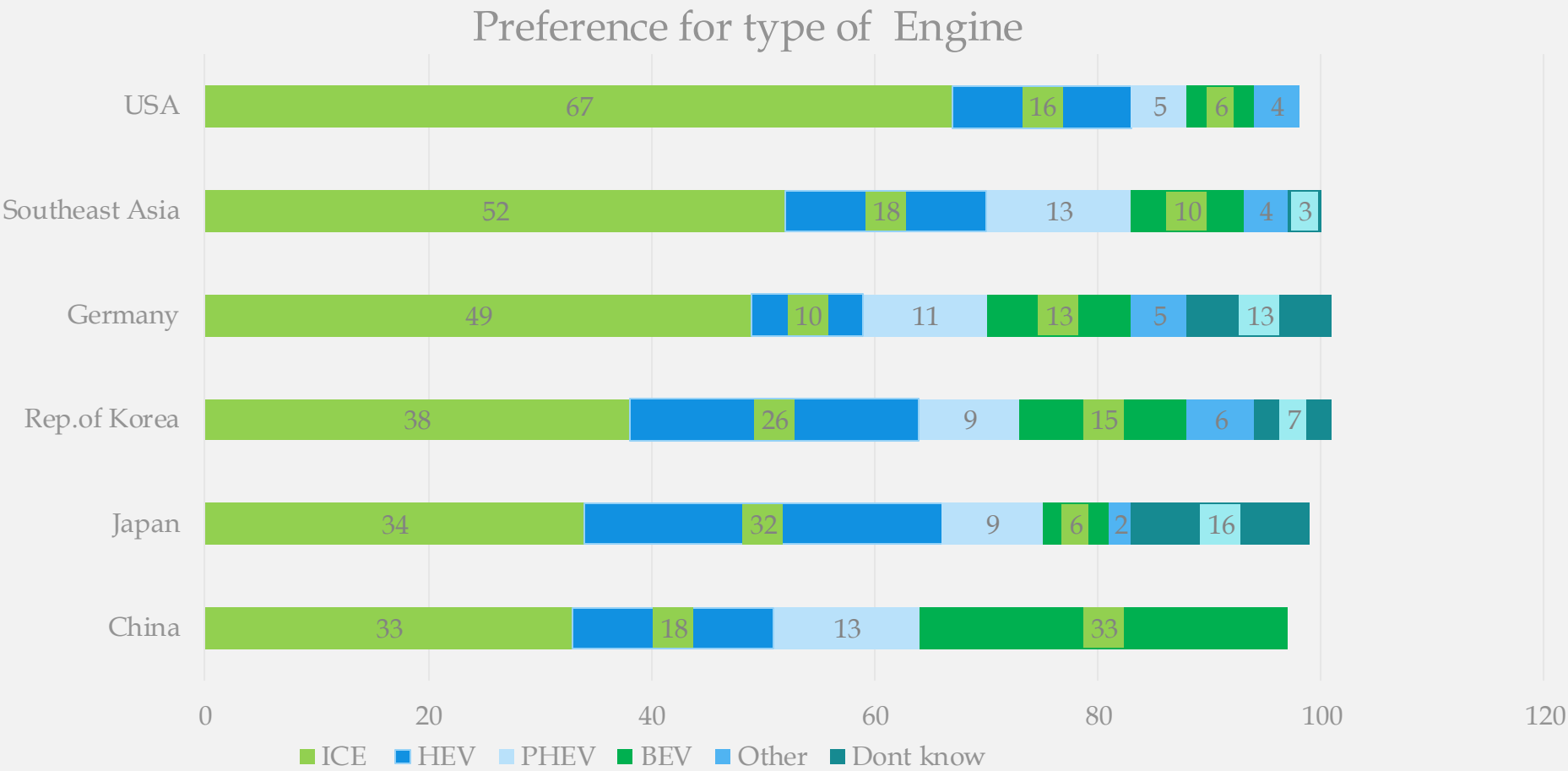
- Rising middle-class income and a huge youth population will result in strong demand. \* In January 2024, the total production of passenger vehicles\*, three-wheelers, two-wheelers, and quadricycles was 23,28,329 units

## **The Two-Wheelers Segment to Register Fastest Growth over the Forecast Period**

- The Indian two-wheeler industry is gaining immense popularity in the country due to the fuel efficiency and lower purchase cost of two-wheelers, the country's rapidly growing population, road traffic congestion, lack of parking spaces, inadequate mobility infrastructure, and reduced carbon emissions, particularly in electric variants.
- Moreover, the two-wheelers segment dominates the market in terms of volume, owing to the expanding middle-class population and a huge percentage of Indians being young. India has a line-up of festivals and auspicious periods between August and November, pushing up two-wheeler sales in the country. Rural India, which forms nearly two-thirds of the country's population, accounts for 55% of the total two-wheeler sales.

