Program on EV Technology and Policy – Day 1

7th May 2022

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Sona Comstar Automotive Technology, Chennai

Unit No	Topics
I	Environmental impact and history, Types of Electric vehicles
II	Electric vehicle, Electrical Propulsion System
III	Energy Storages, Charging System, Effects and Impacts
IV	Electric Mobility Policy Frame Work
V	Tamilnadu E-Vehicle Policy 2019

Objectives

- To learn the environmental impact and history of Electric Vehicles
- To understand the concept of Electric Vehicle and its types
- To study the configurations of Electric Vehicles
- To acquire knowledge about Energy Storages, Charging System, Effects and Impacts
- To appreciate the Electric Mobility Policy Frame work India and EV Policy Tamil Nadu 2019.

Outcomes

- Appreciate the need of an Electric Vehicle
- Compare the different EV vehicle specifications in the market
- Choose the right motor, inverter and battery systems for EVs
- Workout the benefits of EV cost based on the Govt policy

Environmental impact and history

- Environmental Impact of Conventional Vehicle
- Air Pollution
- Petroleum Resources
- History of Electric vehicles & Hybrid Electric Vehicles
- Conventional Drive-train System
- Rear Wheel, Front Wheel and All wheel Drive-train System
- Parts of Drive-train system

Government preparing scheme for battery cell manufacturing to boost EV adoption: Amitabh Kant

The government is not in the business of dictating which technology should be used. Tomorrow a new technology might emerge, said Amitabh Kant while replying to a question.

EESL plans 10 EV charging plazas in FY21

A plaza has more than one charger of different type of power output to service different needs of automobile models.

Simple Energy in talks with investors to raise USD 1 mn

The proceeds will be utilised for testing and certification of its 280-km range range scooter as the company seeks to secure Automotive Research Association of India's (ARAI) approval for its maiden offering by December, before the proposed launch in February-March next year.

Electric carmakers bet New Yorkers want four-wheeled freedom

Lucid Motors, Polestar open NYC showrooms to tap demand, as New Yorkers grow wary of trains and planes as pandemic spreads.

Chinese electric vehicle maker Li Auto aims to raise up to $950 mln in growth push

The IPO is the latest gauge of U.S. investor demand for Chinese companies going public.

Hero MotoCorp invests Rs 84 crore in Ather Energy

Hero MotoCorp has been a part of Ather's growth story since 2016, when it first invested as a part of Series B funding.

E-bikes give the two-wheeled market a jolt

Renewed enthusiasm for two-wheeled transport has turbocharged e-bikes.

EVs can play an important role in giving a new dimension to the national economy: CM Yogi

The chief minister stressed on making electronic vehicles affordable, easy to operate and efficient so that they become popular among the people.

Delhi government likely to incentivize use of electric vehicles

According to Delhi Transport Minister Kailash Gahlot, an incentive-based policy is likely to be formulated that encourages commuters to shift from fossil fuels powered vehicles to electric.

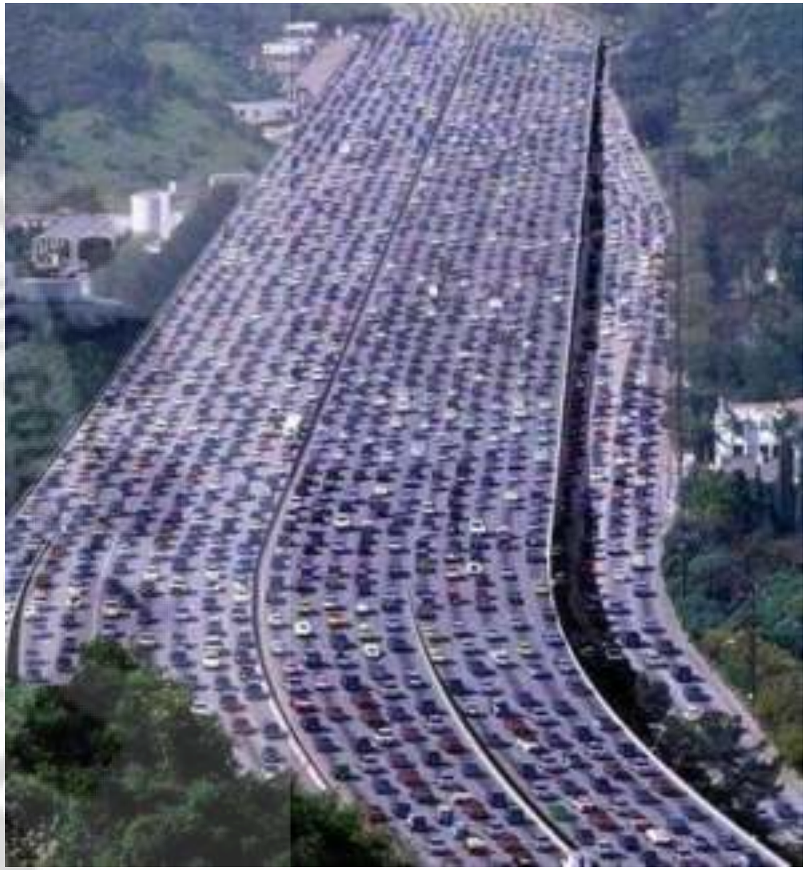
Panel on electric vehicles to submit report within a month

According to the minister, industry players provided a picture of how EV policies are implemented the world over and even made a presentation on the matter.

Switch to electric or ethanol, Nitin Gadkari tells bus operators

Addressing over 3,000 bus operators in Navi Mumbai for a three-day Bus Expo Prawas, Gadkari said the buses running on diesel are not good for the country's future.

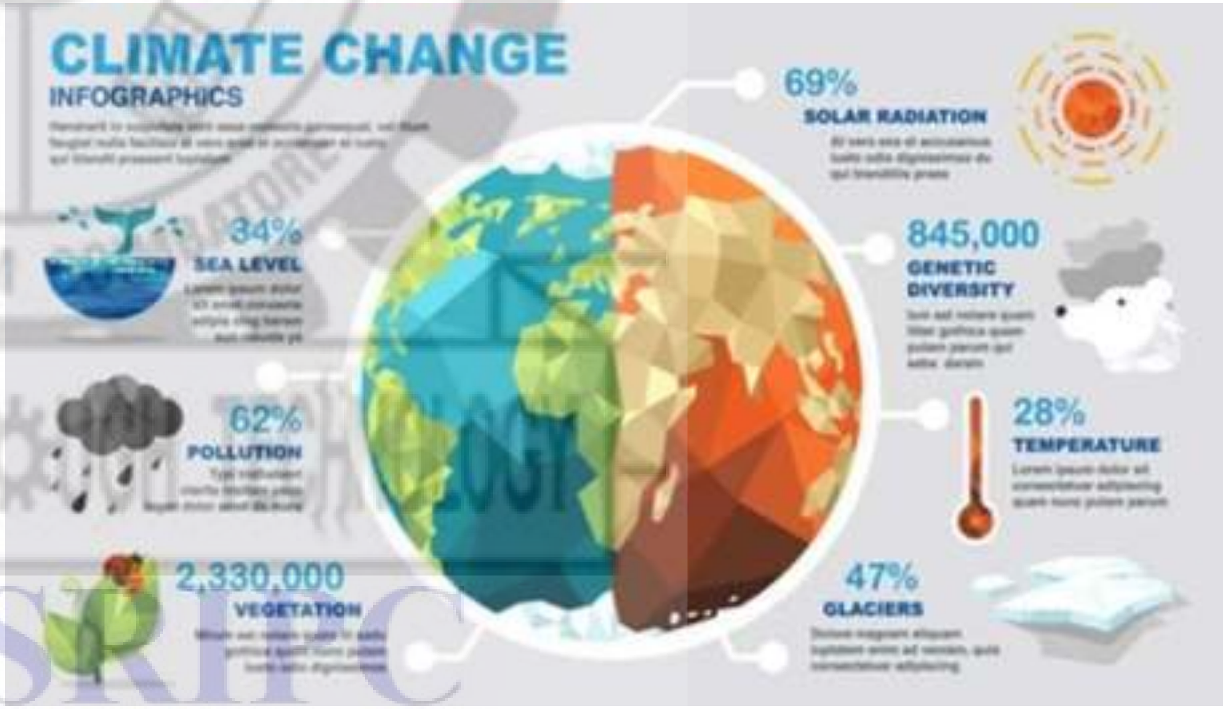
We are in the midst of transformation!



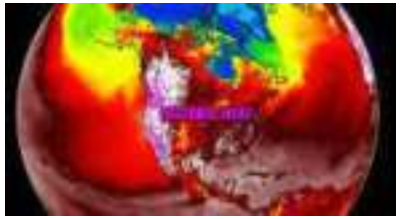
Air Pollution


Causes
Rapid industrialization
Energy use
Agricultural practices
Deforestation
Consumer practices
Livestock
Transport
Resource extraction
Pollution
Effects
Rising temperatures
Rising sea levels
Unpredictable
weather patterns

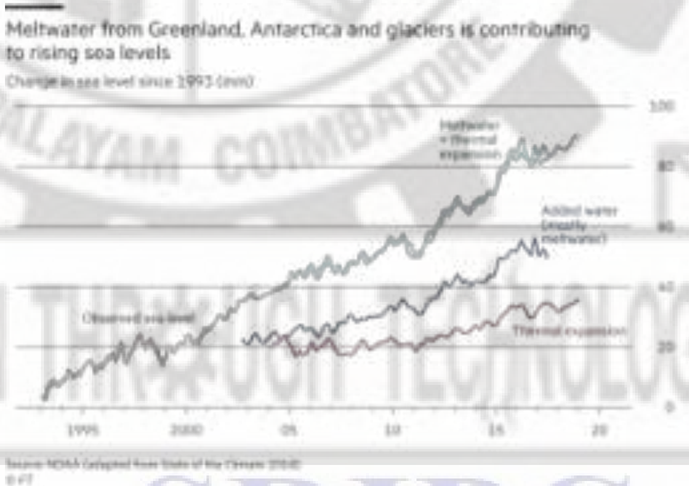

GLOBAL WARMING CLIMATE CHANGE

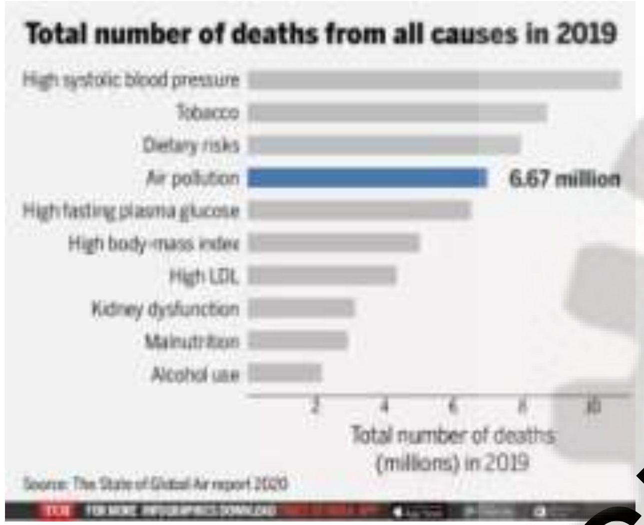

CLIMATE CHANGE
INFOGRAPHICS
69%
SOLAR RADIATION
34%
SEA LEVEL
845,000
GENETIC DIVERSITY
62%
POLLUTION
28%
TEMPERATURE
2,330,000
VEGETATION
47%
GLACIERS

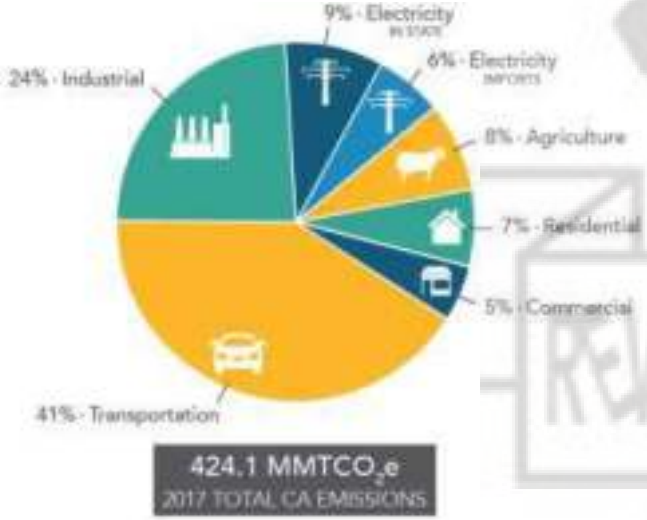

WION
230 dead as Canada records all-time high temperature of 49.5 degrees celsius

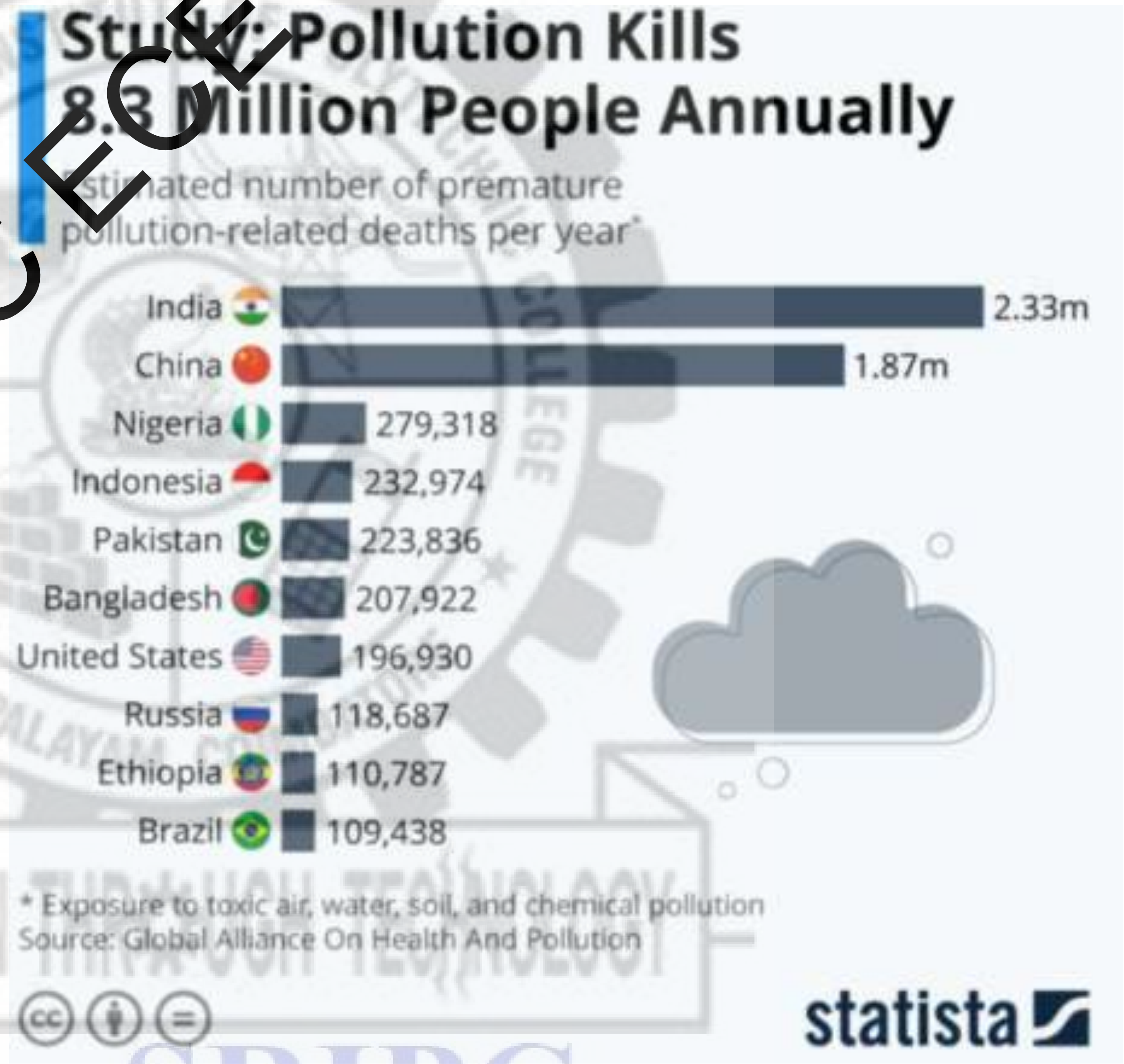



2021 European floods - Wikipedia


Meltwater from Greenland, Antarctica and glaciers is contributing to rising sea levels
Change in sea level since 1993 (mm)


Total number of deaths from all causes in 2019
High systolic blood pressure
Tobacco
Dietary risks
Air pollution
6.67 million
High fasting plasma glucose
High body-mass index
High LDL
Kidney dysfunction
Malnutrition
Alcohol use
2
4
6
8
10
Total number of deaths (millions) in 2019
Source: The State of Global Air report 2020


9% - Electricity
6% - Electricity
24% - Industrial
8% - Agriculture
7% - Residential
5% - Commercial
41% - Transportation
424.1 MMTCO2e
2017 TOTAL CA EMISSIONS


Study: Pollution Kills 8.3 Million People Annually
Estimated number of premature pollution-related deaths per year*
India 2.33m
China 1.87m
Nigeria 279,318
Indonesia 232,974
Pakistan 223,836
Bangladesh 207,922
United States 196,930
Russia 118,687
Ethiopia 110,787
Brazil 109,438
* Exposure to toxic air, water, soil, and chemical pollution
Source: Global Alliance On Health And Pollution
statista

