Chargers and Charging Infrastructure
(Course code: EV-355)

(Lectures: 3 & 4)

CoE for Electric Vehicles and Related Technologies
Department of Electrical Engineering
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Classification of Electric Vehicles

Electric Vehicles are classified as follows:

1. **Battery Electric Vehicle (BEV)**
2. **Hybrid Electric Vehicle**
    1. Hybrid Electric Vehicle (HEV)
    2. Plug-in Hybrid Electric Vehicle (PHEV)
3. **Fuel Cell Electric Vehicle (FCEV)**

Battery Electric Vehicle (BEV)

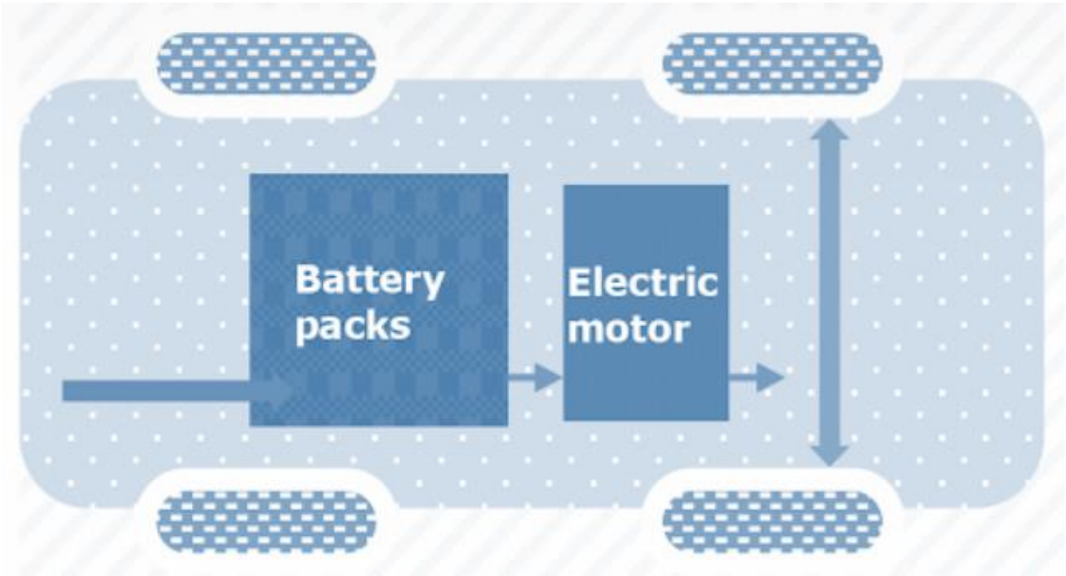
BEVs are also known as **All-Electric Vehicles** (AEV). Electric Vehicles using BEV technology run entirely on a battery-powered electric drivetrain.

Main Components of BEV:

Electric motor, Inverter, Battery, Control Module, Drive train

Examples of BEV:

TATA Nexon, TATA Tigor, Mahindra E20 plus, Hyundai Kona, Mahindra Verito, MG ZS

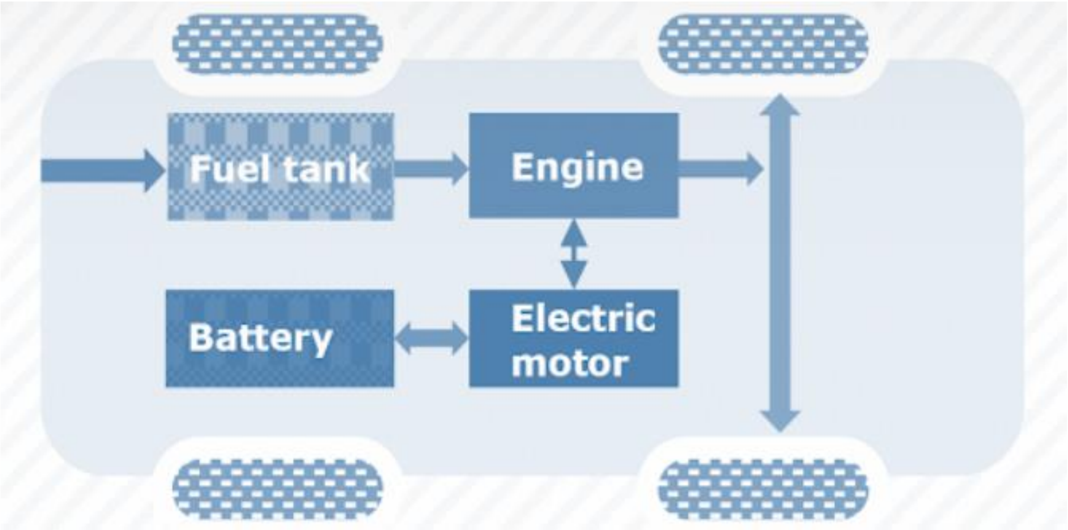


Hybrid Electric Vehicle (HEV)

HEVs are also known as series hybrid or parallel hybrid. HEVs have both engine and electric motor. The engine gets energy from fuel, and the motor gets electricity from batteries. The transmission is rotated simultaneously by both engine and electric motor.