# CONSUMER PREFERENCE - GLOBAL

- Key findings
- Is slowing EV momentum putting current regulatory timelines in jeopardy?
- 1 High interest rates and elevated sticker prices may be causing consumer interest in EVs to soften in some markets. Despite automaker price cuts and government incentives designed to make them more affordable, a variety of other challenges continue to stand in the way, including range anxiety, charging time, and availability of charging infrastructure.
- A significant number of consumers may be thinking about switching vehicle brands. Price tops the list of factors driving the choice of vehicle brand for consumers in developed markets, including Germany, Japan, and the United States, while vehicle performance (China and South Korea) and product quality (India) are top of mind for consumers in other global markets.



# CONSUMER PREFERENCE - INDIA

KEY POINTS – The shift to EVs is happening, but is it moving fast enough?

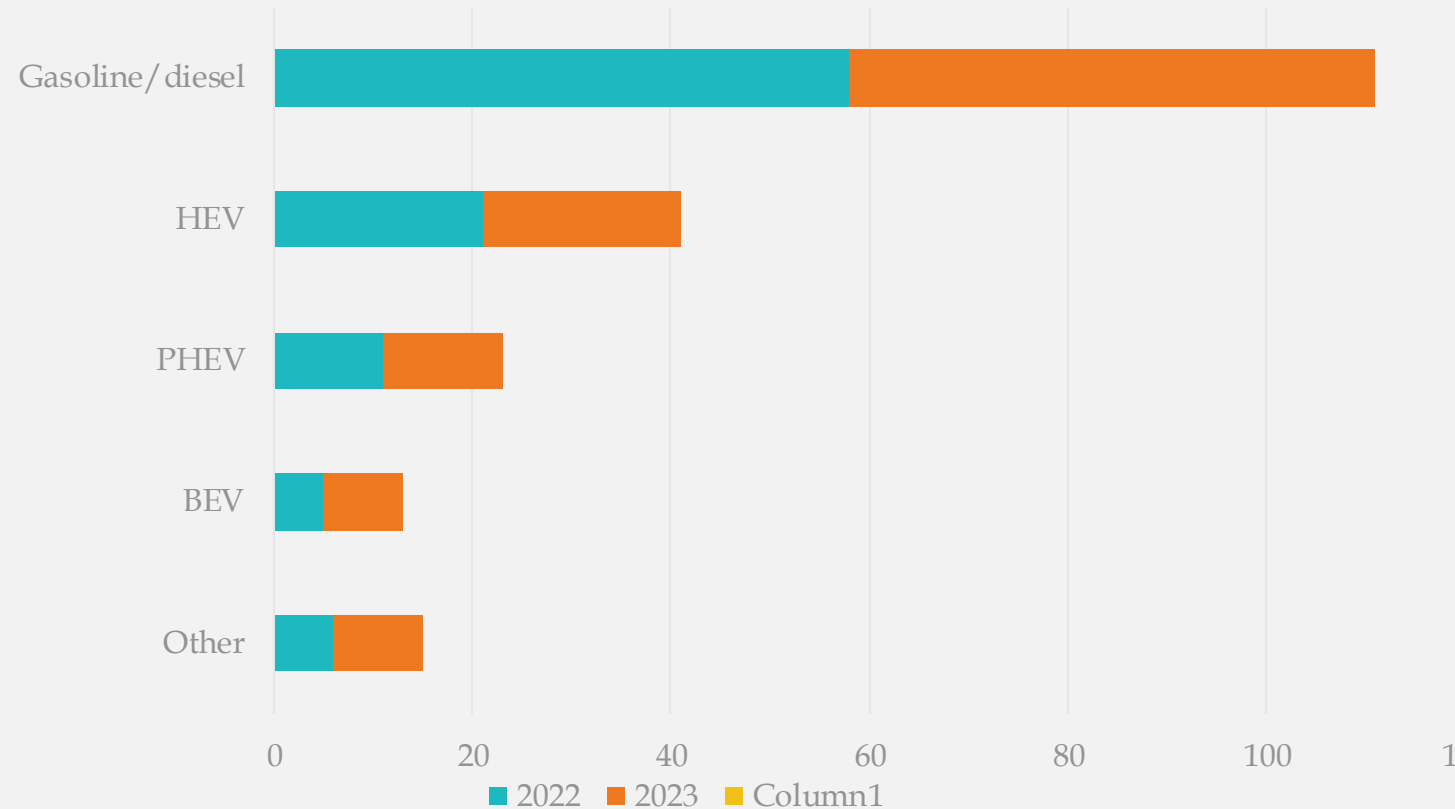
Consumer interest in EVs is growing as consumers look to lower their operating costs. However, there are a variety of challenges standing in the way, including availability of charging infrastructure, concerns regarding battery safety, and the price premium required to access EV technology.