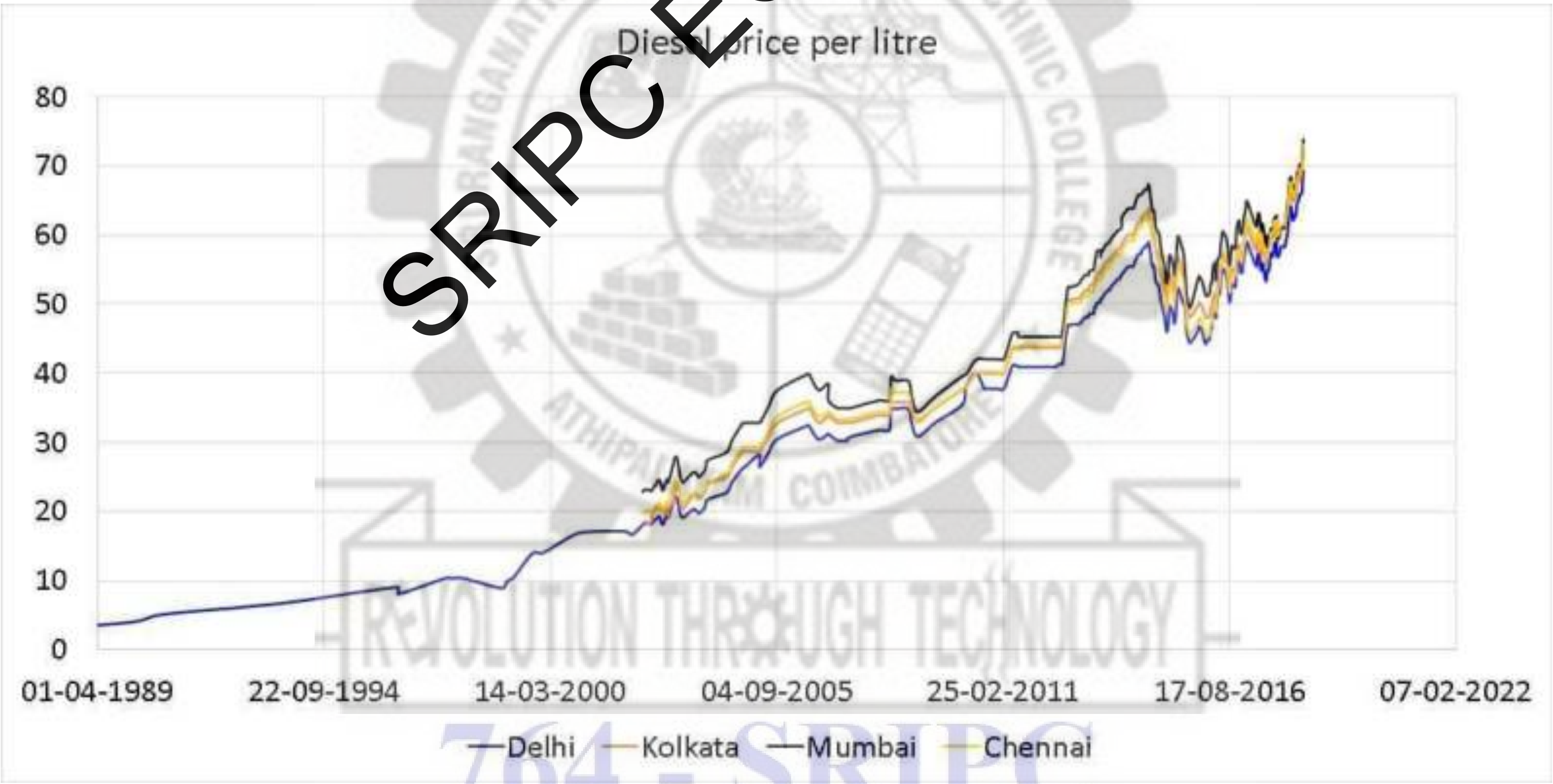
On Board Diagnostics

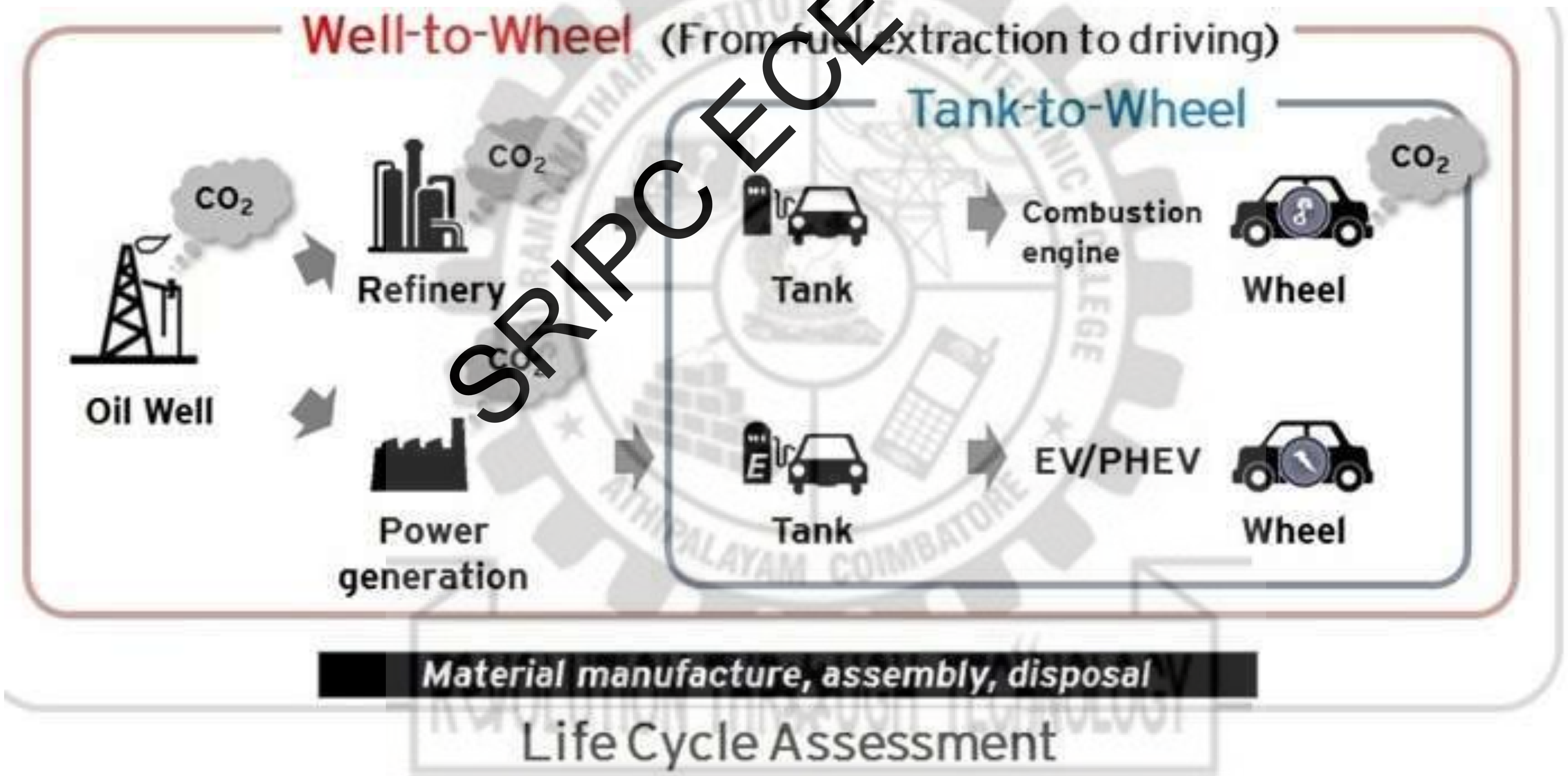
Petroleum Resources

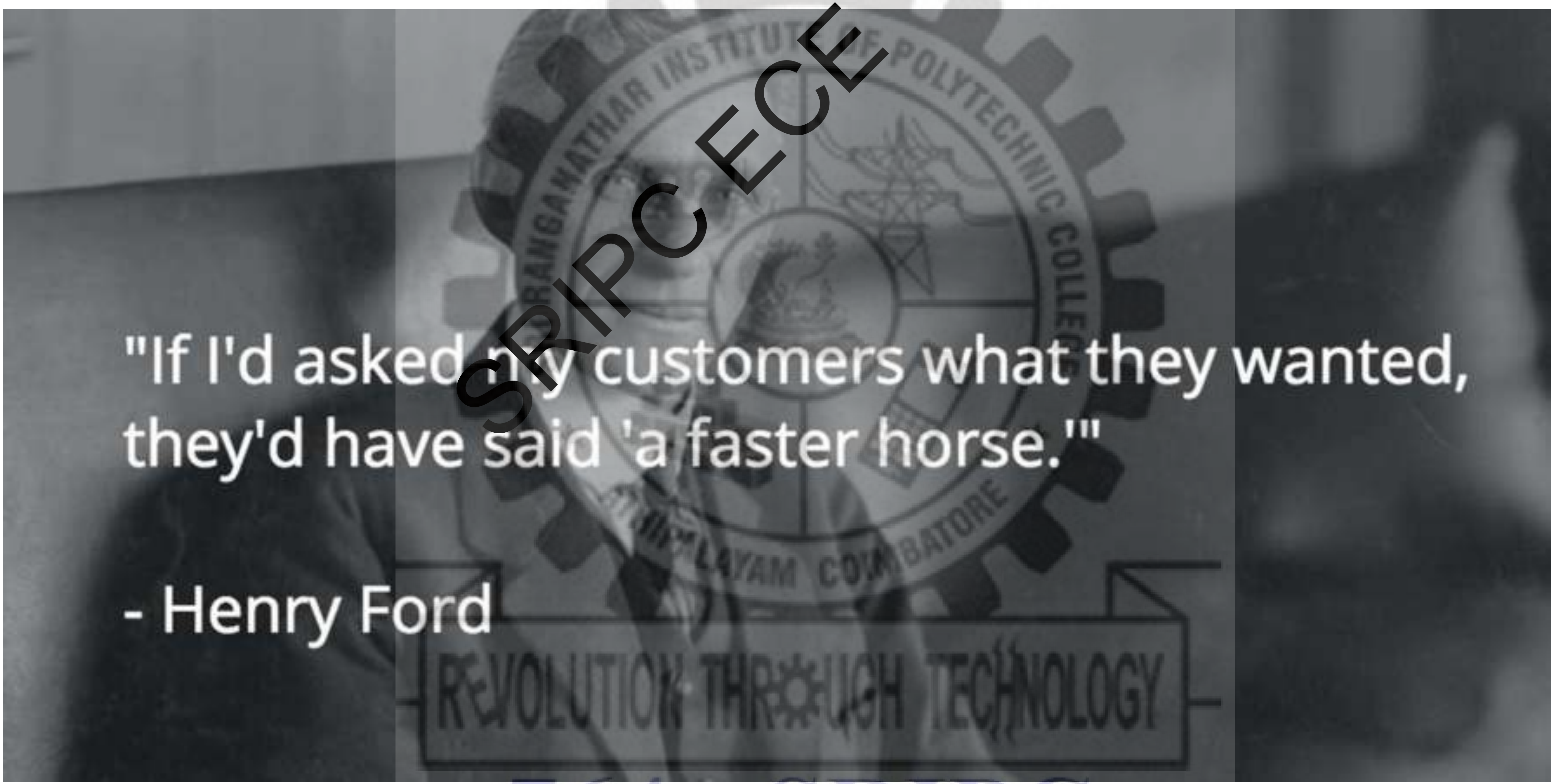
Top countries with the largest oil reserves in 2019

1. Venezuela – 304 billion barrels. ...
2. Saudi Arabia – 298 billion barrels. ...
3. Canada – 170 billion barrels. ...
4. Iran – 156 billion barrels. ...
5. Iraq – 145 billion barrels. ...
6. Russia – 107 billion barrels. ...
7. Kuwait – 102 billion barrels. ...
8. United Arab Emirates – 98 billion barrels.

Diesel Price Movement




Well-to-Wheel (From fuel extraction to driving)
Tank-to-Wheel
CO2
CO2
CO2
CO2
CO2
Oil Well
Refinery
Power generation
Tank
Tank
Combustion engine
EV/PHEV
Wheel
Wheel
Material manufacture, assembly, disposal
Life Cycle Assessment


"If I'd asked my customers what they wanted,
they'd have said 'a faster horse.'"
- Henry Ford

What Mobility Was Supposed to Mean…

What It In Fact Came to Mean…

Paved Roads, Highways, Gas Stations, Motels, …

Suburbia, Fast-Food Restaurants, Taxis, Dealerships, Mechanics, …

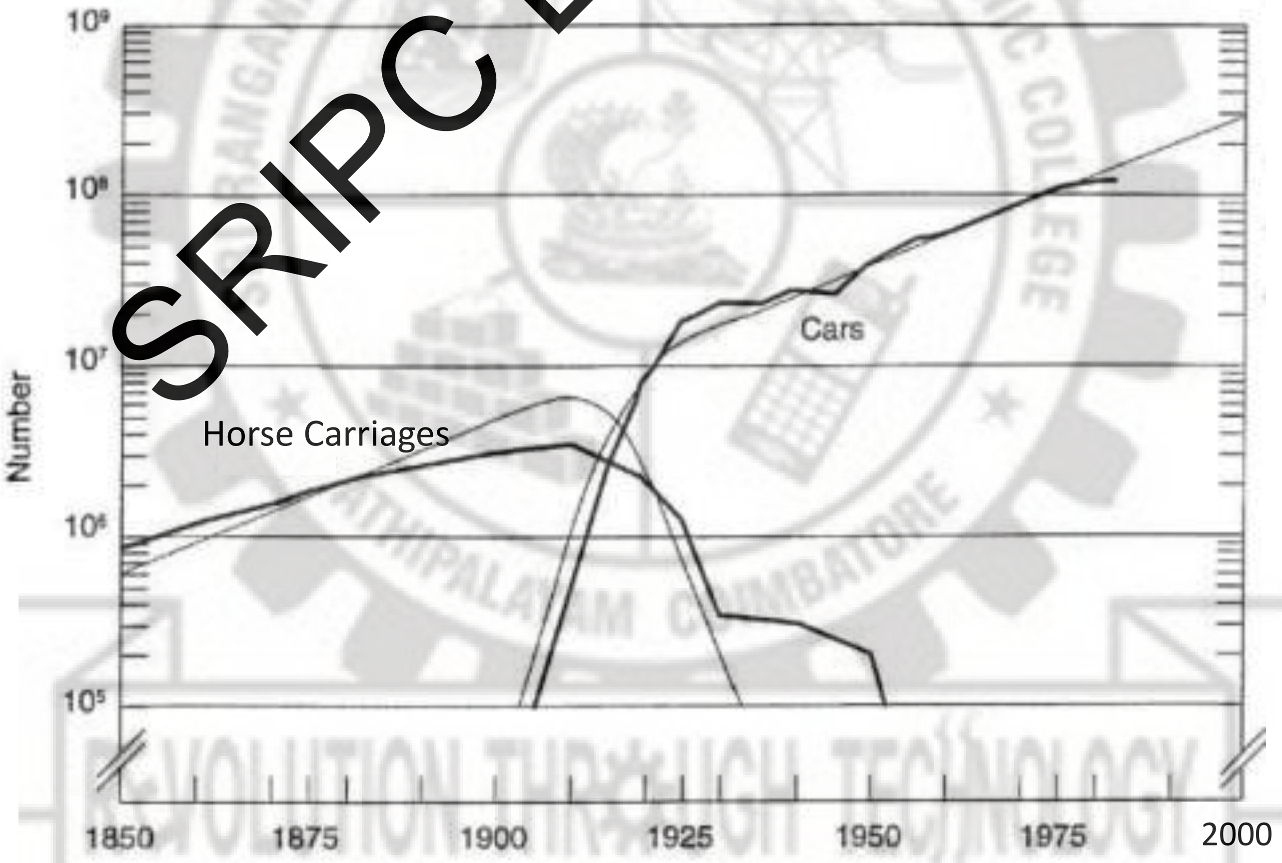
All This Was Preceded by 'The Great Horse Manure Crisis' of 1890s.

But Innovators Were Already at Work…


Gottlieb Daimler in a motor vehicle constructed by himself in 1886.


Karl Benz seated on the 1885 Benz Motorwagen.

...Resulting the First Disruption in Mobility.



Source: Nakicenovic, N., 1986. The automobile road to technological-change - Diffusion of the automobile as a process of technological substitution. Technological Forecasting and Social Change 29 (4), 309–340.

Why Was the Model T Successful?

SOCIETAL CONCERNS ADDRESSED BY MODEL-T

Convenience

- Horses needed time to prepare
- Space for stable
- Difficult to maintain and operate.

Safety

- Frightened and out-of-control horse could create havoc
- Overturning of carriages used to be common

Environment

- Manure on the street
- Dead horses left behind
- Fear of epidemics

Drivers of the First Disruption in Mobility

TECHNOLOGICAL ADVANCES OF 1900s

- Internal Combustion Engine
- High-Strength Alloy Steel
- Mass Production

Drivers of the New Disruption in Mobility

Unprecedented Computing Power

DATA ANALYTICS

TECHNOLOGICAL ADVANCES OF 2000s

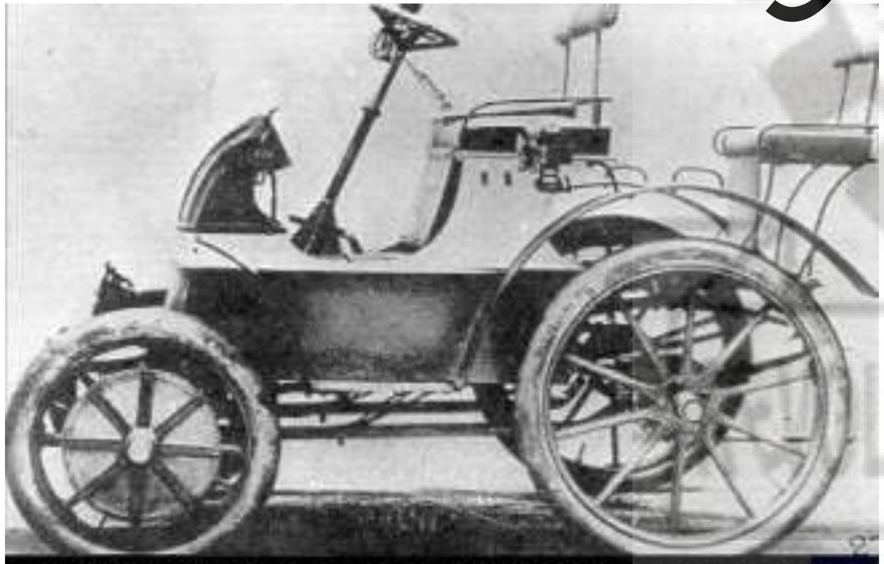
Virtually Free Data Storage

DATA STORAGE

Sensors, Cameras and other IoT Devices

DATA COLLECTION

Thomas Edison aboard his own 1902 Studebaker Electric in the left photo. Edison and his camping buddy Henry Ford also tried their hand at an electric car and built at least one prototype before both decided that the gasoline engine had a more promising future. One factor was that electricity was not yet widely available outside city centers, severely limiting the market for cars tied to that infrastructure. Drivers could carry spare cans of gasoline for long journeys, but spare batteries were a lot heavier per unit of energy.