Main Components of HEV:

Engine, Electric motor, Battery pack with controller and inverter, Fuel tank, Control module



Examples of HEV:

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Plug-in Hybrid Electric Vehicle (PHEV)

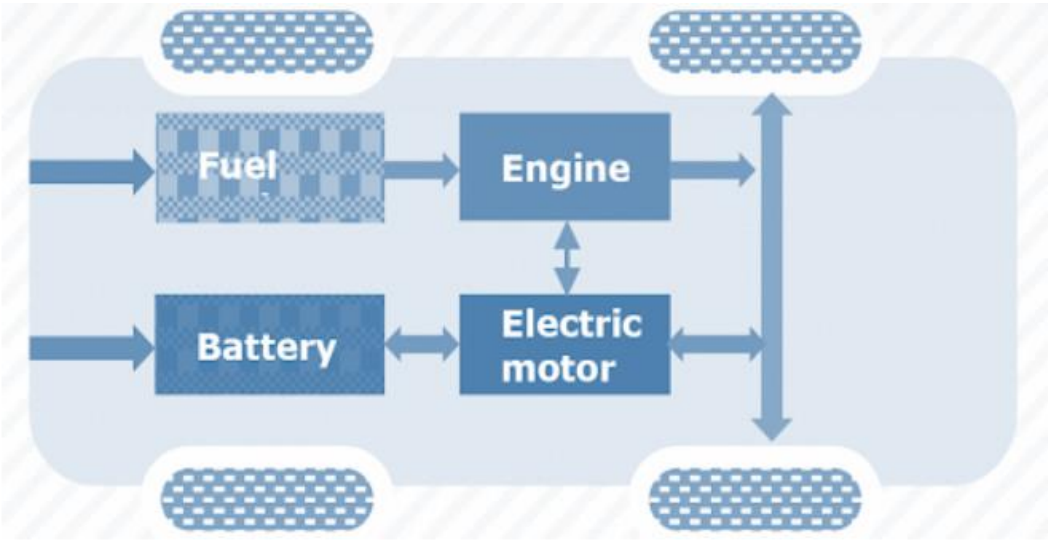
The PHEVs are also known as series hybrids. They have both engine and a motor. PHEVs can run in at least 2 modes:

I. All-electric Mode, in which the motor and battery provide all the car's energy

II. Hybrid Mode, in which both electricity and petrol/diesel are employed

Main Components of PHEV:

Electric motor, Engine, Inverter, Battery, Fuel tank, Control module, Battery Charger



Examples of PHEV:

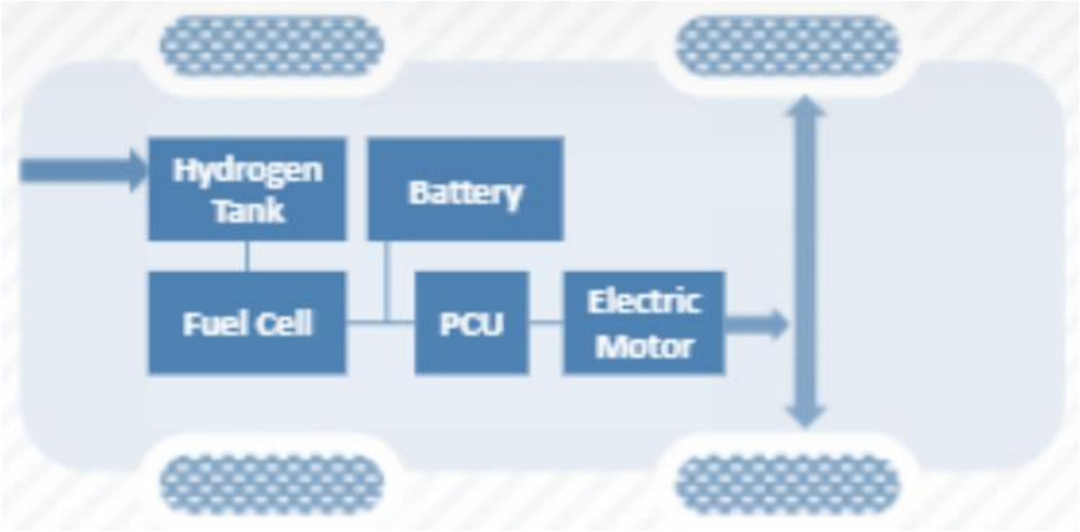
BMW 330e, Mercedes C350e, Mercedes S550e, Mercedes GLE550e, Mini Cooper SE Countryman, Ford Fusion Energi, Audi A3, Fiat 500e, Hyundai Sonata, Kia Optima, Volvo XC90 T8.

Fuel Cell Electric Vehicle (FCEV)

FCEVs are also known as **Zero-Emission Vehicles**. They employ ‘fuel cell technology’ to generate the electricity required to run the vehicle. The chemical energy of the fuel is converted directly into electric energy.

Main Components of FCEV:

Electric motor, Fuel-cell stack, Hydrogen storage tank, battery with converter and controller



Examples of FCEV:

Toyota Mirai, Riversimple Rasa, Hyundai Tucson FCEV, Honda Clarity Fuel Cell, Hyundai Nexo.

Benefits of Electric Vehicles

1. **Lower running costs**

   The electricity cost can be reduced further if charging is done with the help of renewable energy sources installed at home.

2. **Low maintenance cost**

   Electric vehicles have very low maintenance costs because they don’t have as many moving parts as an internal combustion vehicle. The servicing requirements for electric vehicles are lesser than the conventional petrol or diesel vehicles.

3. **Zero Tailpipe Emissions**

   Carbon footprint can further reduced by choosing renewable energy options for home electricity.

4. **Electric Vehicles are easy to drive and quiet**

   Electric vehicles don’t have gears and are very convenient to drive. There are no complicated controls, just accelerate, brake, and steer. Electric vehicles are also quiet, so they reduce noise pollution that traditional vehicles contribute to.

Electric Vehicle Myths and Facts

1. **Electric vehicles are uneconomical**

   Electric vehicles are more economical when you take fuel and maintenance cost.