An unintended benefit of the vehicle inventory crisis  
Product quality still tops the list of factors driving consumer decisions when it comes to which vehicle brand to buy, but expectations regarding the acceptable length of time to wait for delivery may be starting to stretch out as a lasting by-product of the inventory crisis, potentially opening the door to a new “build-to-order” paradigm.

Dealers engender significant trust among consumers. When asked who they trust most, surveyed consumers point to their servicing dealer, signaling the important role this stakeholder has in building and maintaining the customer relationship which should be an important consideration for OEMs looking to redefine the retail process.

Subscriptions to connected vehicle services could be a challenge. Consumer interest in connected vehicle features that provide updates regarding safer driving routes, vehicle health reporting, and road safety are relatively high, but respondents would much rather pay for connected technologies as part of the upfront cost of the vehicle or on a per use basis versus a monthly subscription.

Preference of type of Engine



# KEY PLAYERS OF THE INDUSTRY – GLOBAL / INDIA

Rank	Company	Market Cap (Billion)	Key Offerings
1	Tesla	\$559.85	Electric Vehicles, Sustainable Energy
2	Toyota	\$339.23	Hybrids, Trucks
3	Porsche	\$90.57	Sports Cars, SUVs
4	Stellantis	\$85.19	Diverse Automotive Brands
5	Mercedes-Benz	\$85.07	Luxury Sedans, SUVs, Performance Cars
6	Ferrari	\$78.62	Supercars
7	BYD	\$78.21	Electric Vehicles, Renewable Energy
8	BMW	\$76.12	Premium Vehicles
9	Volkswagen	\$72.33	Quality Vehicles, Innovation
10	Honda	\$60.59	Diverse cars and motorcycles

- INDIAN MARKET –
- Maruti Suzuki – Sales – 16,06,870 units. Market Cap – 4,02,778 crore.
- Hyundai Motor India – Sales – 5,67,546 units. Revenue – 47,043cr
- TATA Motors – Sales – 5,38,640 units . Market Cap – 3,55,693 crore
- Mahindra – 3,59,253 units. Market Cap – 3,55,332 crore.

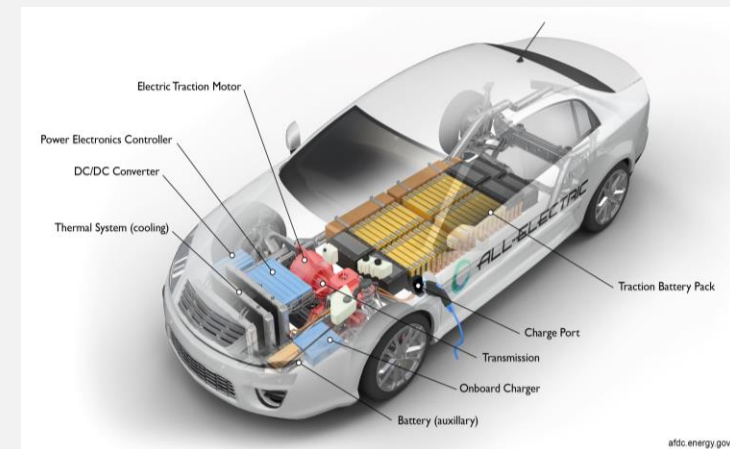
# R&D Investments and Technological Advancements