The early 1900's Lohner-Porsche, originally electric-powered, then with an internal combustion engine powering hub-mounted electric motors.

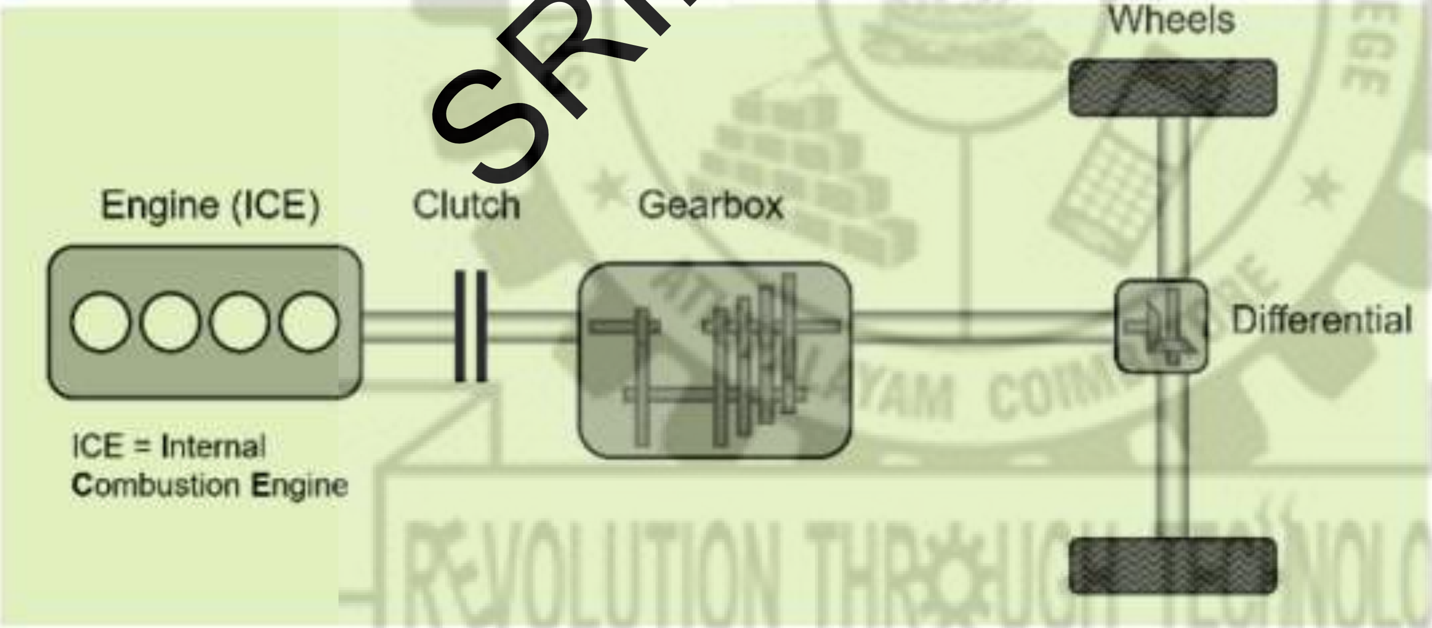
History of Electric vehicles & Hybrid Electric Vehicles





1923-1966 Electric Vehicles

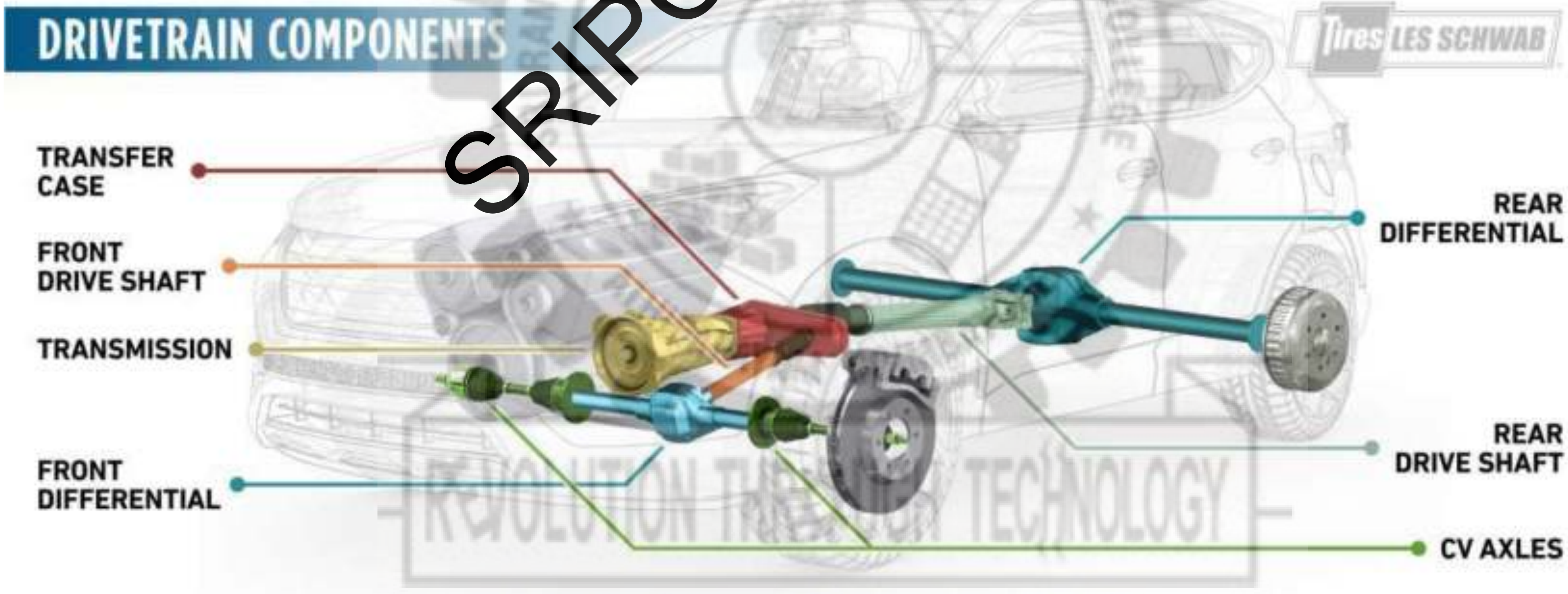
CONVENTIONAL POWERTRAIN



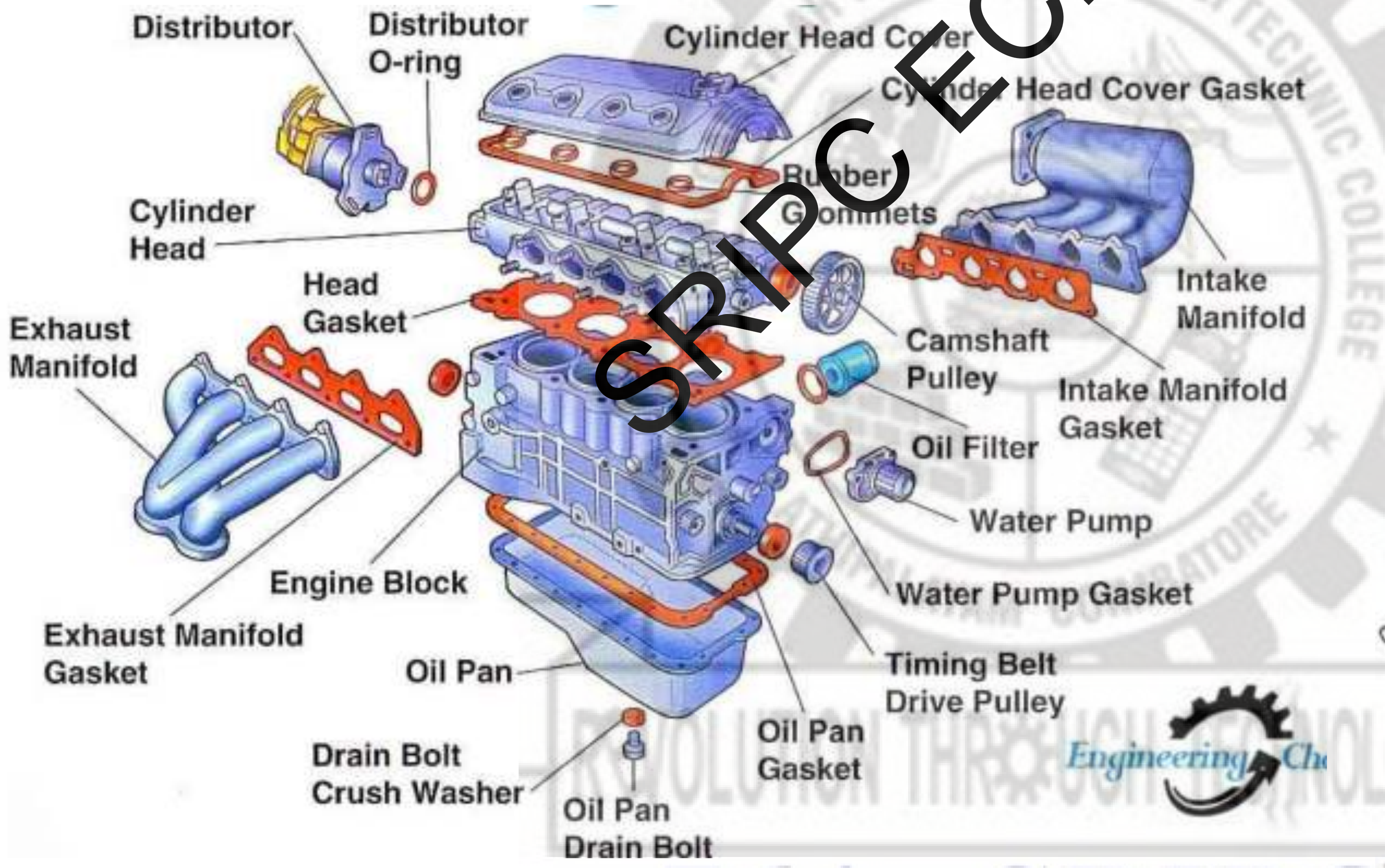
Advantages
- Long range
- Fast refueling
- Low cost per unit

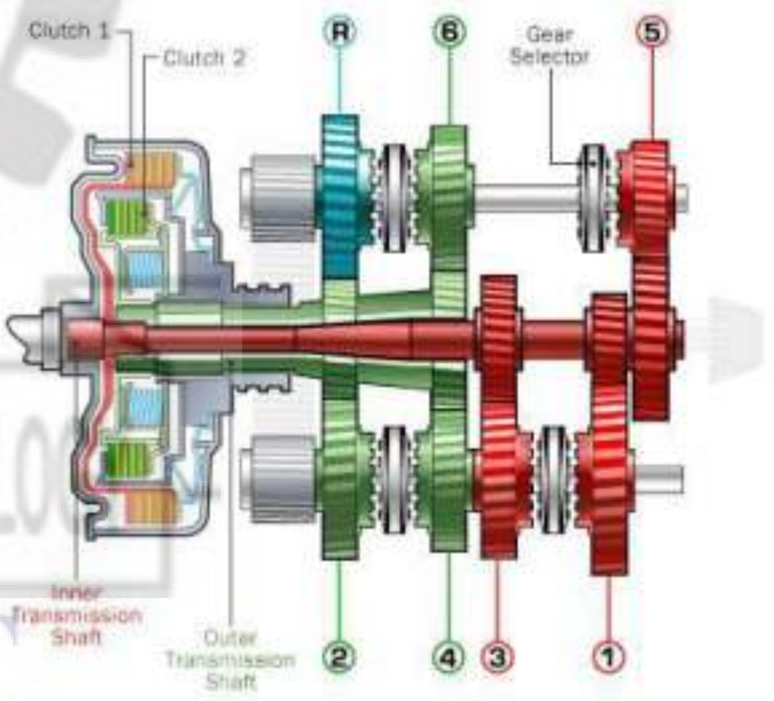
Disadvantages
- Low efficiency
- No regenerative braking
- Exhaust gases
- Noise

Parts of Drive train system

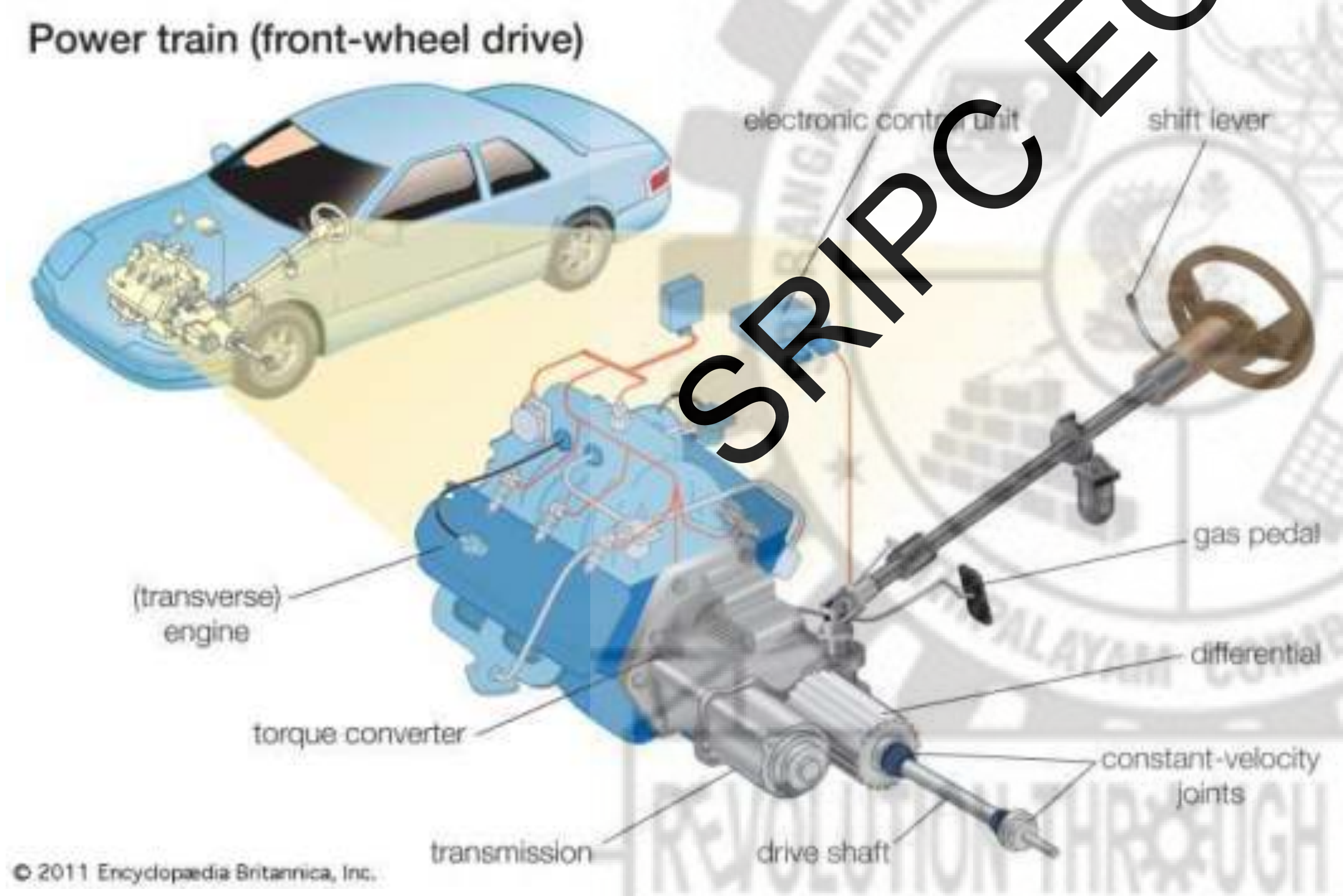


Key parts of Drive train system





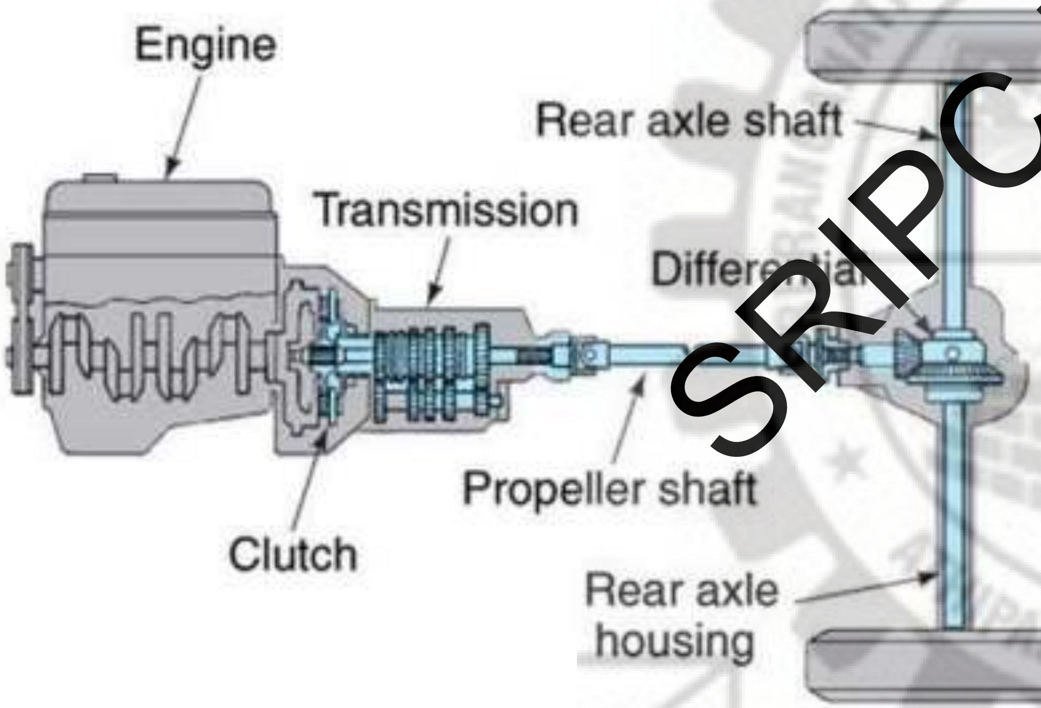
Front Wheel Drive (FWD)



- **Pros:**
  - Extremely efficient in terms of cost, mass, space, and fuel consumption
  - locating engine mass in front of the passenger compartment might improve crash safety.
- **Cons:**
  - Tires tasked with acceleration have less friction available for turning and can wear out more quickly; heavy front weight bias compromises handling responsiveness.