2. **It takes too long to charge**

   - Cars spend over 90% of the time parked. During this downtime at home to charge.
   - If quickly charging required on the road, fast and rapid chargers are entering the Indian market.
   - Some electric vehicles can charge from 20% - 80% in about half an hour on these chargers.
   - As per the Bureau of Energy Efficiency, currently available electric vehicles across vehicle segments (2-wheeler, 3-wheeler, 4-wheeler) can be charged from 0%-80% in around 1 – 5 hours from Slow/Moderate chargers.
   - While using Fast chargers, electric vehicles can be charged in less than 1 hour. Fast chargers are mainly used to charge electric 4-wheelers with bigger batteries.

Electric Vehicle Myths and Facts

contd...

3. India's electric vehicle charging stations are not enough

- There are already 934 charging stations in India with more and more providers, both public and private, entering the space.
- The Ministry of Power (MoP) provides the following minimum requirements for the location of public charging stations:

  At least one charging station should be available in a grid of 3km x 3km.

  One charging station to be set up every 25km on both sides of highways/roads
- The Ministry of Housing and Urban Affairs (MoHUA) amended its Model Building Byelaws (MBBL) 2016 to include the provision of electric vehicle charging in buildings Charging infrastructure shall be provided for electric vehicles at 20% of all 'vehicle holding capacity'/'parking capacity' at the premises.

Electric Vehicle Myths and Facts

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4. India's electricity grid is not suited for electric vehicles

- Electric vehicles result in a reduction of life-cycle carbon dioxide emissions even with the current Indian grid fuel mix.
- The India has committed to having 175 GW of installed Renewable Energy (RE) capacity by 2022 and up to 450 GW by 2030.
- The current weighted average emission factor of the country for the national grid has been nearly constant over the past few years at 0.82 tCO_2 / MWh (as of 2018-19).

Service Providers in INDIA

Three primary areas where businesses can invest and build offerings around electric mob

Micro Mobility	Bounce	Vogo	Yulu	Zyapp
Car Sharing	Lithium Urban	Drivezy	E-Savari Rentals	
Ride Hailing	Ola	SmartE	Blue Smart	
Ride Sharing	BlaBlaCar	sRide		

Service Providers in INDIA

Three primary areas around electric mobility are: **Mobility**, **Infrastructure** and **Energy.**

Mobility as a Service
Electric Vehicle

Micro Mobility	Bounce	Vogo	Yulu	Zyapp
Car Sharing	Lithium Urban	Drivezy	E-Savari Rentals	
Ride Hailing	Ola	SmartE	Blue Smart	
Ride Sharing	BlaBlaCar	sRide		

Service Providers in INDIA

contd...

Infrastructure as a Service

EV Charging Infrastructure

Charging infrastructure manufacturers

Delta Electronics

Mass Tech

ABB India

Exicom

Charging station operators

Amara Raja

EESL

Tata Power

Fortum India

Volttic

Service Providers in INDIA

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Infrastructure as a Service
Traction Battery

Battery Recycling	Gravita India
Battery Subscription	Yet to be explored
Pay as you go	Sun Mobility
Battery-as-a-Service	Sun mobility; Esmito

Service Providers in INDIA

contd...