- Automotive manufacturers could realize time and cost savings and quality improvements by implementing generative AI functions that add value at all stages of the R&D process.
- Three momentous trends** are buffeting the R&D function in the automotive industry, creating the need for profound change. First, the transition from internal combustion engine (ICE) to electric vehicle (EV) technology is a fundamental shift, the likes of which the industry has not experienced since surging oil prices and competition sparked demand for more fuel-efficient vehicles more than a half century ago.
- Second is the trend of software-defined vehicles with a central architecture that is more geared toward consumers. Software provides many opportunities for automotive players to differentiate themselves, with such applications as infotainment and advanced driver-assistance systems. However, software also presents companies with the substantial challenge of transforming hardware-centric operations to support their added role as software providers.
- The third trend is the emergence of generative AI (gen AI). Gen AI is becoming a powerful technology with the potential to completely reconfigure how R&D teams operate. Although the technology is still in its early days, its ability to generate and process language and imagery, integrate insights from various sources, process information across diverse formats, and produce detailed documentation for regulatory purposes points to a radically different R&D future. New entrants to the sector—EV manufacturers in China, the United States, and elsewhere—have already successfully implemented R&D process innovations that accelerate new-vehicle time to market, gaining considerable strategic advantages over established players, whose margins are already squeezed.
- Adoption and investment trends**
- We found a strong inclination to adopt gen AI in the automotive sector. The majority of companies (75 percent of survey respondents) are experimenting with at least one gen AI application; those that are not plan to start within one year (25 percent of respondents).
- Further, investments in gen AI applications for R&D are substantial: more than 40 percent of survey respondents reported that their companies have invested up to €5 million. A few companies—more than 10 percent of respondents—have invested more than €20 million.
- INVESTMENTS OF AUTOMOTIVE INDUSTRY -
- Volkswagen (VLKAF), \$16.5 billion**
- The **line** “we combine science and fiction” defines R&D at Volkswagen. The company reported revenue of \$216.77 billion (€182.11 billion) during fiscal year 2020 (January – December); its allocation towards **R&D** stood at \$16.5 billion (€13.86 billion)—equivalent to around 7.6% of revenue. The company is working to strengthen its innovative power and has witnessed an increasing share of these patents for advanced technologies such as driver assistance systems, automation, and connectivity as well as alternative drive systems.
- The world’s best-known automobile brands—Audi, SEAT, ŠKODA, Bentley, Lamborghini, Bugatti, Porsche, Ducati, Scania, and MAN—are a part of the Volkswagen Group. Volkswagen is working towards its new vision of “shaping mobility – for generations to come,” which is in sync with its **TOGETHER 2025+ strategy**. The group is focused towards making their drives cleaner, quieter, intelligent, and safer by embracing electric drive, digital networking, and autonomous driving. The Volkswagen Group seeks to become a CO2-neutral company by 2050.
- Toyota (TM), \$9.87 billion**
- Toyota, a Japanese multinational, is among the largest automobile companies in the world. The company **reported** a net revenue of ¥27.2145 trillion (\$256.7 billion) on a consolidated basis, a decrease of 8.8% as compared to the previous fiscal. Toyota’s R&D expenditures were approximately ¥1,090.4 billion (\$9.87 billion) during fiscal 2021 (April 2020-March 2021) as compared to ¥1,110.3 billion in fiscal 2020.
- According to Toyota, “The intellectual property that R&D generates is a vital management resource that Toyota utilizes and protects to maximize its corporate value.” The company was **granted** 2,079 patents in 2020 and owns 22,157 patents, which is the 11th highest number of patents in terms of current cumulative patent holdings. Toyota **established** the Toyota Research Institute (TRI) in January 2016 to accelerate R&D of artificial intelligence (AI) technology.

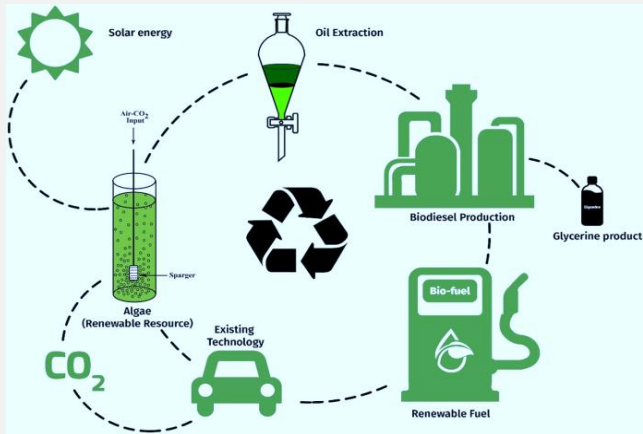


# INNOVATIONS IN BEVs

1. **BATTERY TECHNOLOGY :** Development of solid-state batteries promises higher energy density, faster charging times, and improved safety compared to traditional lithium-ion batteries.
2. **CHARGING INFRASTRUCTURE:** The development of ultra-fast chargers (up to 350 kW) significantly reduces charging times. Dynamic wireless charging are being developed to provide seamless charging experiences.
3. **AUTONOMOUS DRIVING:** Integration of ADAS(Advanced Driver-Assistance Systems) technologies, including adaptive cruise control and lane-keeping assist enhances safety and convenience.
4. **POLICY SUPPORT:** Government incentives, subsidies, and regulations aimed at reducing emissions are accelerating the adoption of BEVs.
5. **CORPORATE COMMITMENTS:** Major automakers and companies are committing to electrifying their fleets, which is driving innovation and production at scale.