1. Mauti Suzuki Alto
2. Chevrolet Beat
3. Hyundai Verna
4. Hyundai i10
5. Honda City
6. Honda Civic
7. Toyota Corolla
8. Mitsubishi Outlander
9. Maruti Suzuki Ciaz
10. Volvo S40

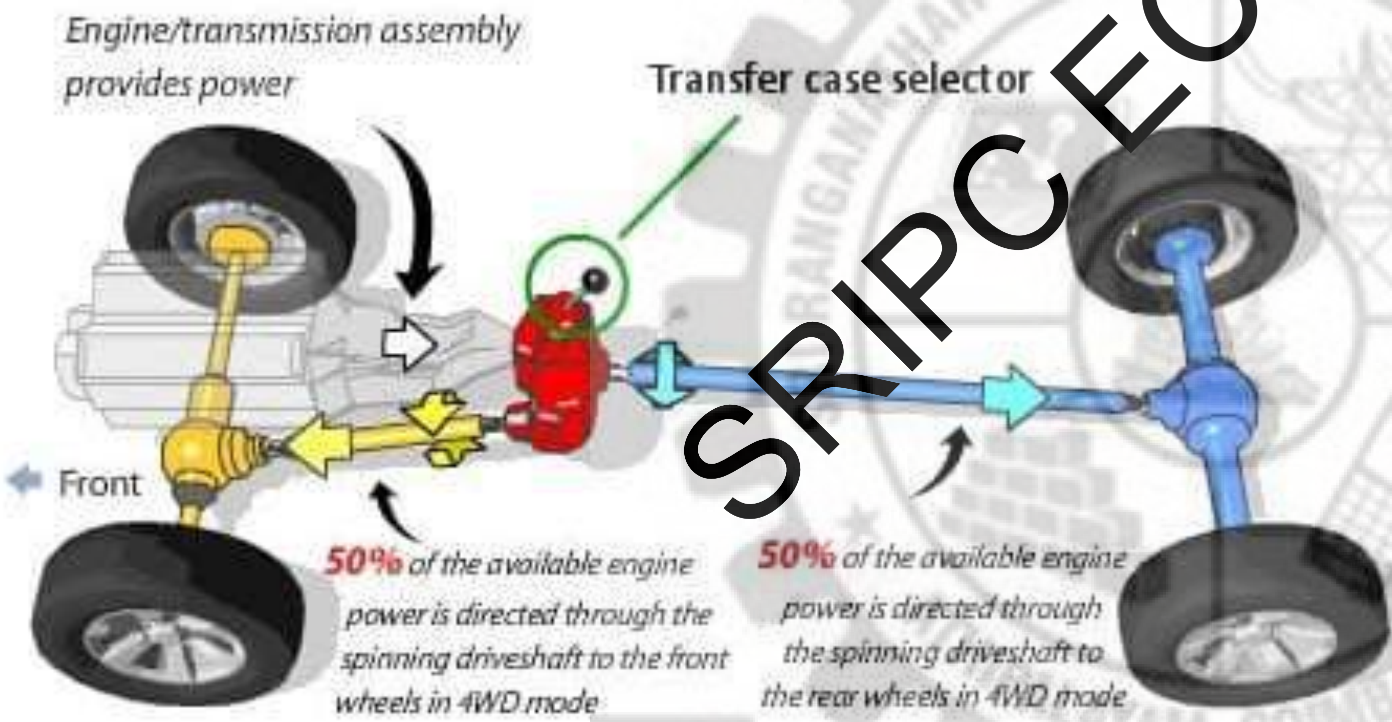
Rear Wheel Drive (RWD)



- ***Pros:*** *improves both steering feel and ultimate cornering grip; (mid- or rear-engine): engine weight over drive wheels plus dynamic rearward weight shift during acceleration optimizes accelerative traction.*
- ***Cons (Front engine):*** *added mass, cost, friction, rotational inertia of driveshaft, and gearing*

- Mahindra TUV300. ...
- Mahindra Bolero. ...
- Mahindra Scorpio. ...
- Tata Safari Storme.
- Toyota Innova.
- Ford Endeavour.
- Toyota Fortuner....
- MG Gloster.

AWD Pros And Cons:



- Mahindra Thar.
- Mahindra Alturas.
- Toyota Fortuner. ...
- Ford Endeavour. ...
- Jeep Compass. ...
- MG Gloster.

- **Pros:** Inherent traction advantage in all conditions, especially accelerating through turns and as engine power approaches or exceeds a level that can overwhelm two driven tires.
- **Cons:** Added cost, weight, rotational inertia, and friction reduce efficiency in all driving situations

CASE - Mega Trends in Automotive Industry

Connectivity

Source Picture: dbta.com

Autonomous Drive

Source Picture: Google

Shared Services

Source Picture: Daimler

Electrification

Source Picture: sigearth.com

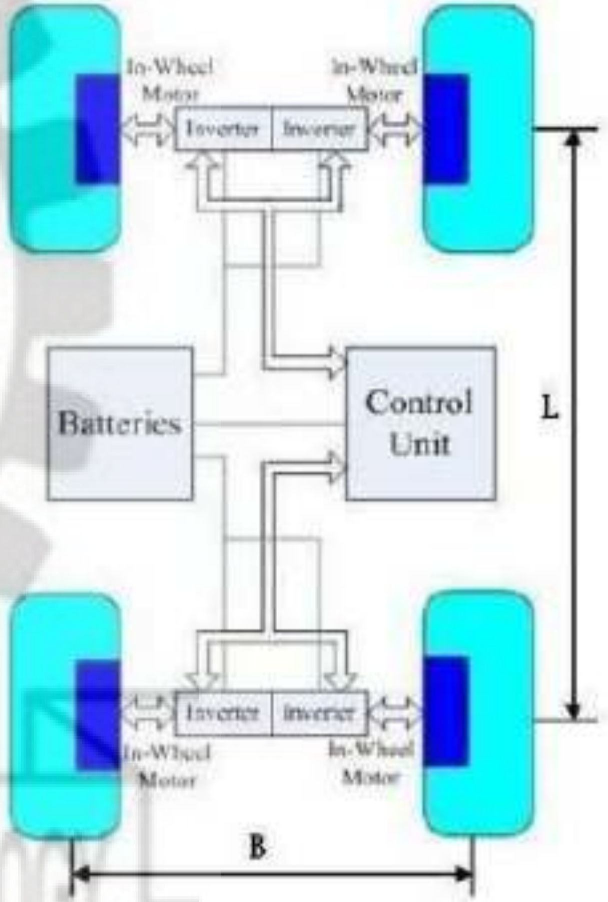
End of Session-1

Any Questions?

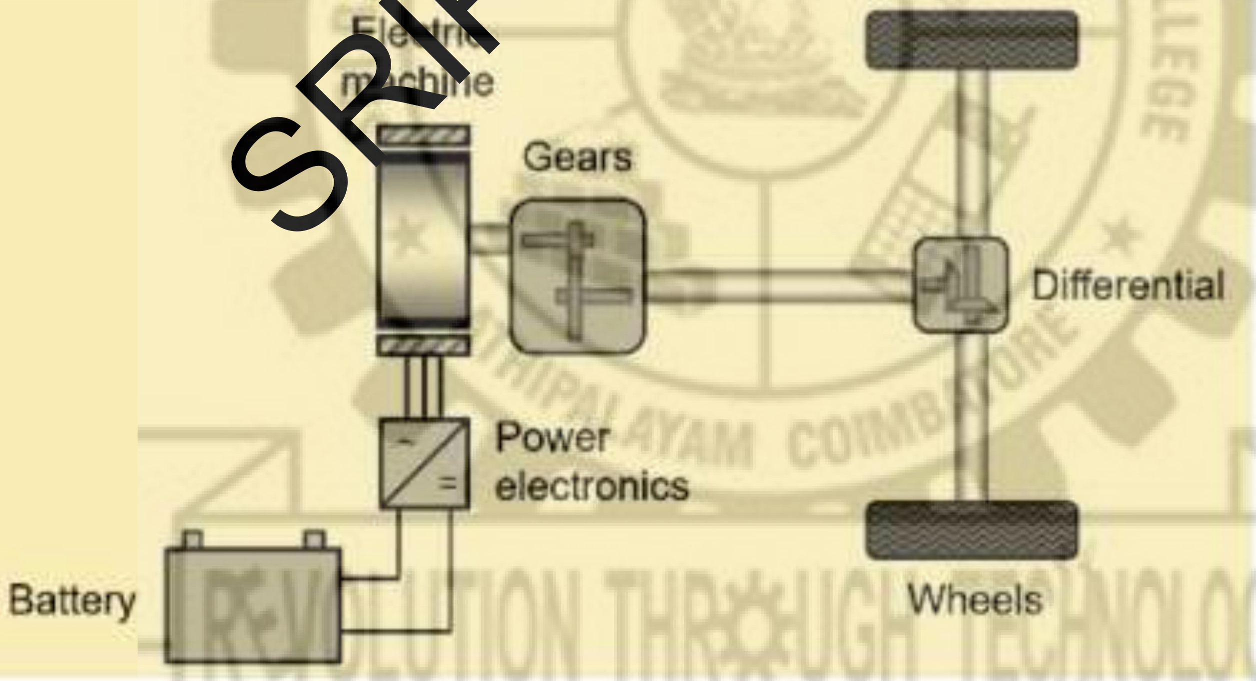
Types of Electric Vehicles

- Introduction to Battery Electric Vehicle (BEV)
- Definition BEV
- Necessity BEV
- Different between BEV and Conventional Vehicle
- Advantages of BEV
- Block diagram of BEV
- Hybrid electric Vehicle(HEV)
- Plug-in Hybrid Electric Vehicle (PHEV)
- Fuel Cell Electric Vehicle (FCEV)

Introduction to Battery Electric Vehicle

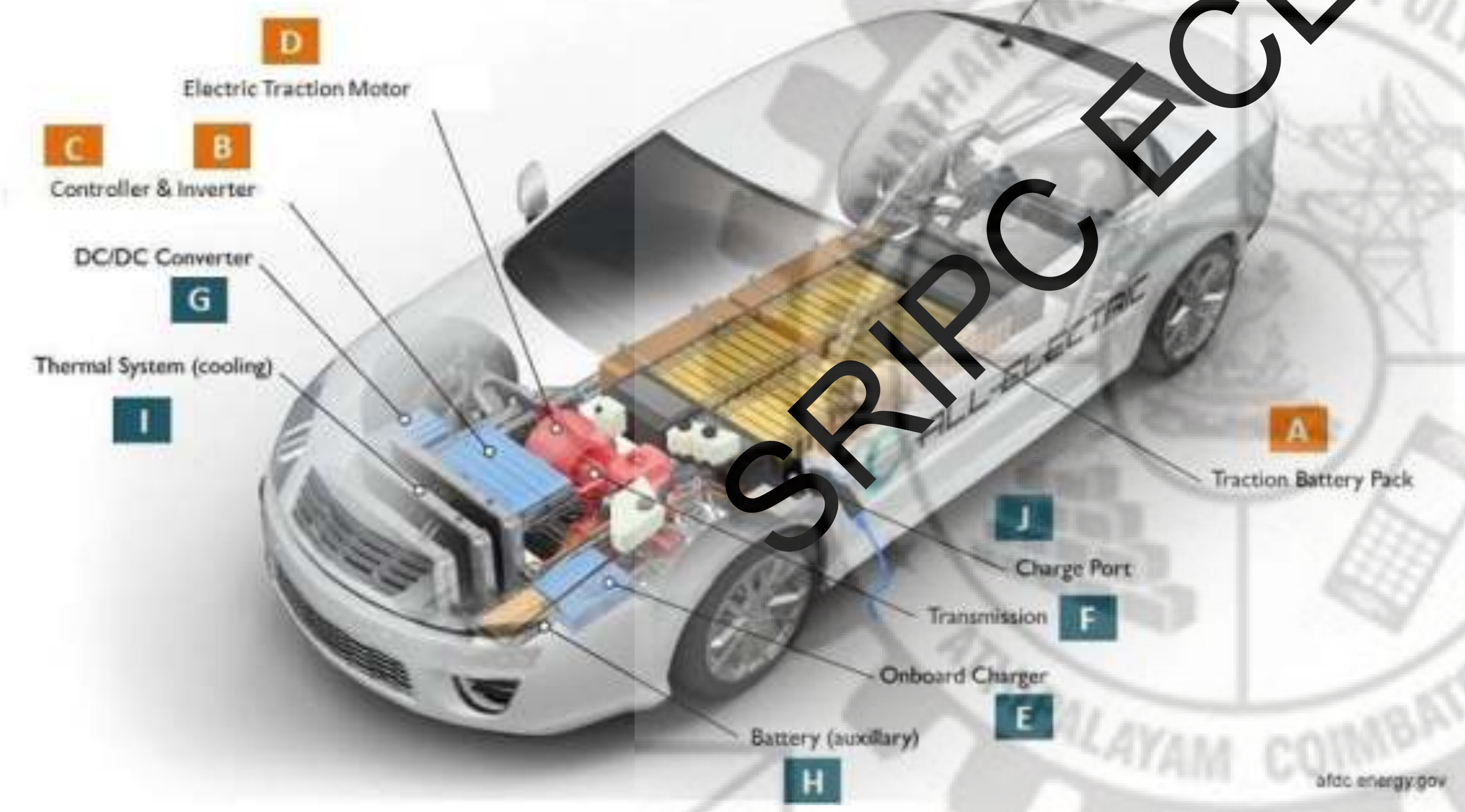


FULLY ELECTRIC POWERTRAIN



Advantages
- High efficiency
- Regenerative braking
- No emissions
- Low noise

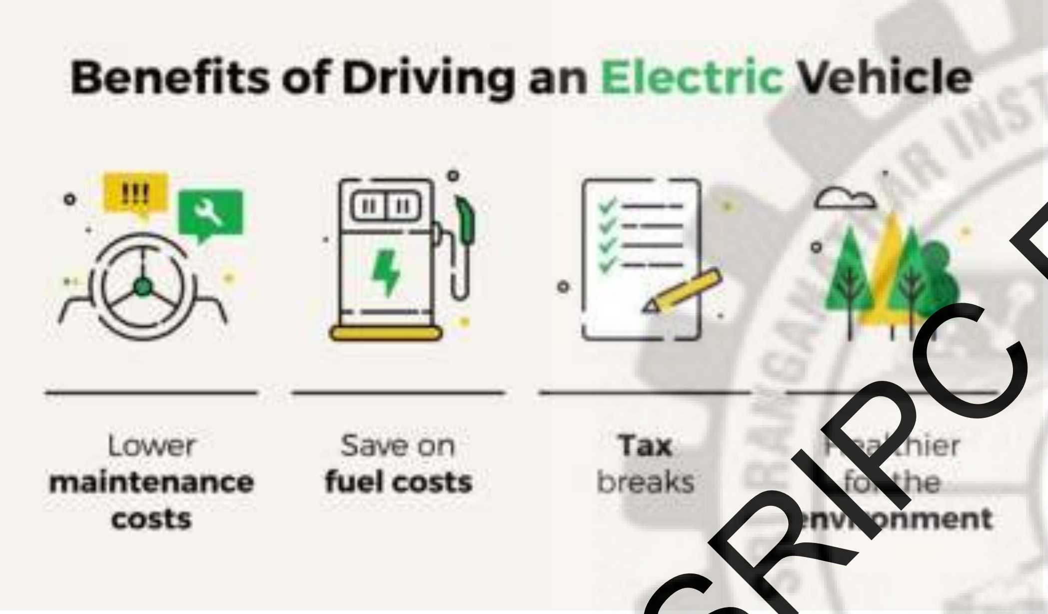
Disadvantages
- Shorter range
- Slow "refueling" (charging)
- Battery high cost
- Battery low energy density

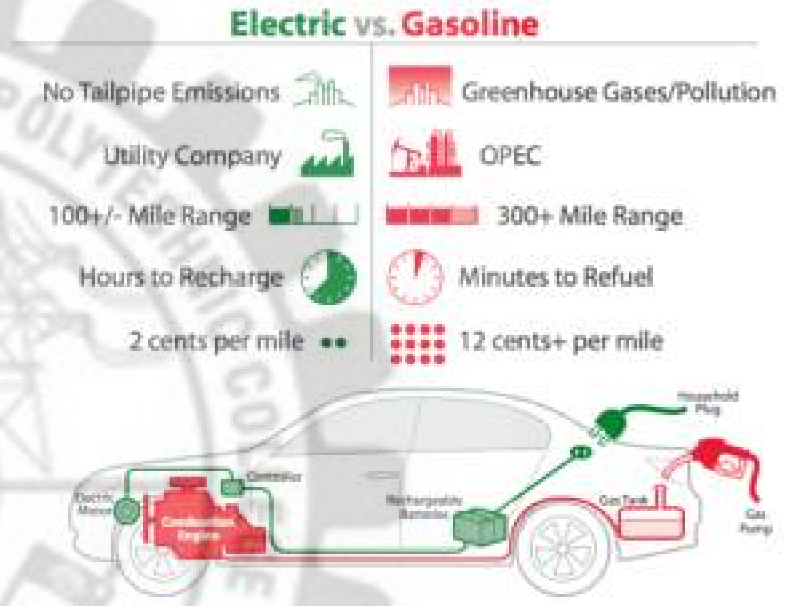


Motor

Electric Car !!