Energy as a Service

Virtual power plant

Yet to be explored

Renewable Energy and EV Charging System

Yet to be explored

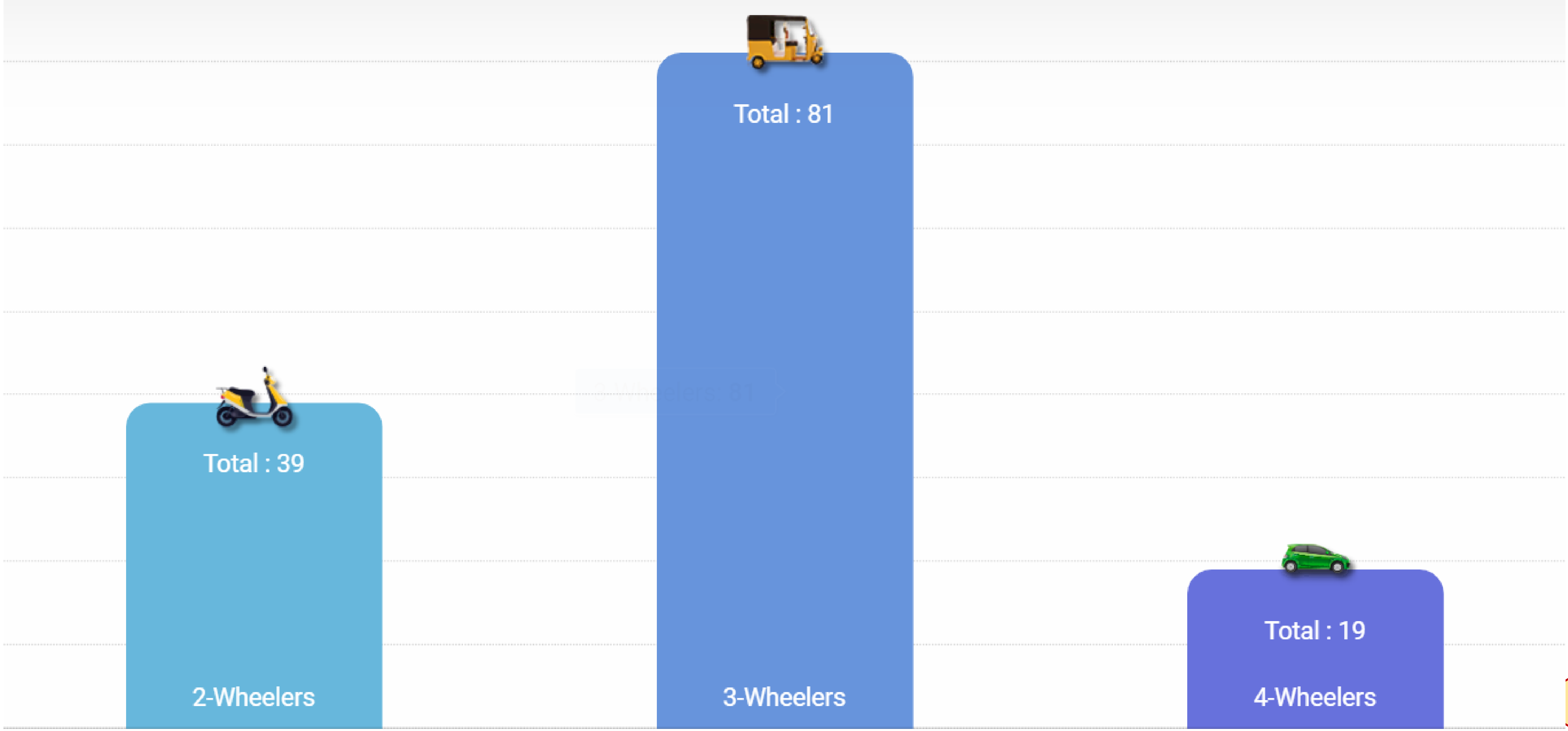
Network as a service

Numocity

Numocity Technologies

Manufacturers in INDIA

The models approved by Faster Adoption and Manufacturing of Hybrid and Electric Vehicles (FAME II) along with their manufacturers are as follows:



Two-wheelers Manufacturers in INDIA

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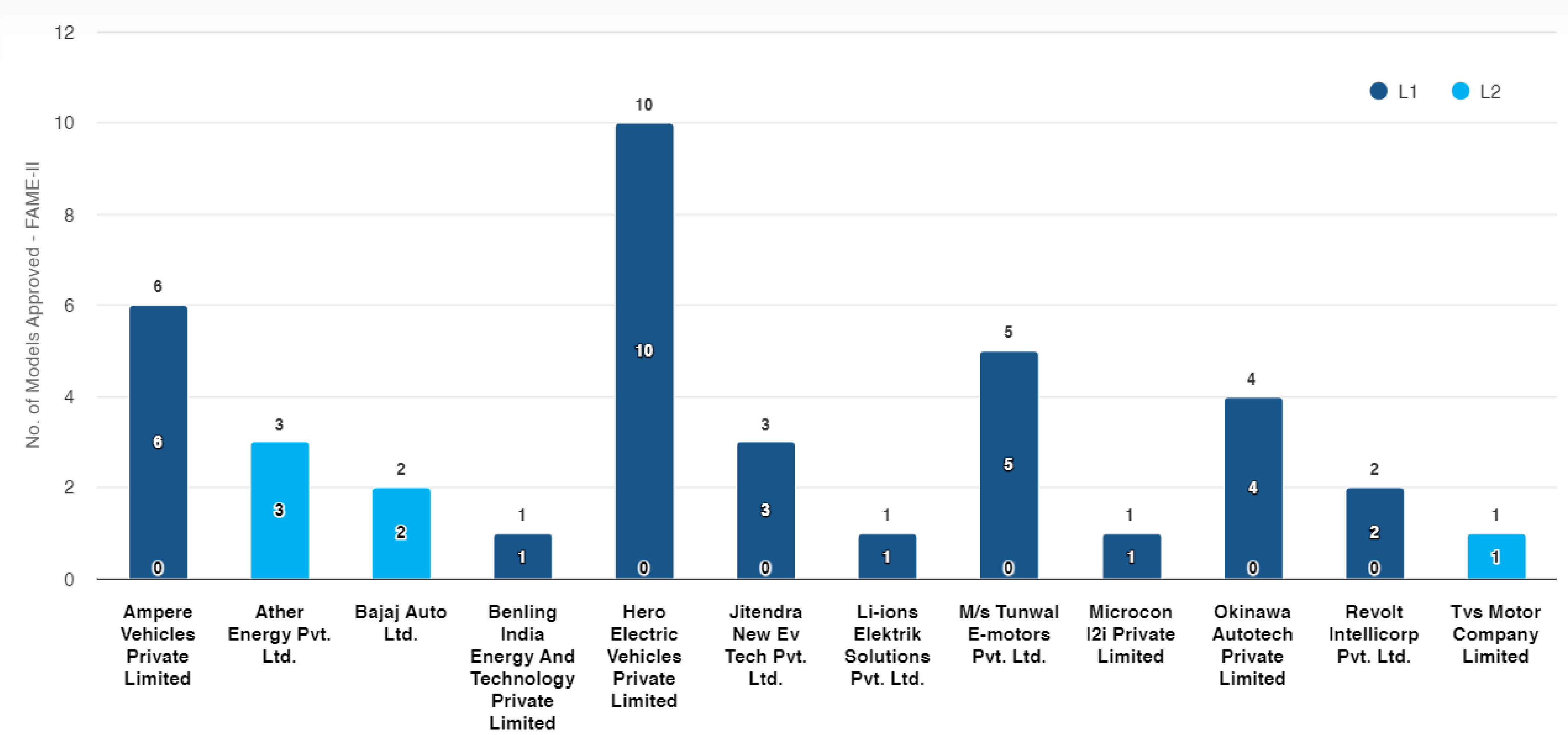

An L1 vehicle is defined as a two-wheeler with a maximum speed not exceeding 45 kilometres per hour (km/h) and motor power not exceeding 0.5kW if fitted with an electric motor. The L2 vehicle category comprises two-wheelers other than those in the L1 category.