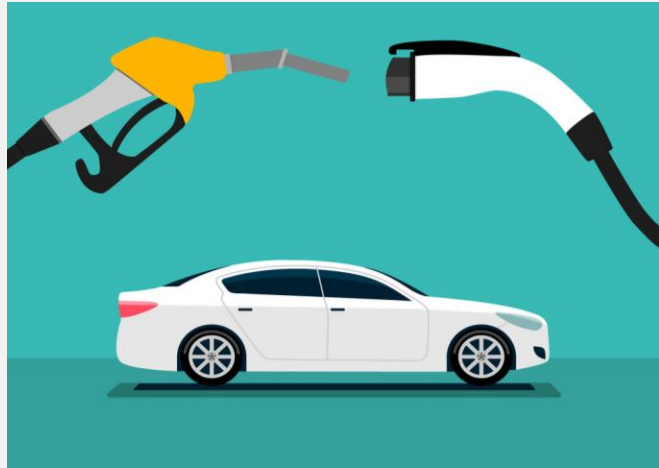


# INNOVATIONS IN GFVs



1. **HYDROGEN FUEL CELLS:** Advances in proton exchange membrane (PEM) fuel cells have improved efficiency, durability, and cost-effectiveness as well as in green hydrogen production and safer, more efficient storage solutions.
2. **ADVANCE BIO-FUELS:** Development of second and third-generation biofuels from non-food crops and waste biomass. Also internal combustion engines optimized for biofuels, improving performance and reducing emissions.
3. **SYNTHETIC FUELS:** Use of carbon capture technologies and renewable energy sources to produce synthetic fuels.
4. **INFRASTRUCTURE:** Expansion of refueling stations and charging infrastructure for green fuel vehicles. Implementation of stringent emissions reduce reliance on fossil fuels.
5. **POLICY SUPPORT:** Subsidies, tax credits, and stringent emissions regulations promoting green fuel adoption.

# HYBRID VEHICLES



## OVERVIEW:

Hybrid vehicles combine an internal combustion engine (ICE) with one or more electric motors. They have become increasingly popular due to their improved fuel efficiency, lower emissions, and enhanced driving experience.

## ADVANTAGES:

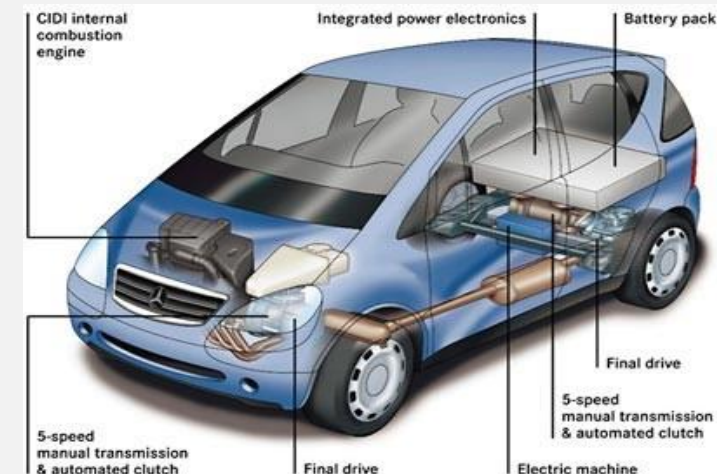
Reduced fuel consumption due to the combined use of an electric motor and ICE increases fuel efficiency. Reduced greenhouse gas and pollutant emissions compared to conventional vehicles decreases gas emissions.

## TYPES:

There are three types of hybrid vehicles- **Mild-Hybrid**(cannot drive the vehicle independently on electric power alone), **Full-Hybrid**(Capable of driving on electric power alone for short distances and at low speeds) and **PlugIn-Hybrid**(Can drive longer distances on electric power alone).

## ADVANCEMENTS:

- Carbon fiber and aluminum being used to reduce vehicle weight.
- Advanced electric motors with higher efficiency and power
- Improved energy density and longer lifespan of lithium-ion batteries



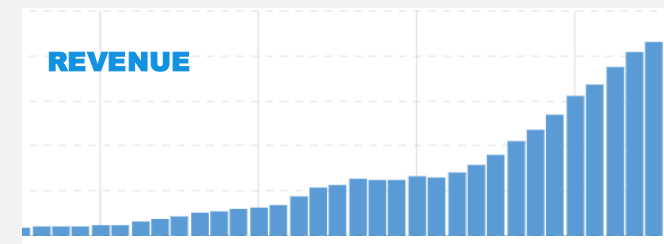
# TESLA: IN-DEPTH STUDY

Tesla Inc., founded in 2003 by Martin Eberhard and Marc Tarpenning, with Elon Musk joining shortly after, has emerged as a leader in electric vehicles (EVs), energy storage, and solar energy products. Its mission is to accelerate the world's transition to sustainable energy.

Tesla sells directly to consumers, bypassing traditional dealership networks. Tesla controls much of its supply chain, from battery production to manufacturing. Along with EVs Tesla also produces battery products and full self-driving software.