Inverter


Benefits of Driving an Electric Vehicle
Lower maintenance costs
Save on fuel costs
Tax breaks


Electric vs. Gasoline
No Tailpipe Emissions
Greenhouse Gases/Pollution
Utility Company
OPEC
100+/- Mile Range
300+ Mile Range
Hours to Recharge
Minutes to Refuel
2 cents per mile
12 cents+ per mile


analyticSteps
www.analyticsteps.com
Energy Efficiency
Curtailing Noise Pollution
Fewer Particulates
Advantages of Electric Car
CO2
Cleaner CO2 emission
Night charging leads to cleaner energy
Zero tailpipe emissions


Benefits of Electric Vehicles
Lower noise pollution
Lower repair & maintenance costs
Faster acceleration
Higher energy conversion efficiency
No idling
Smaller, lighter engine

COMPARE AGAIN!

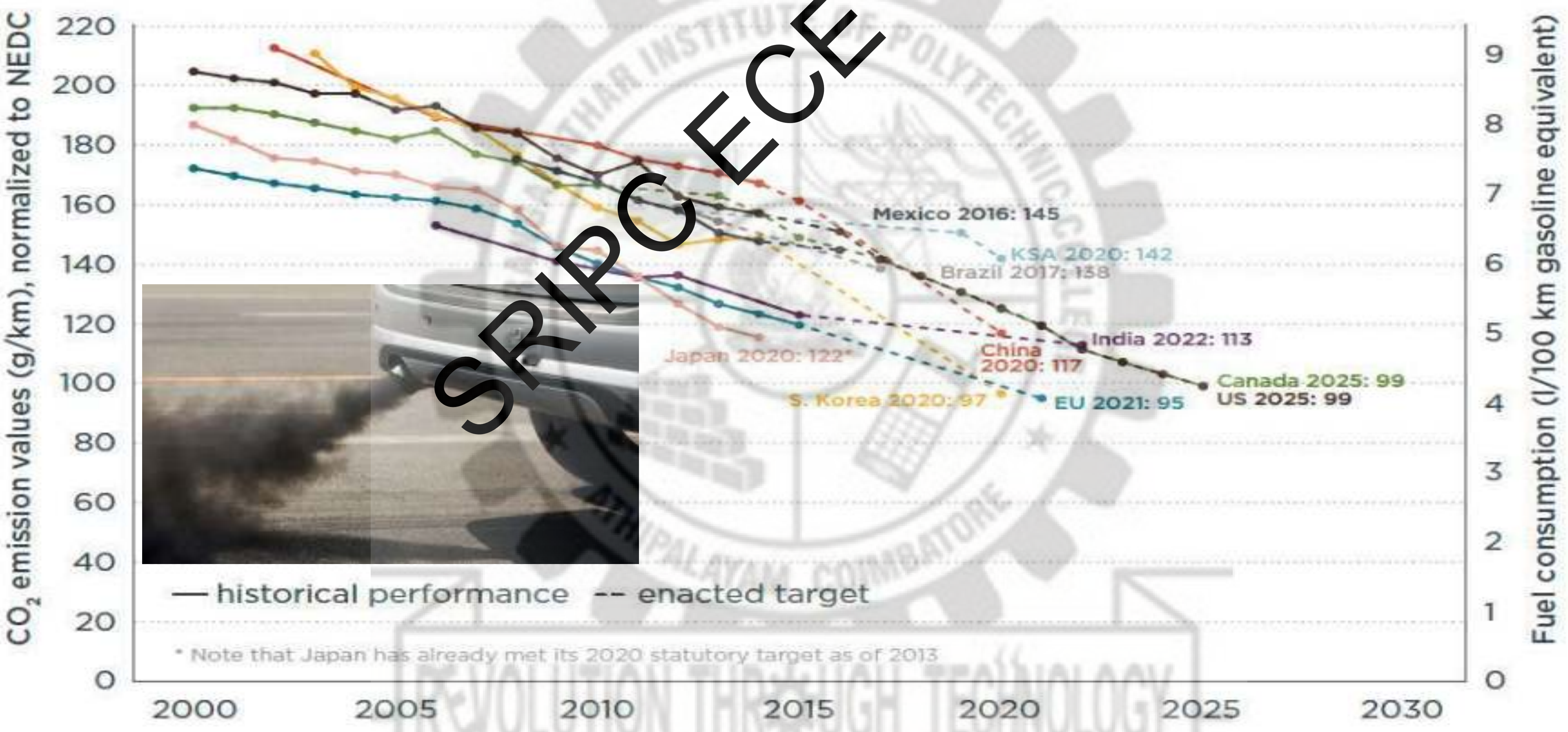
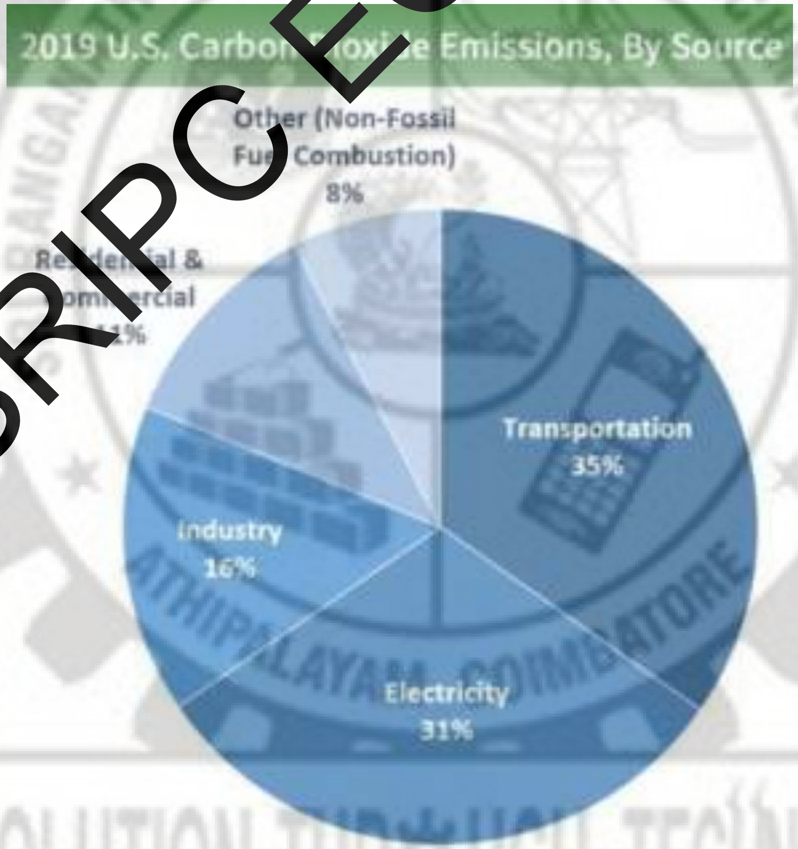
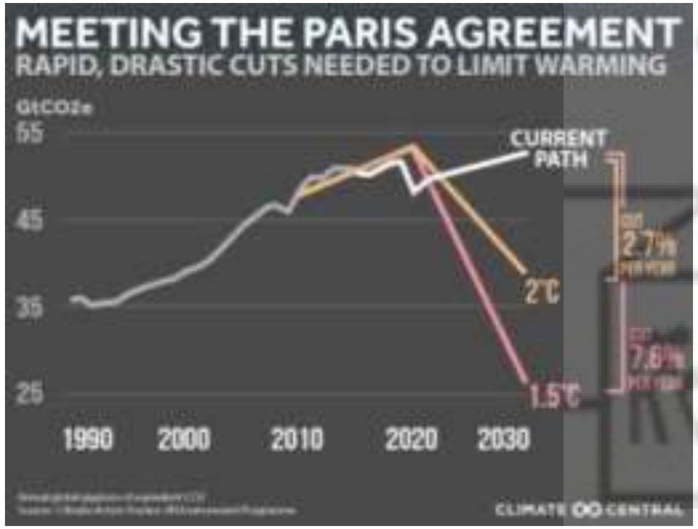


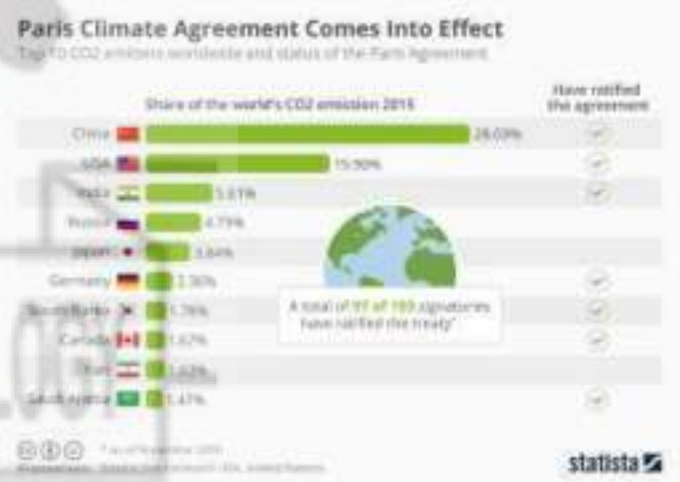
Figure 2. Historical fleet CO_2 emissions performance and current standards (gCO_2/km normalized to NEDC) for passenger cars


COP21/CMP11
Paris, France


2019 U.S. Carbon Dioxide Emissions, By Source
Other (Non-Fossil Fuel Combustion) 8%
Residential & Commercial 11%
Transportation 35%
Industry 16%
Electricity 31%


CO2
CO2
CO2

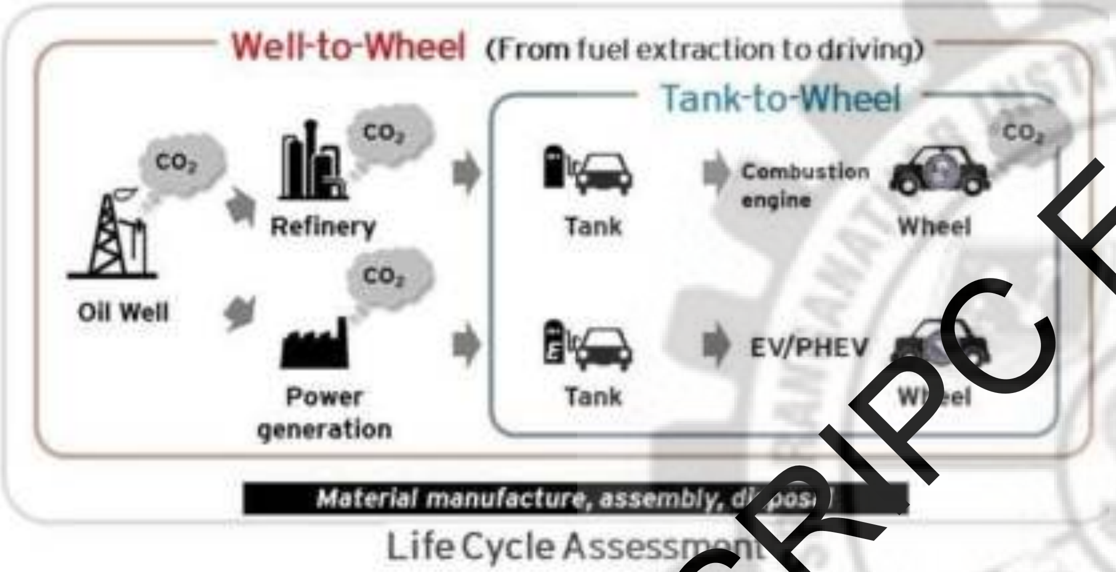

MEETING THE PARIS AGREEMENT
RAPID, DRASTIC CUTS NEEDED TO LIMIT WARMING
GtCO2e
55
45
35
25
CURRENT PATH
2°C
1.5°C
2.7%
7.6%
1990
2000
2010
2020
2030
CLIMATE CENTRAL


Paris Climate Agreement Comes Into Effect
statista

Sustainable Mobility defined as:

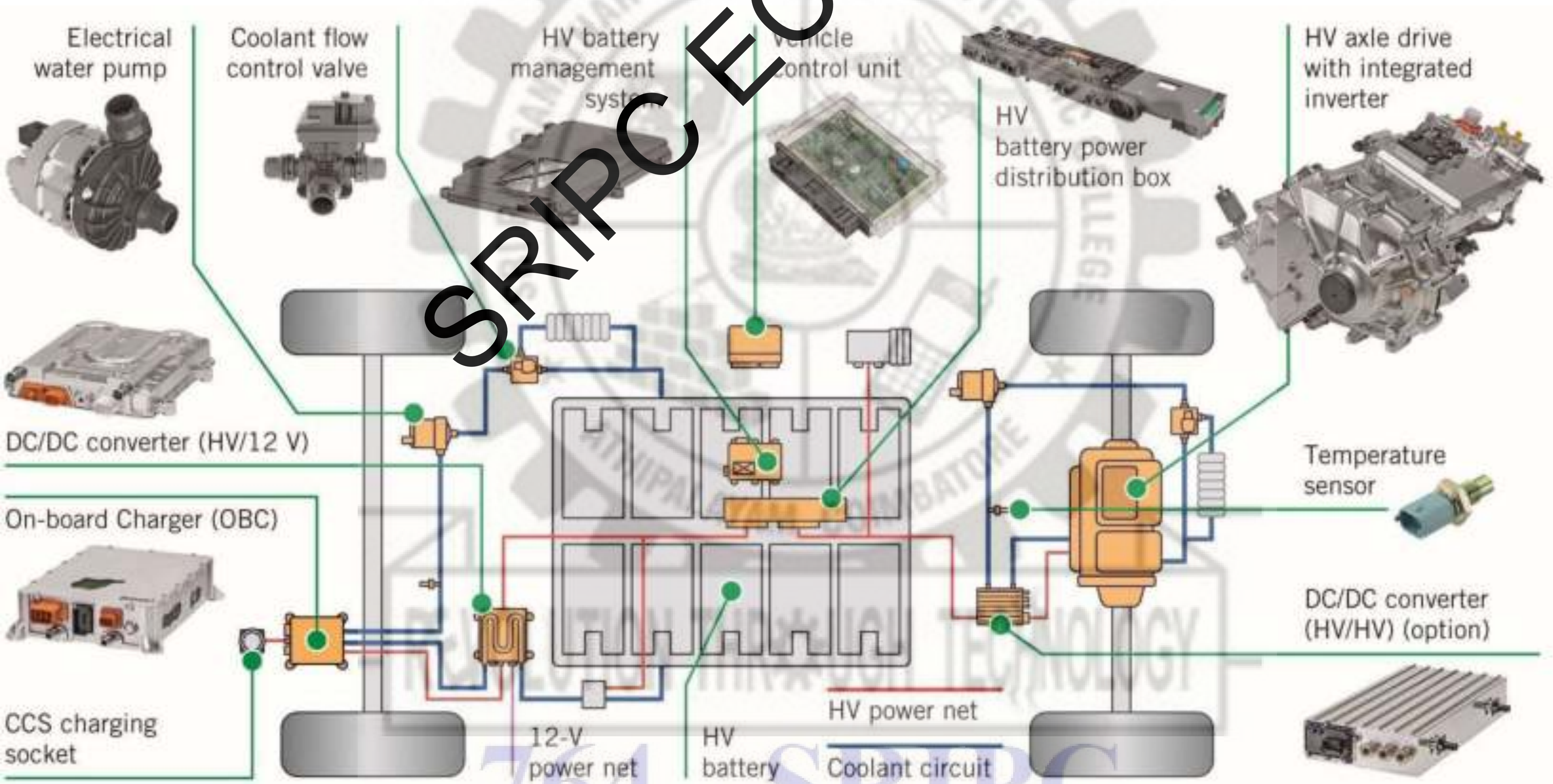
“the ability to meet the needs of society to mover freely, gain access, communicate, trade, and establish relationships without sacrificing other essential human or ecological values, today or in the future”

- *Infrastructure development*
  - *Bike friendly*
  - *More public transports*
    - *metro, train, e-bus*
  - *V2x enabled*
- *Personal Mobility*
  - *E-bike*
  - *E-vehicles*
  - *Car sharing*


Well-to-Wheel (From fuel extraction to driving)
Tank-to-Wheel
CO_2
Oil Well
Refinery
Power generation
Tank
Combustion engine
Wheel
EV/PHEV
Tank
Wheel
Material manufacture, assembly, disposal
Life Cycle Assessment