Three-wheelers Manufacturers in INDIA

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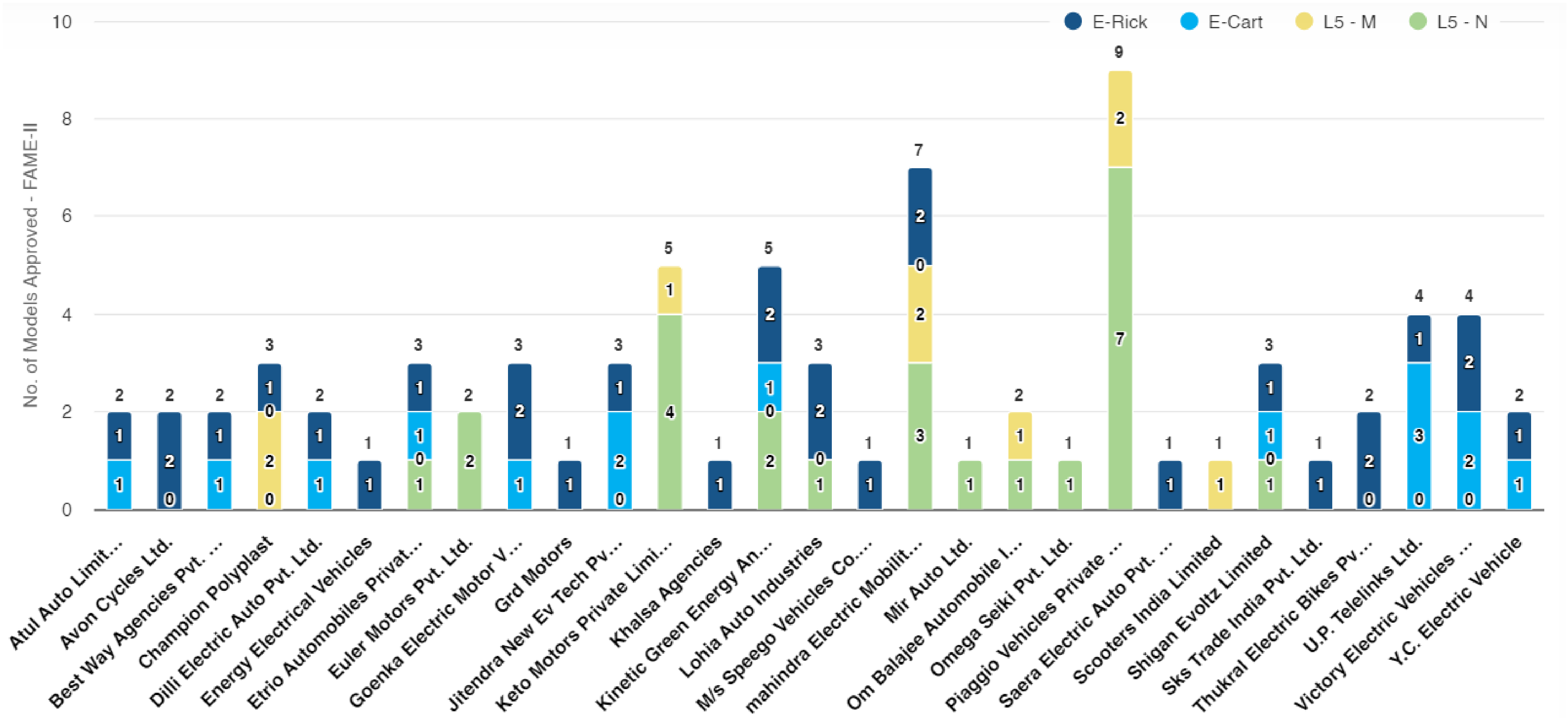

L5M: Means a L5M category-Passenger carrier (Auto rickshaw) and Gross vehicle Weight is equal to 1500 kilograms.