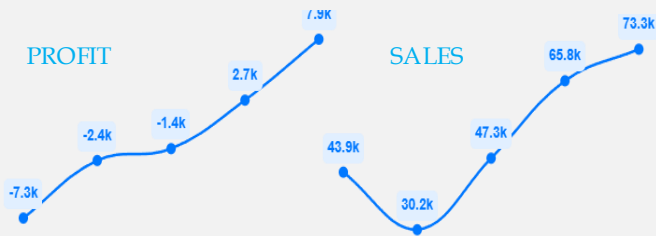
Tesla's competitive advantages include: Innovation, Brand and Customer Loyalty, Large-scale production capabilities with Gigafactories worldwide while Increasing competition from traditional automakers and Regulatory and Political Risks pose as major challenges. Tesla's 2023 deliveries match its 2012-2021 total. Total revenue for the year 2023 was around \$81.4B with over 1.31M units with the net income of \$12.56B

In future it focuses on expanding its product line, launching more affordable EVs with innovations in battery. It is expanding presence in new markets, especially in emerging economies like India. It has aimed to produce 2 million vehicles annually by 2025 and increase production capacity for energy storage products.





# TATA: IN-DEPTH STUDY



Tata Motors Ltd. is an Indian multinational automotive manufacturing company. Founded in 1945, Tata Motors has evolved into one of the largest automobile manufacturers globally. The company is increasingly focusing on EVs as part of its strategy to address the growing demand for sustainable transportation. The product line consists of : Passenger Vehicles, Electric Vehicles, Commercial Vehicles, Luxury Vehicles (JLR).

Tata Motors has a strong presence in both passenger and commercial vehicle segments. Plus has first mover advantage in the Indian EV market with rigorous R&D in this sector though is ought to face competition from the global players. Insufficient charging infrastructure in key markets also is a major drawback. For EV components like batteries managing supply chain disruptions is difficult.

The company grossed over \$43B dollars in revenue with a reported loss of \$1.6B. Around 40,000 units of EVs were sold grossing around \$1.6B and capturing 60% of the Indian EV market.

Tata Motors has a strong foundation with its diverse portfolio, innovative approach, and global presence. The focus on electric vehicles, sustainability, and global expansion will be critical to its success in the coming years.



# FUTURE OF BEVs AND GFVs

## BATTERY ELECTRIC VEHICLES (BEVs):

The Indian market for BEVs is poised for significant growth, driven by government initiatives like the Faster Adoption and Manufacturing of Hybrid and Electric Vehicles (FAME) scheme, which provides subsidies and incentives for both manufacturers and buyers.

Investment in charging infrastructure will accelerate, with the government and private sector working together to establish a widespread network of charging stations across urban and rural areas. By 2030, India aims to have over 2 million public charging stations.

Local manufacturing of batteries and BEVs will reduce costs, making electric vehicles more affordable for consumers. The government's push for indigenization and production-linked incentives (PLIs) will support this trend.

Advancements in battery technology, such as solid-state batteries, will improve range and reduce charging times, addressing key concerns of Indian consumers. Additionally, innovations in energy storage and recycling will further enhance the sustainability of BEVs.

Increased environmental awareness and rising fuel prices will drive consumer preference towards BEVs. By 2030, BEVs could account for 30-40% of new vehicle sales in India, particularly in the two-wheeler and three-wheeler segments.

## GREEN FUEL VEHICLES (GFVs):

The use of CNG as a green fuel will continue to grow, especially in the commercial vehicle segment. The government's push for cleaner fuels and expanding CNG infrastructure will support this trend.

Hydrogen fuel cell vehicles (FCVs) will emerge, particularly for heavy-duty applications such as buses and trucks. India's National Hydrogen Mission aims to make the country a global hub for hydrogen production and export, which will foster the development of FCVs.

The Indian government is promoting the use of biofuels and has set targets for ethanol blending in petrol, aiming to reach 20% blending by 2025. This initiative will reduce dependence on fossil fuels and lower emissions from traditional ICE vehicles.

Continued government support through policies, subsidies, and incentives will drive the adoption of green fuels. Public-private partnerships will play a crucial role in developing infrastructure and technology for green fuel vehicles.

# Future Trends in the Automobile Industry

- **1. Hybrid**

- Sorry to say but hybrid is not the future, it is the past. The technology has been available commercially in the world for last 25 years. But hybrid cars are not the final answer, had they been nobody would have invested precious dollars on researching PHEV or BEV cars. Reason just hybrid is not enough to control in urban area pollution.
- Sadly no manufacturer in India is thinking about a plugin hybrid. Toyota and Maruti are happy to dupe the customers with "Smart Hybrid" in the name of hybrid tech.