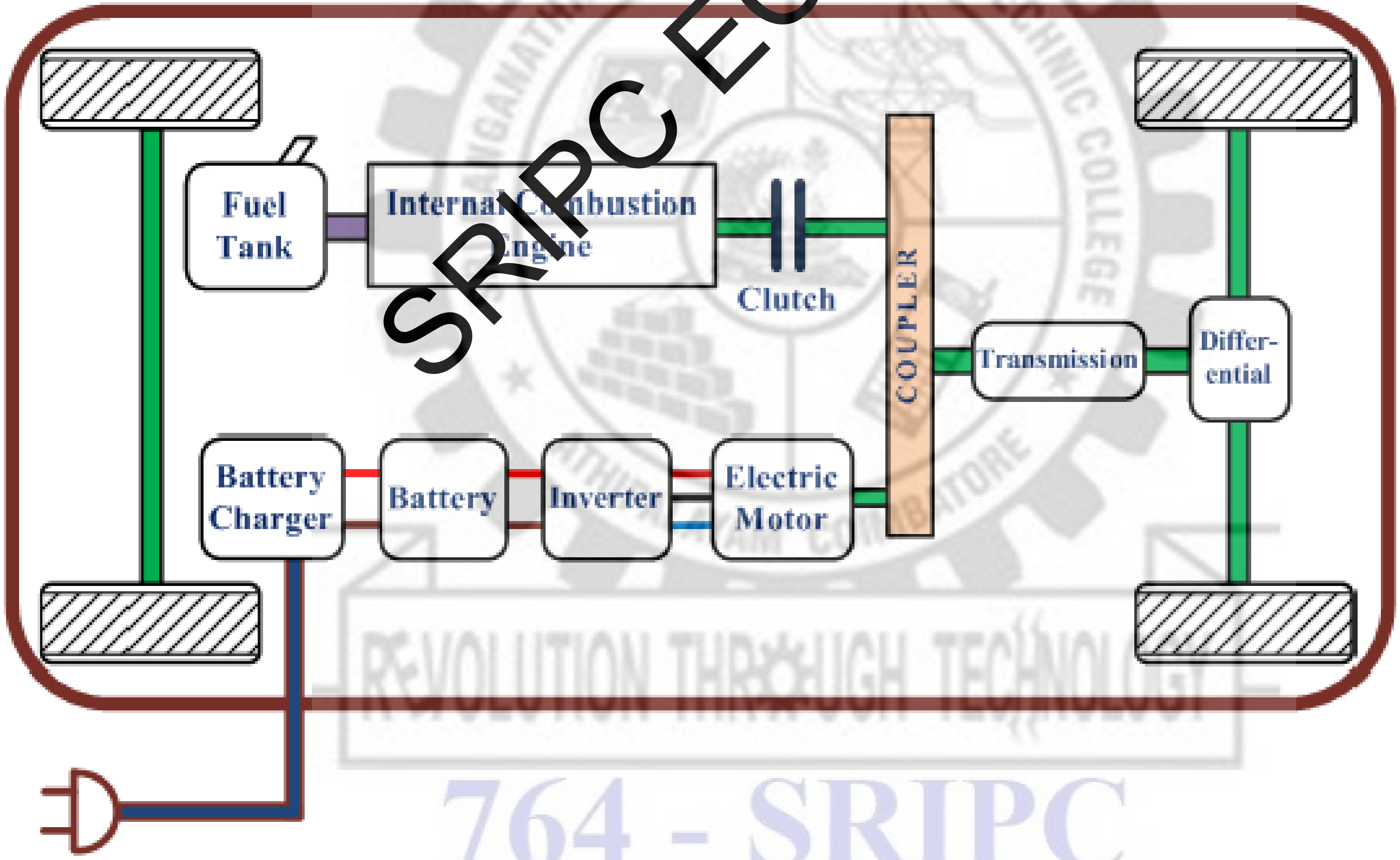
Different between BEV and Conventional Vehicle

Block diagram of BEV



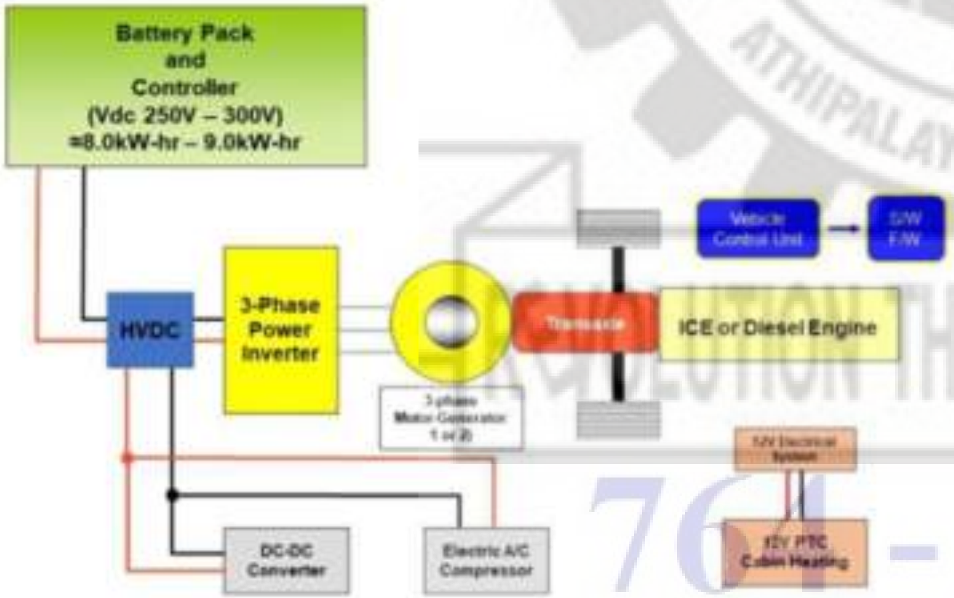
Hybrids

Plugin Hybrid electric Vehicle(PHEV)

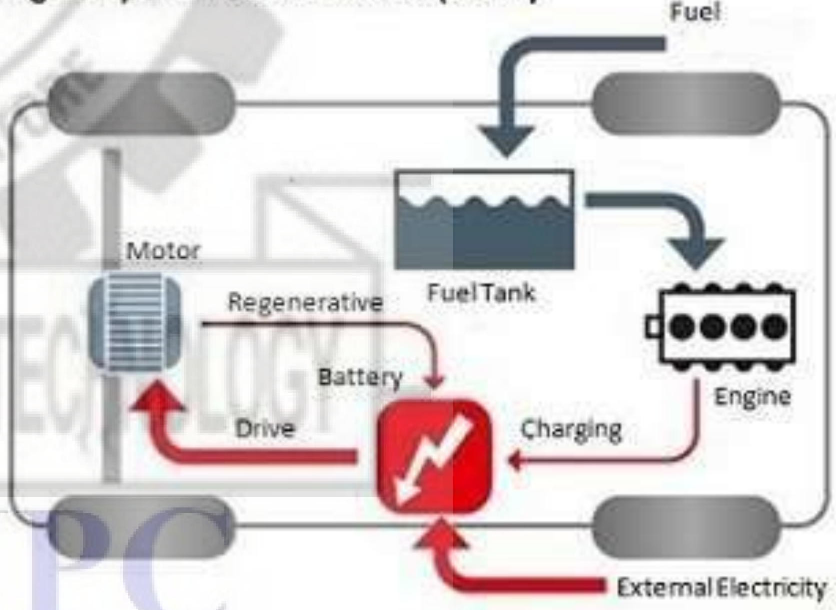


Plug-in Hybrid Electric Vehicle (PHEV)

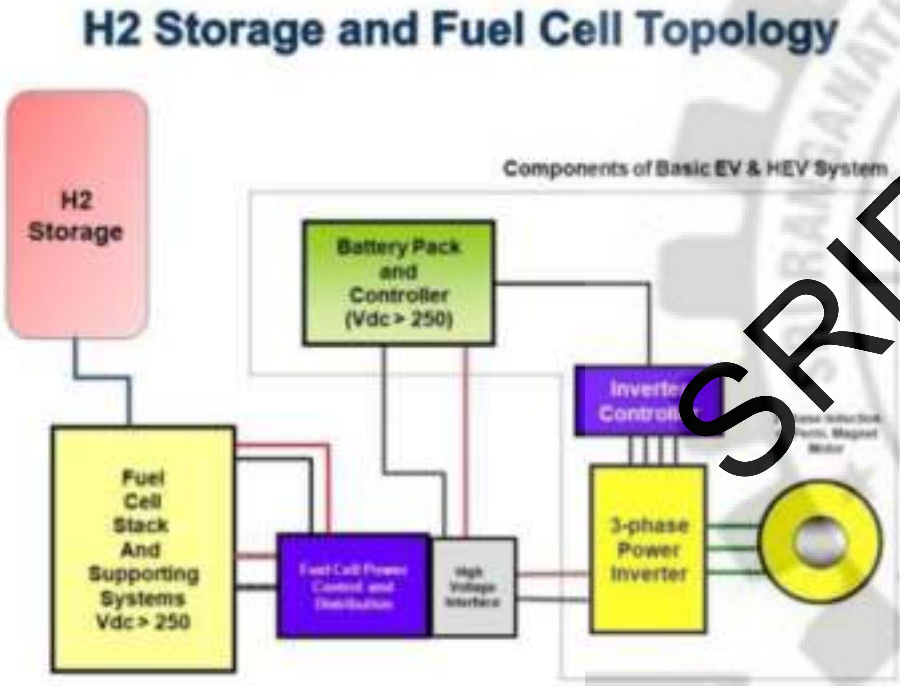
PHEV Topology

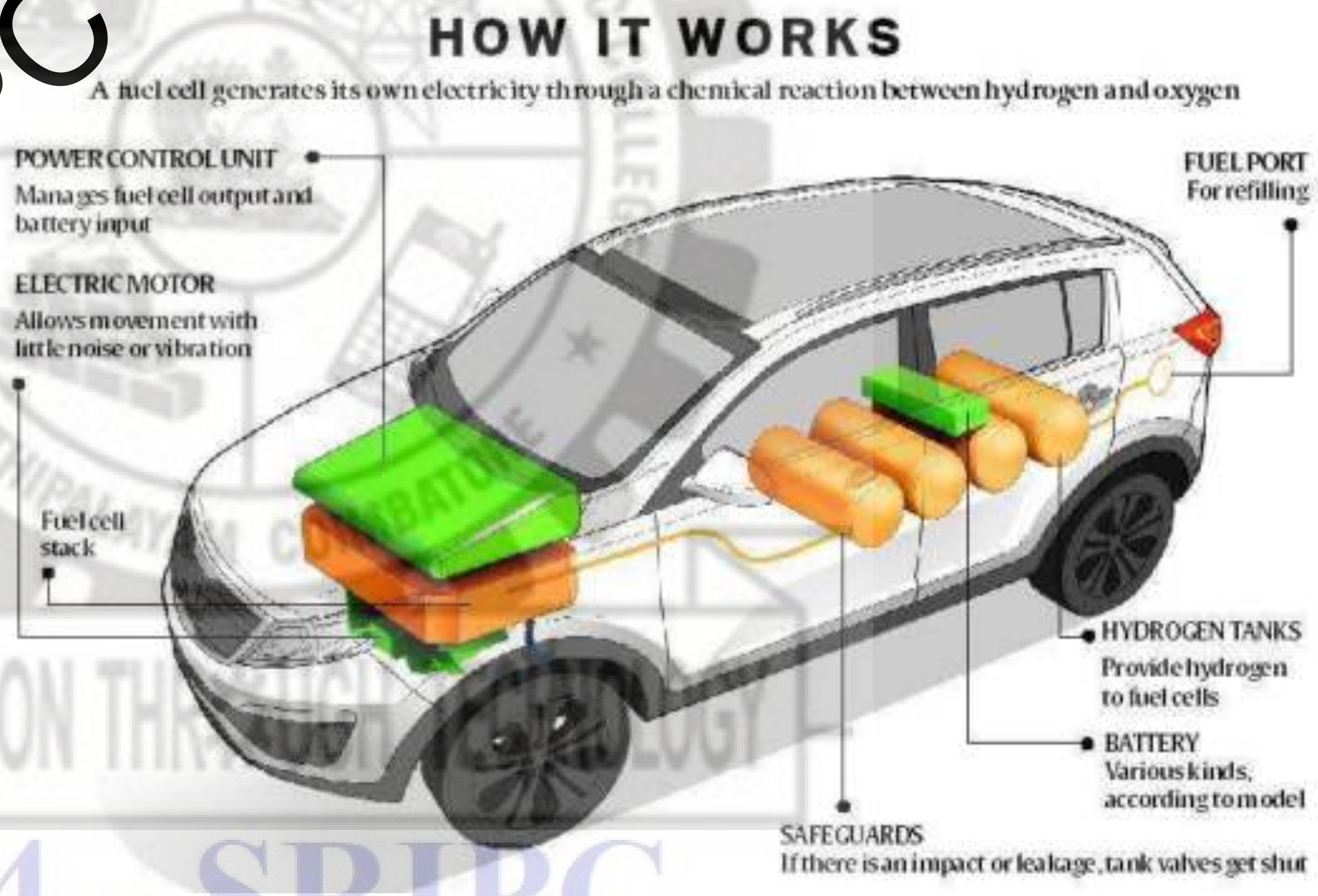


Plug-in Hybrid Electric Vehicle (PHEV)



Fuel Cell Electric Vehicle (FCEV)





MILD HYBRID

- Meets fuel consumption standards at minimum cost
- For customers not paying extra for low fuel consumption
- Based on conventional ICE PT
- Offers some performance improvement (downsizing the ICE)

FULL HYBRID

- Bigger Electric Machine
- Most of the braking is regenerative
- All electric drive mode at low power demand
- Medium performance improvement (downsizing ICE)

PLUG-IN HYBRID

- Big Electric Machine - modest performance in all-electric mode
- Electric Driving range of about 50km
- Based on conventional ICE PT
- Performance improvement

BEV WITH REX

- Big electric machine for full performance in all electric mode
- Limited range extended power
- Battery size can be smaller than long range BEV

FULL ELECTRIC

- Big EM allows full performance in all electric mode
- Range > 200km
- Fast chargers to extend range

COMPARISON

	ICE Convent.	Mild HEV	Full HEV	Plug-in HEV	BEV w. REX	BEV
ICE power	100 kW	100 kW	100 kW	100 kW	25 kW	0 kW
Stop ICE at standstill	No Yes	Yes	Yes	Yes	Yes	Not relevant
Recuperation power	No	10 kW	25 kW	50 kW	100 kW	100 kW
Electric Traction power	No	No	25 kW	50 kW	100 kW	100 kW
Charging from grid	No	No	No	Yes	Yes	Yes
Battery size	-	0.5 kWh	1.5 kWh	10 kWh	>20 kWh	>30 kWh
Max traction power	100 kW	110 kW	125 kW	150 kW	100 kW	100 kW
Relative fuel consump.	100%	90%	75%	25-50%	10%	0%

End of Session-2

Any Questions?

Electric Vehicles

- Configurations of Electric Vehicle
- Performance of Electric Vehicles
- Tractive Effort in Normal Driving
- Energy consumption.
- Concept of Hybrid electric drive trains
- Architecture of Hybrid Electric Drive trains
  - Series, Parallel and Series & Parallel

Electric-Car Boom

Models by style and range available through 2020

13

Bloomberg New Energy Finance

RECAP: WHY EV?

ICE VEHICLE

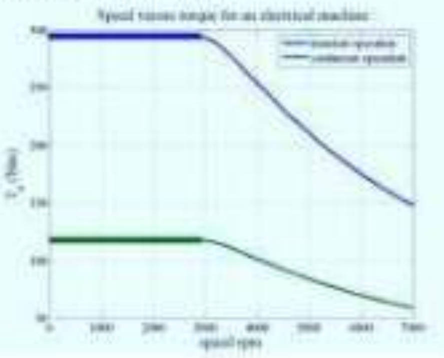
Moving Parts	150
Wearing Parts	24
High torque in specific RPM range	
Tank to Wheel efficiency	25%

ELECTRIC VEHICLE

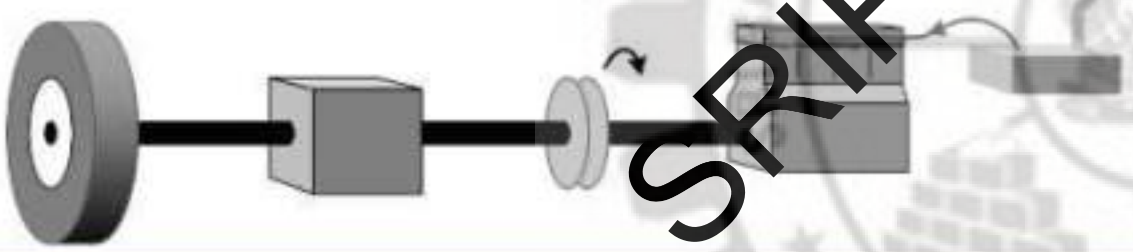
Moving Parts	24
Wearing Parts	11
High torque at low RPM	
Battery to Wheel efficiency	80-90%

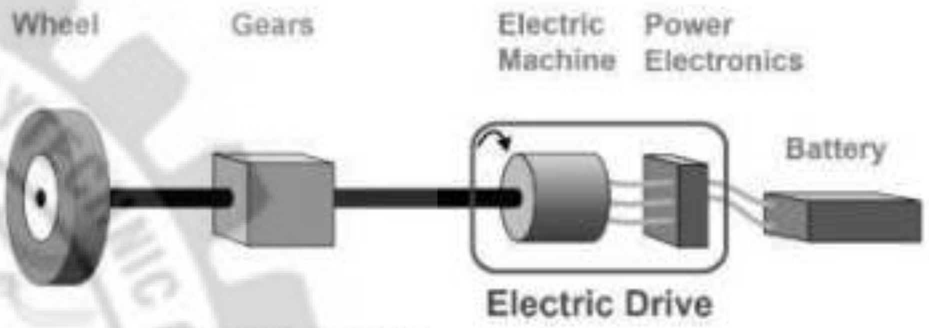
- Mechanical Simplicity
- On-Demand Performance delivery
- Complex Coordination easily achieved
- Zero Emissions solution