Four-wheelers Manufacturers in INDIA

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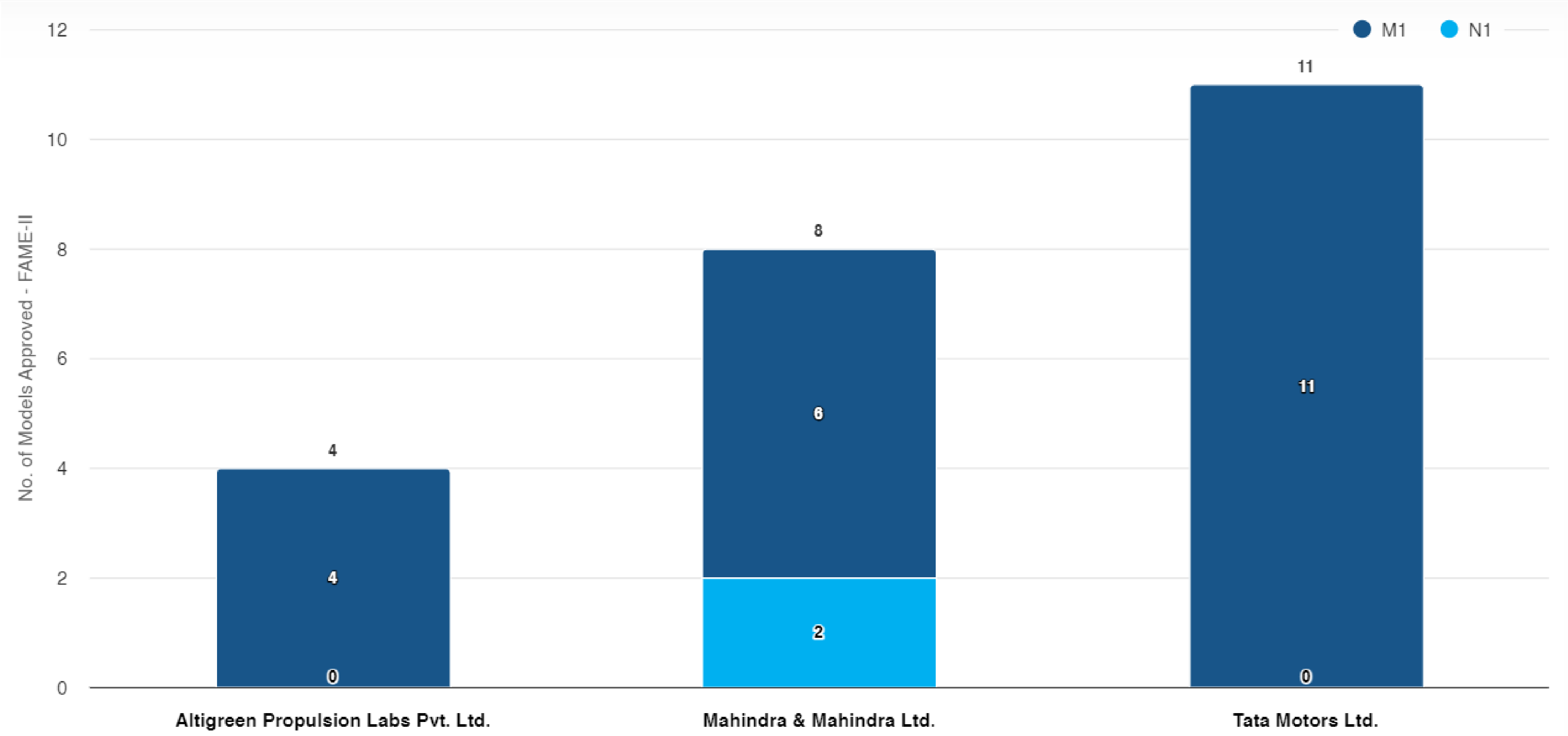
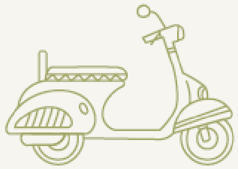
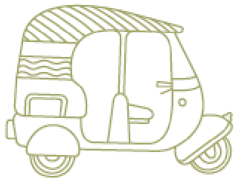
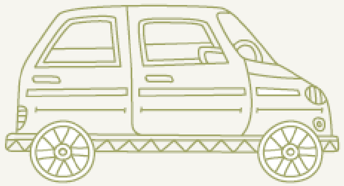
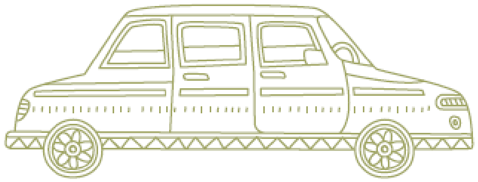
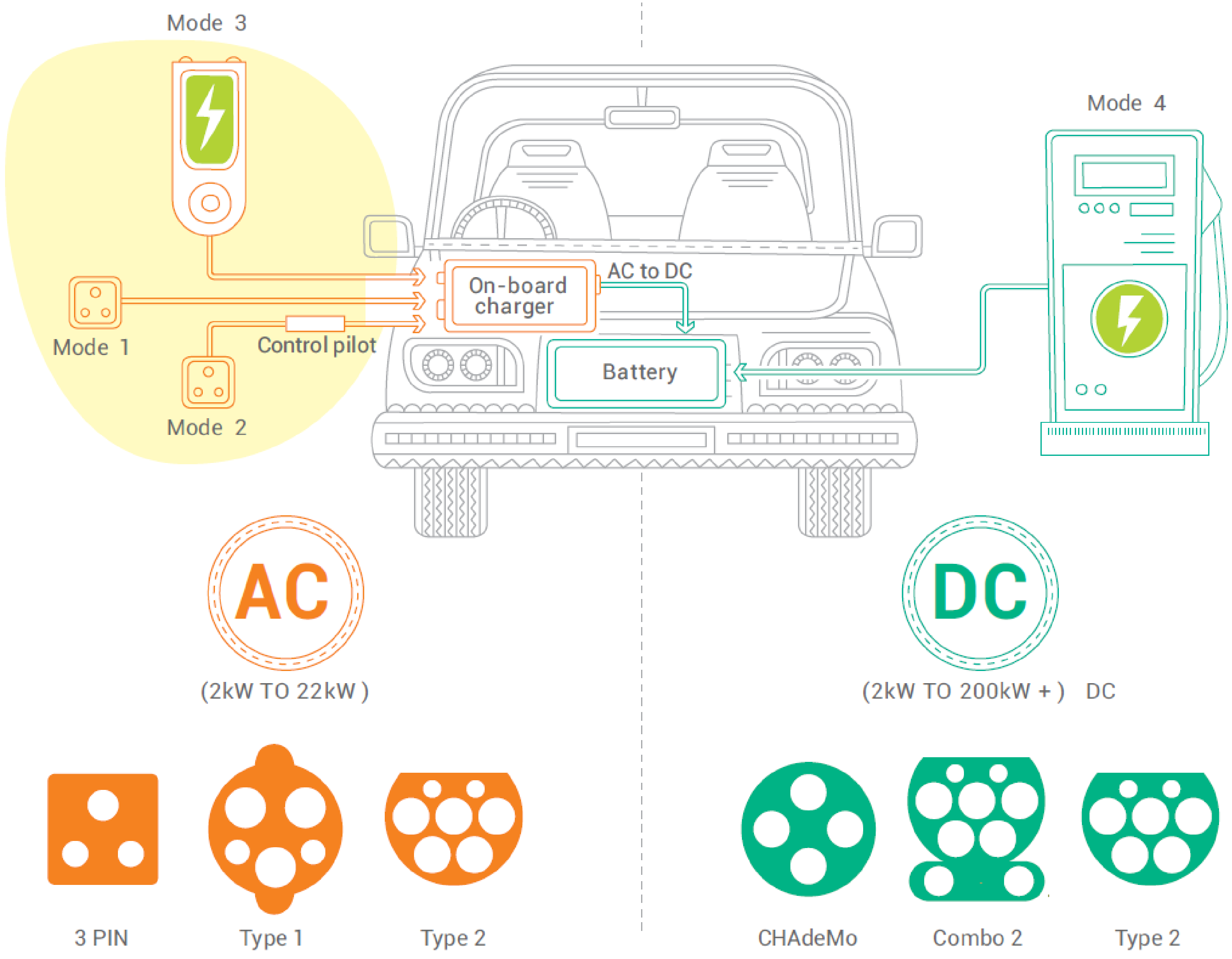