- **2. Electric**

- Electric is again not the future, it is the present. By the end 2024/ early 2025, all major manufacturers would have an electric car in the portfolio in India.
- Today will electric cars in India are under manufacturer warranty, we will really need to wait 8 years before majority of the current cars are out of warranty and see what the real cost to fix the car is. The batteries which are not fit for use in the car can be used for second life implementation like BeSS or can be recycled. Both will provide some level of compensation to the car owner. Soon there will be providers who will be ready to repair or replace batteries at a lower price.

- **3. Synthetic fuel**

- Synthetic fuel is a distant dream. Formula 1 is thinking of introducing it from 2026 so mass production would be not before 2030 that is also if the cost of producing it comes down. I would have been a better option to add Ethanol blending as an option in the poll. Toyota showcased E85 compliant Hycross this year. - link (Toyota unveils its Strong Hybrid flex-fuel Innova Hycross (upto 85% ethanol blending)). I think Green Ethanol blending is a better bet than synthetic fuel.

# Environmental Policies and Regulations

## 1. Impact on Innovation

Environmental regulations have had a significant impact on the automotive industry's innovation. In response to the regulations, car manufacturers have been forced to invest in research and development to find new ways to reduce emissions. This has led to the development of new technologies, such as electric and hybrid cars. The regulations have also encouraged the use of lightweight materials, which has resulted in more fuel-efficient vehicles. However, these innovations have come at a cost, and car manufacturers have had to invest heavily in research and development, which has increased the cost of production.

## 2. Impact on the Economy

Environmental regulations have also had an impact on the economy. The regulations have led to the creation of new jobs in the automotive industry, particularly in the research and development of new technologies. However, the cost of producing environmentally friendly vehicles has also led to an increase in the price of cars, which has had an impact on the affordability of vehicles for consumers. The regulations have also led to increased competition in the automotive industry, as car manufacturers compete to meet the regulations and gain a competitive advantage.

## 3. impact on Consumer behavior

Environmental regulations have had an impact on consumer behavior. The regulations have led to an increase in demand for environmentally friendly vehicles, such as electric and hybrid cars. Consumers are also more informed about the environmental impact of vehicles and are more likely to choose a vehicle that has a lower impact on the environment. However, the increased cost of producing environmentally friendly vehicles has also led to a decrease in demand for cars, as consumers are less likely to be able to afford a new car.

## 4. Comparison of Options

There are several options for reducing the environmental impact of vehicles, including introducing regulations, encouraging the use of alternative fuels, and promoting the use of public transport. Introducing regulations has been an effective way of reducing emissions from vehicles, but it has also had a significant impact on the automotive industry. Encouraging the use of alternative fuels, such as hydrogen or biofuels, could also reduce emissions, but these fuels are not yet widely available. Promoting the use of public transport could also reduce emissions, but it requires significant investment in infrastructure.

# Strategic Recommendations for BEVs



## 1. Investment in R&D:

Focus Areas: Battery technology, energy efficiency.

Investment Example: Tesla's R&D expenditure reached \$1.5 billion in 2022.

## 2. Infrastructure Development:

Charging Stations: Increase accessibility.

Current Data: India has around 1,800 public charging stations (2022).

## 3. Government Incentives:

Subsidies and Tax Breaks: Promote incentives for EV purchases.

Example: India's FAME II scheme allocates ₹10,000 crore for EV adoption.

## 4. Cost Reduction Strategies:

Local Manufacturing: Reduce costs through domestic production.

Example: Tesla's Gigafactory in Shanghai reduced production costs by 65%.

## 5. Consumer Awareness and Education:

Marketing Campaigns: Promote BEV benefits.

Data: 40% of Indian consumers are unaware of EV benefits.

# Strategic Recommendations for Hybrid Vehicles

- **1. Expand Manufacturing Capabilities**

- Investing in hybrid vehicle manufacturing facilities can yield substantial returns. Companies like Toyota are significantly expanding their hybrid vehicle production capacities, including a \$90 million investment to boost hybrid transaxle and engine production in their U.S. plants. This trend reflects the increasing market demand for hybrid vehicles, driven by environmental regulations and consumer preferences for more sustainable transportation options .

- **2. Enhance R&D for Advanced Hybrid Technologies**

- Allocating funds towards research and development can lead to breakthroughs in hybrid technology, such as more efficient hybrid powertrains and advanced battery systems. This investment can differentiate your offerings in a competitive market. Innovations in hybrid transaxles and electric motor components, as seen with Toyota's advancements, can significantly enhance vehicle performance and appeal .

- **3. Develop Strategic Partnerships**

- Forming alliances with technology firms, battery manufacturers, and other automotive companies can facilitate the development and deployment of hybrid technologies. Partnerships can also help mitigate risks and share the high costs associated with R&D and production scaling. Collaborations in the automotive industry, such as joint ventures for battery production, are becoming increasingly common and can be highly beneficial .