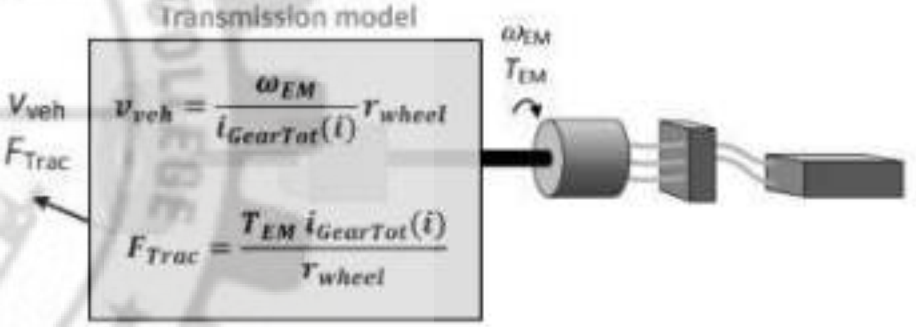
On-demand performance



BEV POWERTRAIN





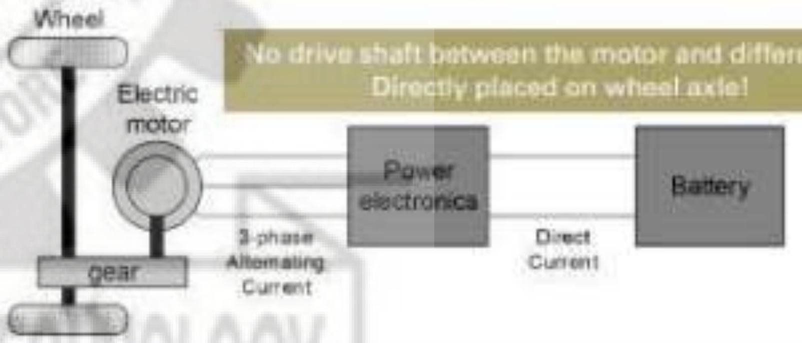


Battery->power electronics converting the batteries direct current into alternating currents for the electric machine->electric machine converting electric power->mechanical power

Electric machine capable of operating and producing torque at all speeds
=>there is no need for a clutch in a battery electric powertrain

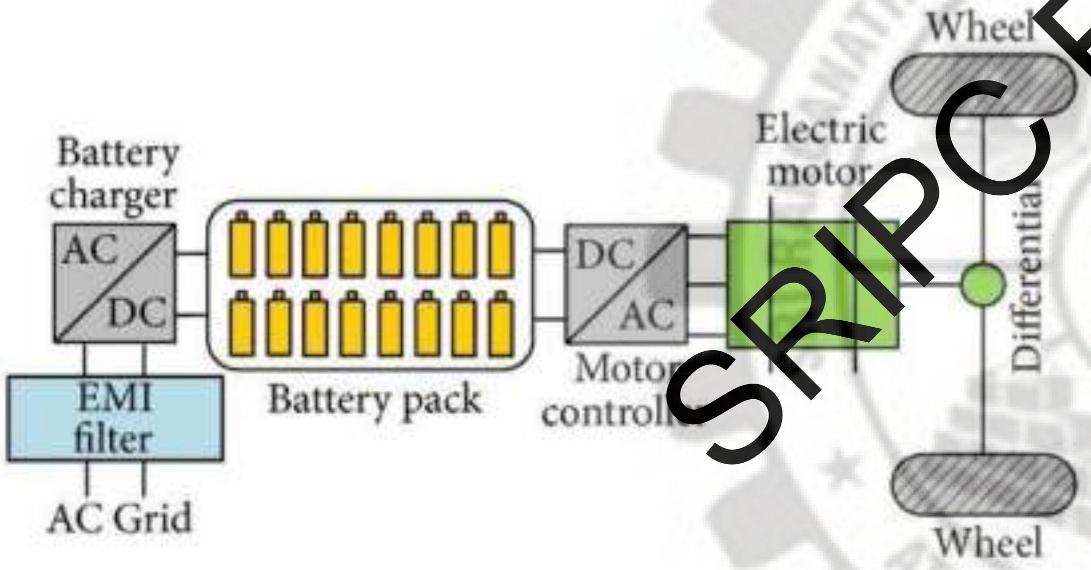
As in the case of ICE powertrain, we can describe how the torque and the speed of the electric machine relate to the traction force and vehicle speed, with the transmission model

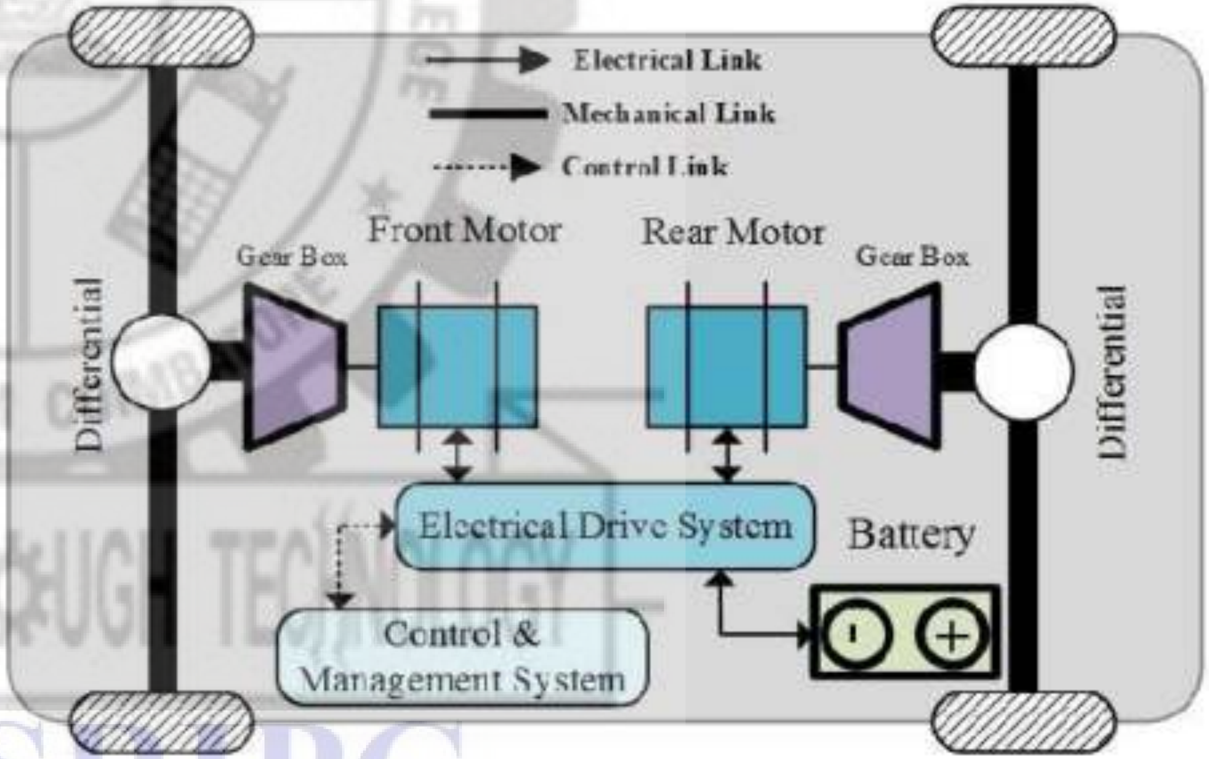
No drive shaft between the motor and differential!
Directly placed on wheel axle!



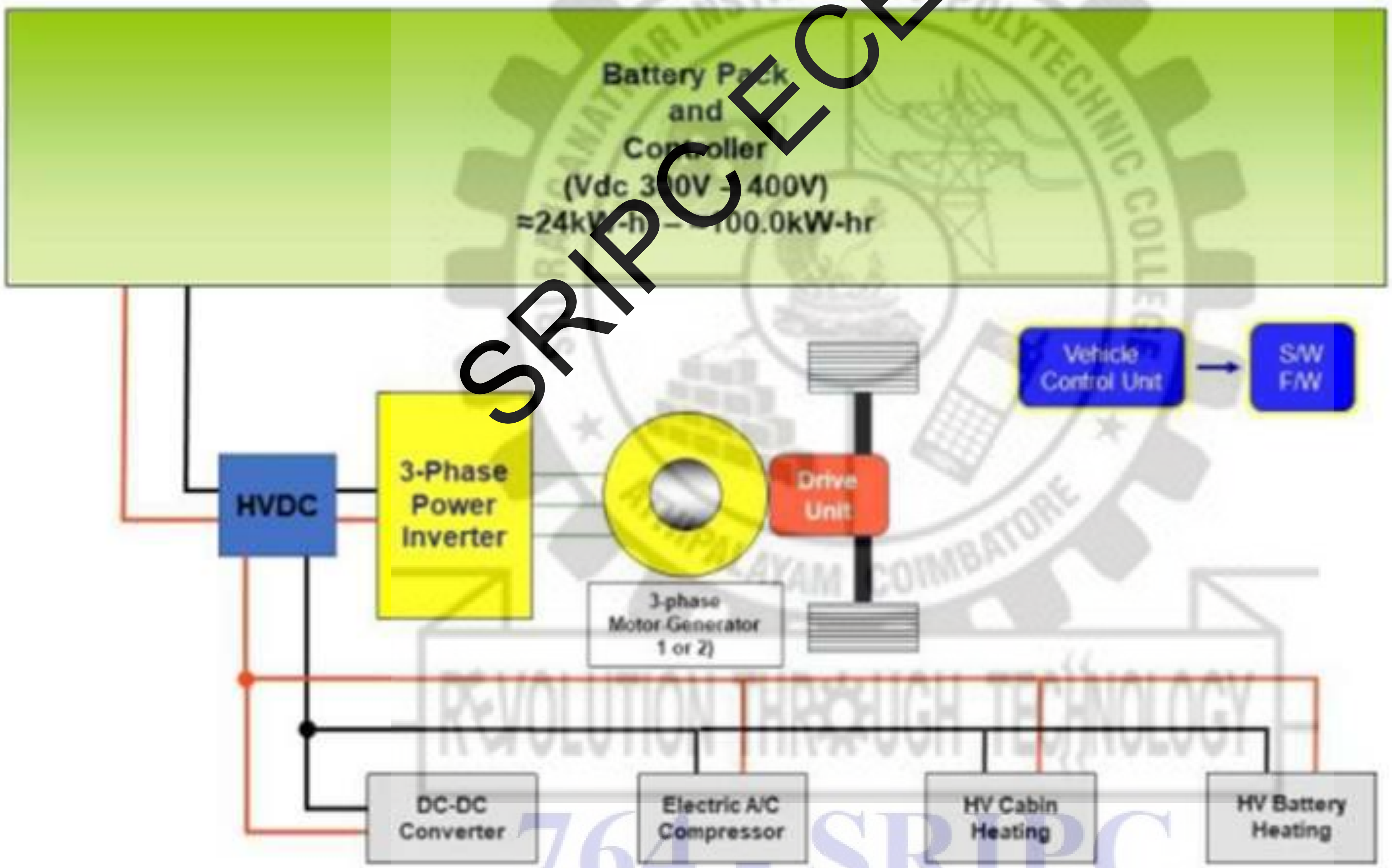
Since an electric machine can operate efficiently in a wider operating range than the combustion engine, there is less reason for having several gears to select from. Can have a single gear, or have two gears or maybe even more to improve efficiency/extend vehicle operating range without upgrading electric machine

Configurations of Electric Vehicle

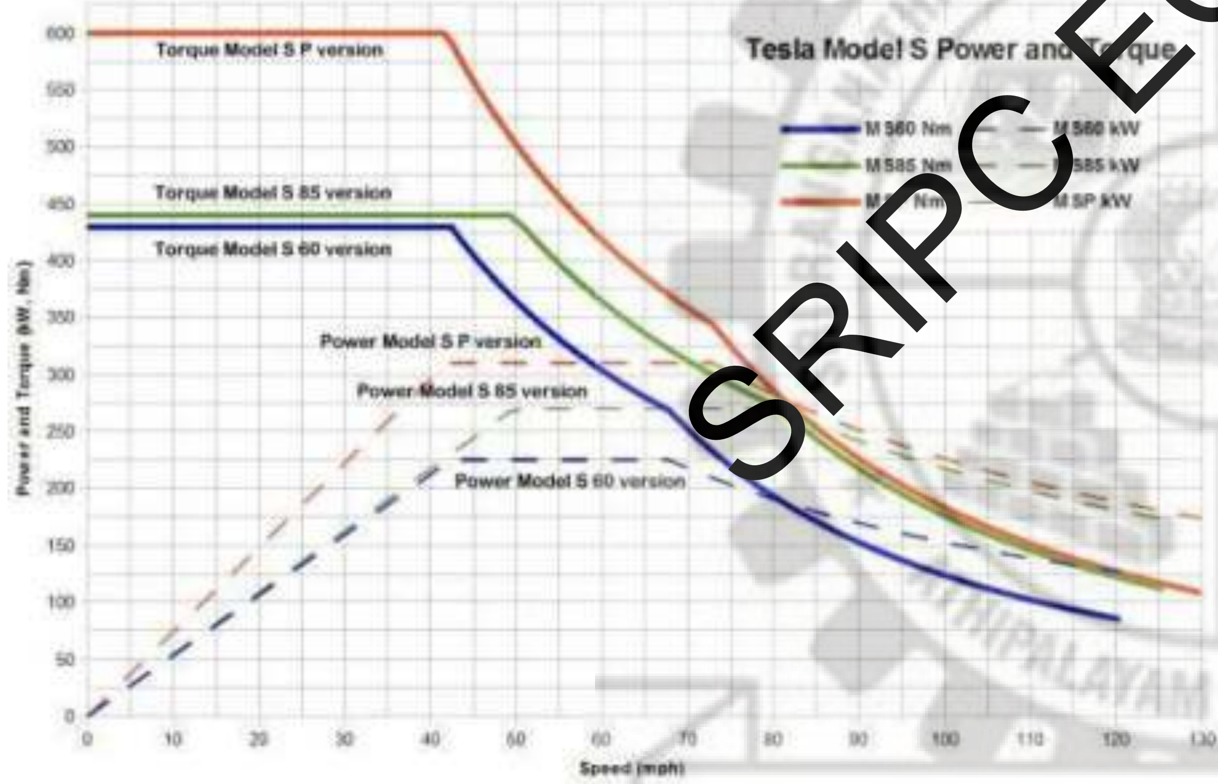


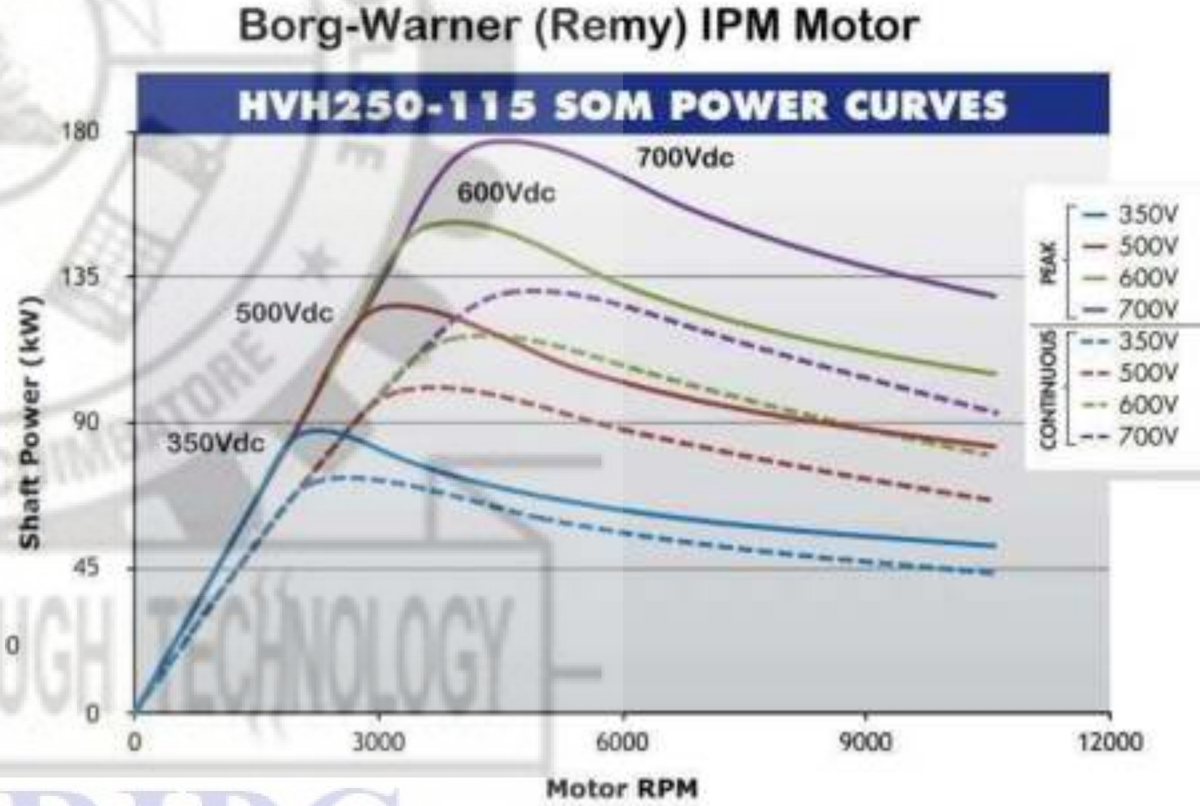


BEV Topology



Performance of Electric Vehicles





Tractive Effort in Normal Driving

CONTROL, VEHICLE SPEED & PT MODES

- Driver control force comes from the PT
- F_{Net} determines acceleration of vehicle
- Speed changes over time with acceleration/deceleration

Vehicle Modes:
$F_{Trac} > F_{Res}$ => Acceleration
$F_{Trac} = F_{Res}$ => Constant Speed
$F_{Trac} < F_{Res}$ => Deceleration