M1: means a motor vehicle used for the carriage of passengers, comprising not more than eight seats in addition to the driver's seat. N1: means a motor vehicles used for carriage of goods and having a Gross vehicle Weight not exceeding 3.5 tons

Typical Battery Specifications for Different EV Segments

VEHICLE SEGMENT	BATTERY CAPACITY	BATTERY VOLTAGE
 E-2W	1.2-3.3 kWh	48-72V
 E-3W (passenger/ goods)	3.6-8 kWh	48-60V
 E-cars (1st generation)	21 kWh	72V
 E-cars (2nd generation)	30-80 kWh	350-500V

Typical Charging Methods with Power Ratings



Electric Vehicle Charging Specifications

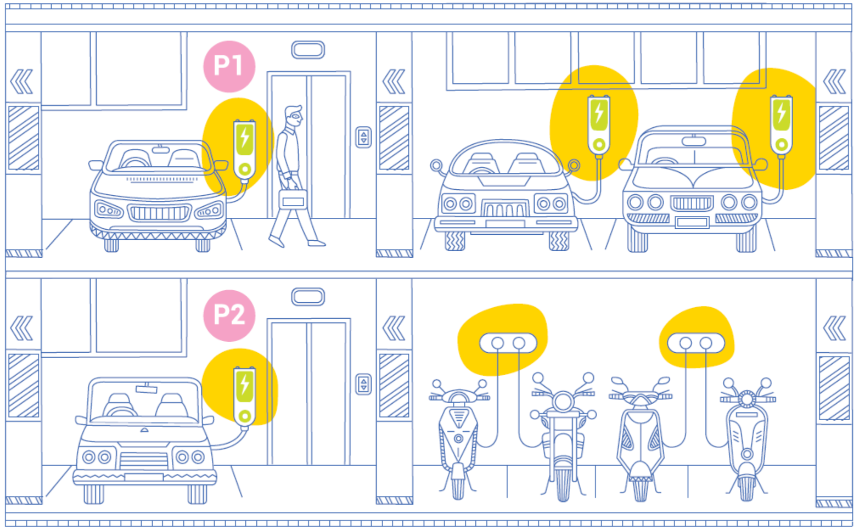
S. No	Charging Station	Voltage (V)	Power (kW)	Type of Vehicle	Type of compatible charger
1	Level 1 (AC)	240	<=3.5 kW	4w ,3w,2w	Type 1, Bharat AC-001
2	Level 1 (DC)	>=48	<=15 kW	4w,3w,2w	Bharat DC-001
3	Level 2 (AC)	380-400	<=22 kW	4w,3w,2w	Type 1, Type 2, GB/T ,Bharat AC-001
4	Level 3 (AC)	200-1000	22 to 4.3 kW	4w	Type 2
5	Level 3 (DC)	200-1000	Up to 400 kW	4w	Type 2, CHAdeMO,CCS1,CCS2

Electric Vehicle Supple Equipment Power Ratings

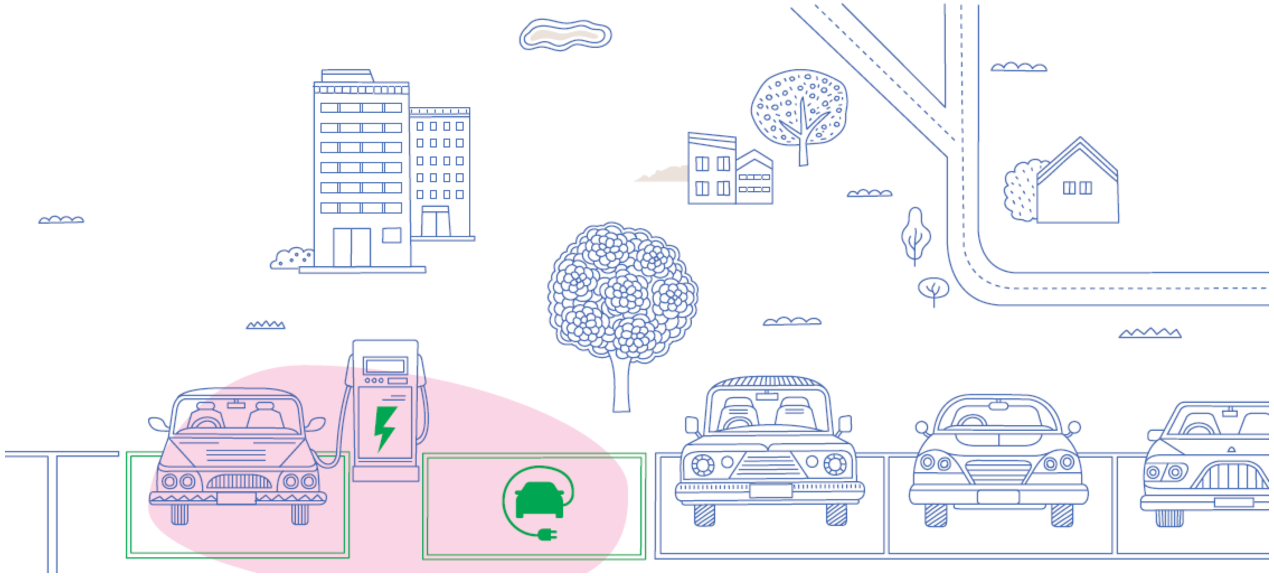
	Power level	Current type	Compatible EV segments
Normal power charging	P ≤ 7kW	AC & DC	E-2Ws, e-3Ws, e-cars, other LCVs (up to 1 ton)
	7kW < P ≤ 22kW	AC & DC	
High power charging	22kW < P ≤ 50kW	DC	E-cars, LCVs and MCVs (1-6 tons)
	50kW < P < 200kW	DC	