- **4. Focus on Sustainable Supply Chains**

- Investing in sustainable and resilient supply chains ensures the long-term availability of critical components, such as lithium-ion batteries. Companies should consider securing partnerships with suppliers who prioritize sustainable practices and have robust logistics to handle the increasing demand for hybrid vehicle components .

- **5. Government Incentives and Compliance**

- Leverage government incentives for hybrid vehicle production and sales. Many countries offer tax breaks, subsidies, and other incentives to promote the adoption of hybrid and electric vehicles. Staying informed and compliant with evolving environmental regulations can also provide a competitive edge and avoid potential penalties .



# Strategic Recommendations for Green Fuel Vehicles

- **1. Invest in Hydrogen Fuel Infrastructure**
- **Hydrogen Production & Distribution:** Increase investments in the development of green hydrogen production facilities using renewable energy sources like wind and solar. This includes scaling up electrolysis technology and expanding hydrogen distribution networks to facilitate wider adoption .
- **Policy Support:** Advocate for government policies that incentivize the production and use of green hydrogen, such as subsidies, tax credits, and research funding .
- **2. Expand Biofuel Adoption**
- **Advanced Biofuels:** Focus on developing and deploying advanced biofuels, which have lower greenhouse gas emissions compared to traditional biofuels. Support innovation in feedstock selection and processing technologies to improve efficiency and sustainability .
- **Sector Integration:** Integrate biofuels into sectors that are difficult to electrify, such as aviation and maritime transport. Encourage partnerships with airlines and shipping companies to pilot and scale the use of sustainable aviation fuels (SAFs) and bio-marine fuels.
- **3. Leverage Public-Private Partnerships**
- **Collaborative Projects:** Foster collaborations between governments, private sector companies, and research institutions to share risks and benefits in green fuel projects. Public-private partnerships can help accelerate infrastructure development and innovation .
- **4. Promote Green Fuel in Transport Sector**
- **Transition Strategies:** Implement the Avoid-Shift-Improve (ASI) framework to reduce transport emissions. This involves avoiding unnecessary travel, shifting to less carbon-intensive modes, and improving the energy efficiency of vehicles through green fuels .
- **Urban Planning:** Encourage urban planning that supports the use of green fuel vehicles, such as creating low-emission zones, investing in hydrogen refueling stations, and incorporating biofuel options in public transport ([BCG Global](#)) .

# Investment Roadmap



## **1. Embrace Electrification**

Focus on enhancing battery technology, charging infrastructure, and EV manufacturing capabilities.

## **2. Develop Autonomous Driving Technology**

Invest in advanced driver-assistance systems (ADAS) and fully autonomous systems.

## **3. Focus on Sustainability and ESG Compliance**

Direct investments towards sustainable manufacturing practices and reducing carbon footprints.

## **4. Expand into Emerging Markets**

Focus on local manufacturing plants and affordable vehicle models to capture market share in Asia and Africa.

## **5. Invest in Connected Vehicle Technologies**

Develop in-car connectivity features, over-the-air updates, and advanced telematics.

## **6. Strengthen Supply Chain Resilience**

Build resilient supply chains to mitigate risks from geopolitical tensions and natural disasters.

## **7. Enhance Consumer Experience and Brand Value**

Invest in customer data analytics, personalized marketing, and innovative product design.

# A COMPREHENSIVE OUTLOOK

**Market Overview:** The global automobile sector's market size is \$3.8 trillion as of 2022. Significant contributor to global greenhouse emissions (15%).

**Environmental Impact:** Conventional vehicles contribute heavily to pollution and health issues. BEVs, despite having zero tailpipe emissions, face challenges in manufacturing emissions, particularly battery production.

**Cost Analysis:** BEVs have higher initial costs but lower long-term operational expenses. Green Fuel Vehicles and Hybrid Vehicles offer balanced costs with moderate environmental benefits.

**Global Market Trends:** The shift towards EVs, driven by environmental policies and consumer demand. Challenges in global EV adoption due to economic factors and technological limitations.

**Government Initiatives:** Policies and schemes like NEMMP and FAME in India promoting EV adoption. Battery-swapping policy to overcome charging infrastructure challenges.

**Consumer Preferences and Challenges:** Global consumer interest tempered by high costs and interest rates. In India, interest is high but hindered by infrastructure and safety concerns.

**Investment Opportunities:** Indian EV market poised for over \$200 billion investment by 2030. Significant potential for growth and innovation in the EV sector.

**Technological Innovations:** Generative AI enhancing R&D processes, speeding up vehicle development. AI's role in integrating insights and producing regulatory documentation efficiently.

Thank you