Charging Infrastructure

Private Charging



Semi-Public Charging



Public Charging

Battery Swapping (Advantages and Challenges)

- An alternative battery recharging method that is receiving global attention is battery swapping, in which a depleted EV battery is removed from the vehicle and replaced with a fully charged one.
- The technology is being tried out for various EV segments, including e-2Ws, e-3Ws, e-cars and even e-buses.

Sl. No.	Advantages	Barriers
1.	EV recharging is completed in minutes.	Lack of standardization among EV batteries.
2.	Batteries can be charged away from swapping point, allowing more freedom in setting up swap facilities.	Unsuitable battery pack design to enable ease of swapping (weight and dimensions).
3.	Reduction in upfront cost of EV, as battery ownership is replaced by battery leasing	Greater number of batteries needed to power same number of EVs
4.	Increased predictability of battery life due to controlled charging conditions	Shorter commercial life of battery packs due to customer preference for new batteries with higher range

Introduction to Chargers

- ❖ Charging of electric vehicles (EV) can be done today with AC or DC charging.
- ❖ AC charging is done using the on-board AC/DC power converter of the EV using a single phase or three phase AC connection.
- ❖ Currently, there exits three types of AC charging systems used globally:

  1. Type1 SAE J1772-2009, single phase charger used in US
  2. Type 2 Mennekes VDE-AR-E 2623-2-2, single and three phase charger used in Europe
  3. Tesla dual charger for single phase AC and DC

  Due to space and weight restrictions on the EV, AC charging is limited to Level 2 charging power levels of up to 22kW (Three-phase 400V, 32A).

Introduction to Chargers

contd...

- Type 1 plug provides for single phase charging using three power pins – namely phase (L1), neutral (N) and earth pin (E).
- The Type 2 plugs used widely in Europe supports three-phase charging using five power pins - three phase pins (L1,L2,L3) and neutral (N) and earth pin (E).

	Plug	Number of pins Communication	Charging level	Voltage & current	Maximum power
US	Type1 SAE J1772	3 power pins – L1,N,E 2 control pins – CP, PP (PWM over CP)	AC Level 1	1Φ 120V, upto 16A	1.9 kW
			AC Level 2	1Φ 240V, upto 80A	19.2 kW
Europe	Type 2 Mennekes	4 power pins – L1,L2,L3,N,E 2 control pins – CP, PP (PWM over CP)	AC Level 1	1Φ 230V, upto 32A	7.4 kW
			AC Level 2	3Φ 400V, upto 32A	22 kW
SAE	Type 4 SAE J1772 CCS	3 power pins – DC+,DC-,E 2 control pins – CP, PP (PLC over CP, PE)	*DC Level 1*	200-450V DC, upto 80A	36kW
			DC Level 2	200-450V DC, upto 200A	90kW
			DC Level 3	200-600V DC, upto 400A	240kW
Chademo	Type 4 Chademo	3 power – DC+,DC-,E 7 control pins (CAN communication)	DC Level 3	200-500V, upto 125A	62.5kW
	Tesla US	3 power pins – DC+,DC-,E 3 power pins (reused) – L1,N,E 2 control pins – CP, PP	DC Level 3	For Model S, 400V, upto 300A	120kW

Introduction to Chargers

contd…

DC Chargers

- ❖ The off-board chargers are unrestricted by space and weight constraints of on-board chargers, they can go up to Level 3 charging power levels of 240kW.
- ❖ Currently, there exist three types of DC charging systems used globally:
  1. **Type 4 CCS/COMBO (Combined Charging System)**
  2. **Type 4 Chademo**
  3. **Tesla dual charger for single phase AC and DC**

The three systems use three power pins for transferring the power namely - two DC power pins DC+, DC- and one earth pin (E). They differ however in the communication and control protocol used.

Dynamic Charging vs Static Charging

Dynamic charging as used here refers to charging an EV with variable power. This is in contrast to static charging where the EV is charged with a constant power.

The term dynamic charging must not be confused with dynamic ‘on-road’ charging which refers to charging a car while driving.

The benefits of dynamic charging are:

- To match EV charging with uncontrollable renewable generation like solar or wind.
- To match EV charging with variable grid prices so as to optimize the cost of charging.

Dynamic charging is hence a method of demand side management by which the mismatch between renewable generation and load can be minimized without the use of additional storage systems.

This gives benefits of reduced cost of charging, lower reserve generation capacity in the grid, lesser grid violations due to EV charging and reverse flow of renewable generation.

Thankyou