PT Modes:
$F_{Trac} > 0$ => Traction
$F_{Trac} = 0$ => Coasting
$F_{Trac} < 0$ => Braking

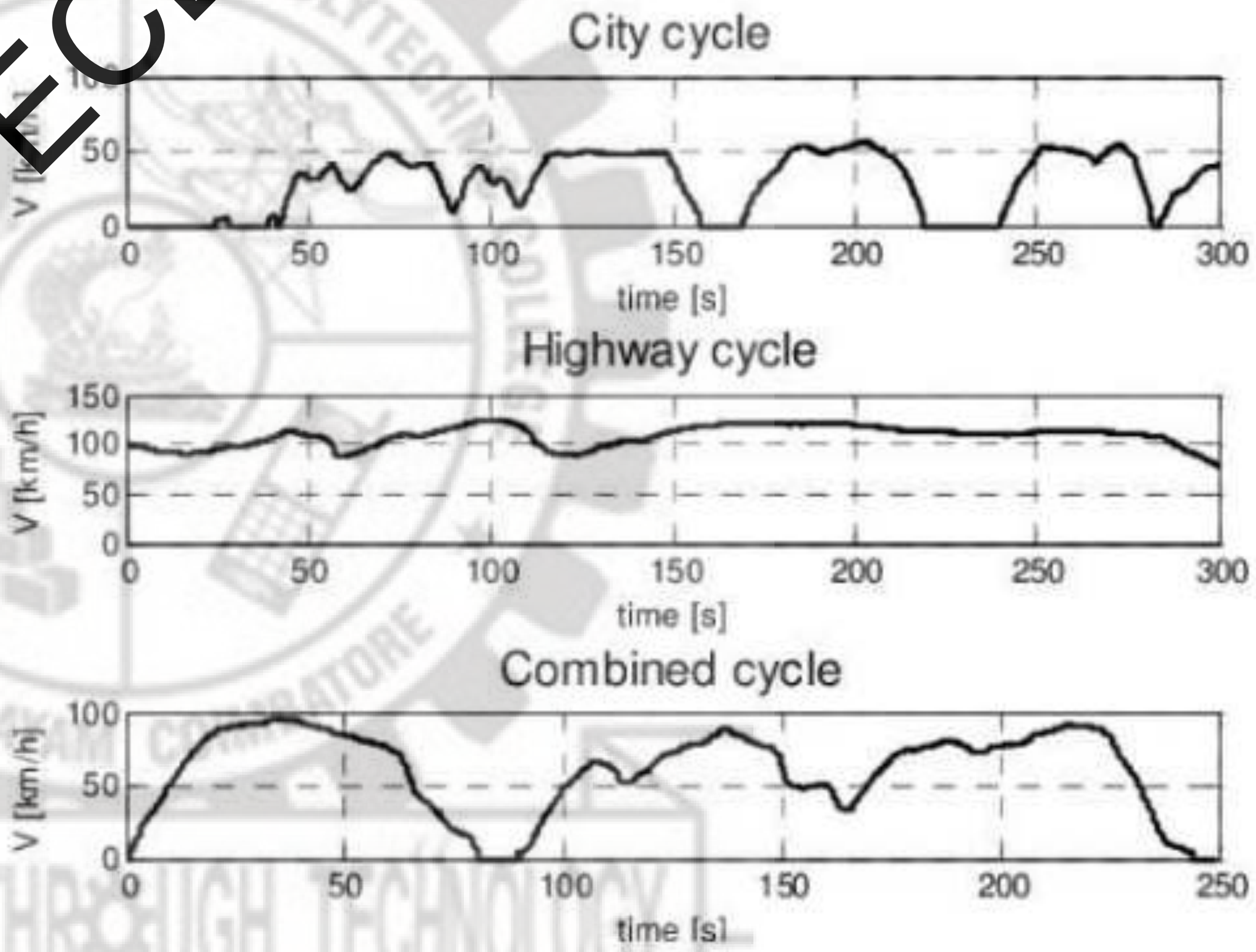
Running resistance:
$F_{resistance} = F_{roll} + F_{aero} + F_{grad} =$
$= c_r \cdot m_{veh} \cdot g \cdot \cos(\alpha) + c_d \cdot 1/2 \cdot \rho_{air} \cdot A_f \cdot v_{veh}^2 + m_{veh} \cdot g \cdot \sin(\alpha)$

$$F_{Net} = F_{Trac} - \underbrace{F_{Aero} - F_{Roll} - F_{Grad}}_{F_{Res}}$$

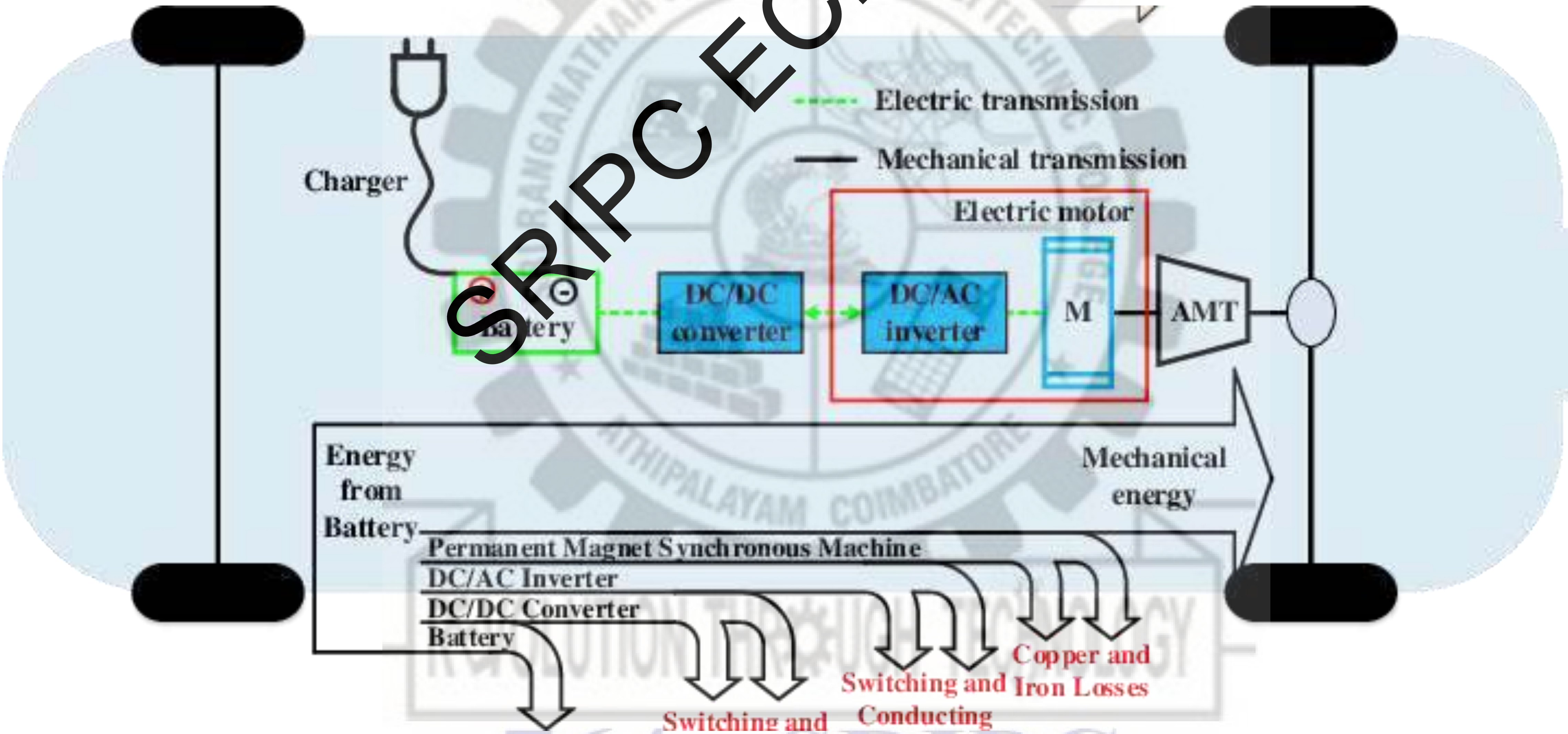
$$a_{Veh} = F_{Net} / m_{Veh}$$

DRIVE CYCLES

- A standardized drive profile which can be used to benchmark and compare fuel economy and emissions
- A driving cycle is a series of data points representing the speed of a vehicle versus time
- Driving cycles are produced by different countries and organizations to assess the performance of vehicles in various ways, as for example fuel consumption and polluting emissions



Power flow efficiency

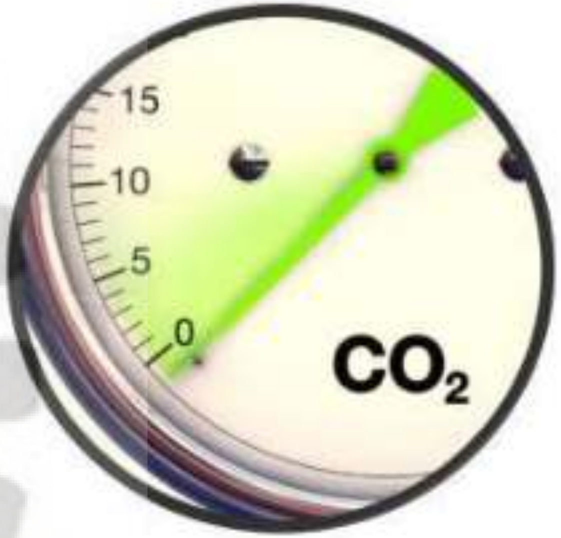


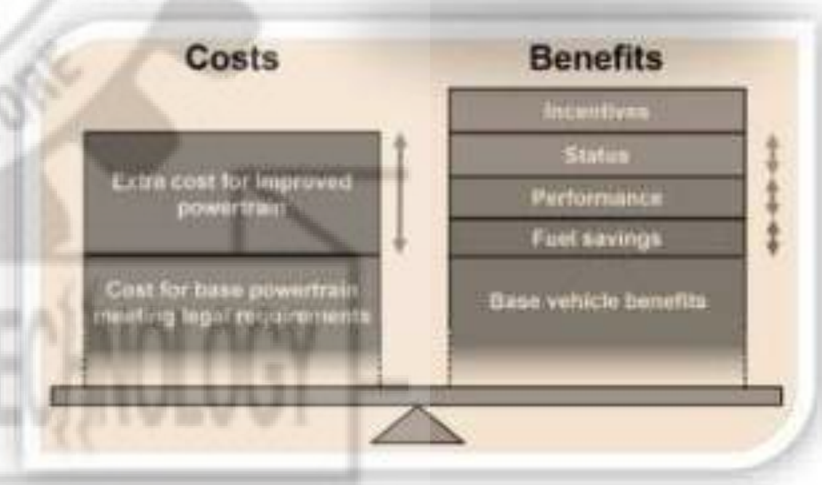
WHY HYBRID POWERTRAINS?

- Save Fuel:
  - Turning engine off at standstill conditions
  - Regenerative braking
  - Engine off at low power demands
  - Optimize for engine operating points (improve efficiency)

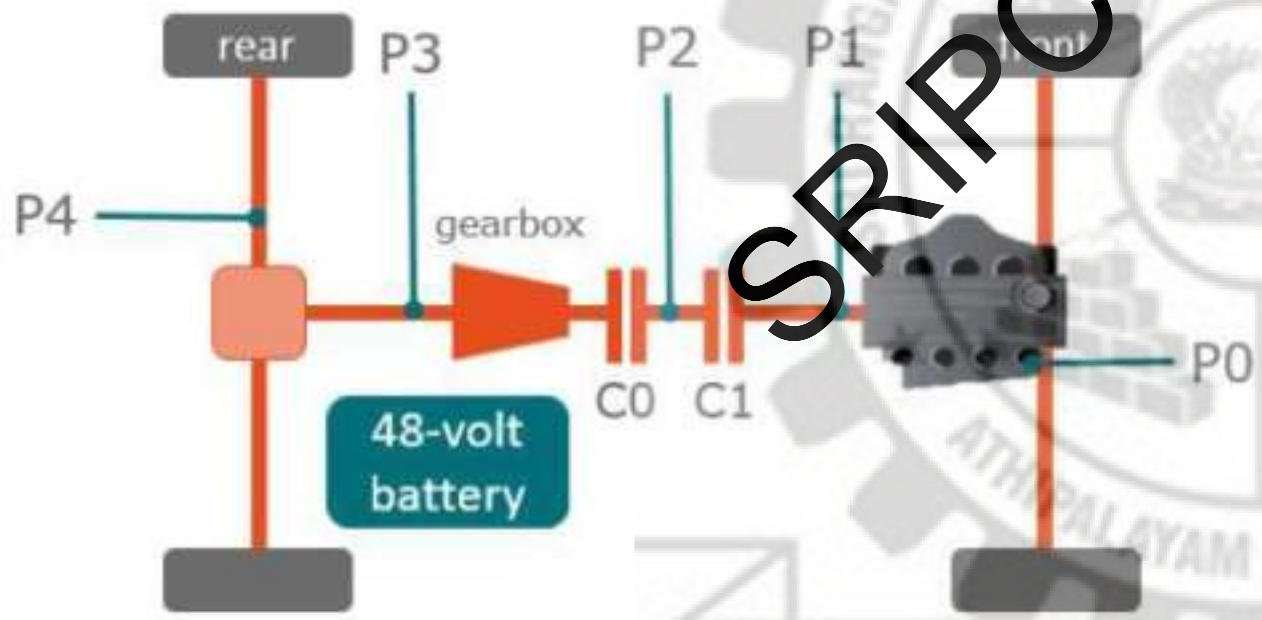
- Improve performance
- Improve PT response

- Draw energy from grid





Hybrid Topologies



P0 – BSG
- Cheap
- Limited efficiency due to belt losses

P1 – Crankshaft drive
- Mounted on crankshaft
- Restricted to length of the axis

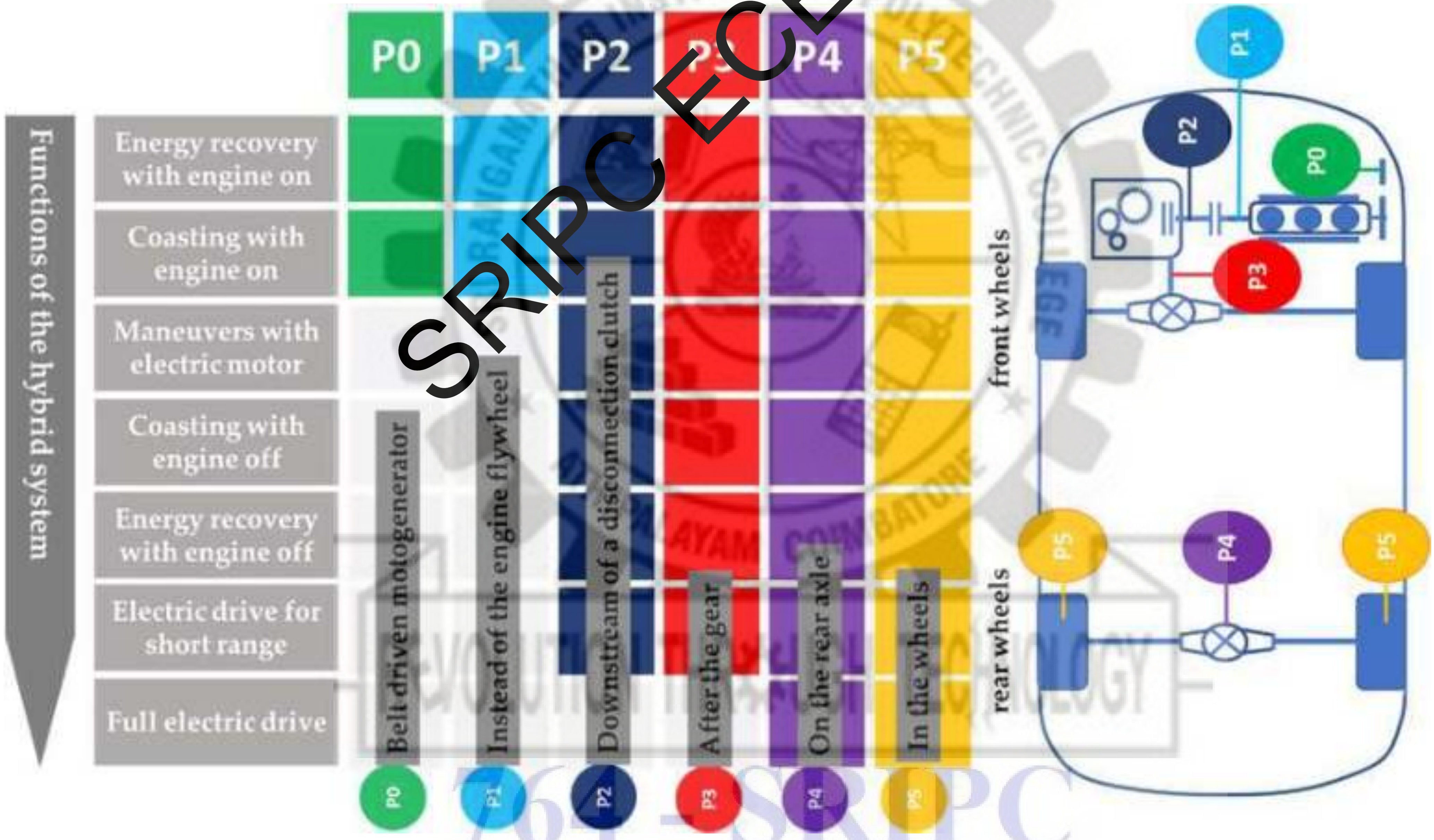
P2 – Drive on gearbox input shaft
- Integrated starter generator (ISG)
- More expensive
- No drag losses
- Engineless coasting functionality

P3 – Drive on gearbox output shaft
- Enhanced P2 capabilities

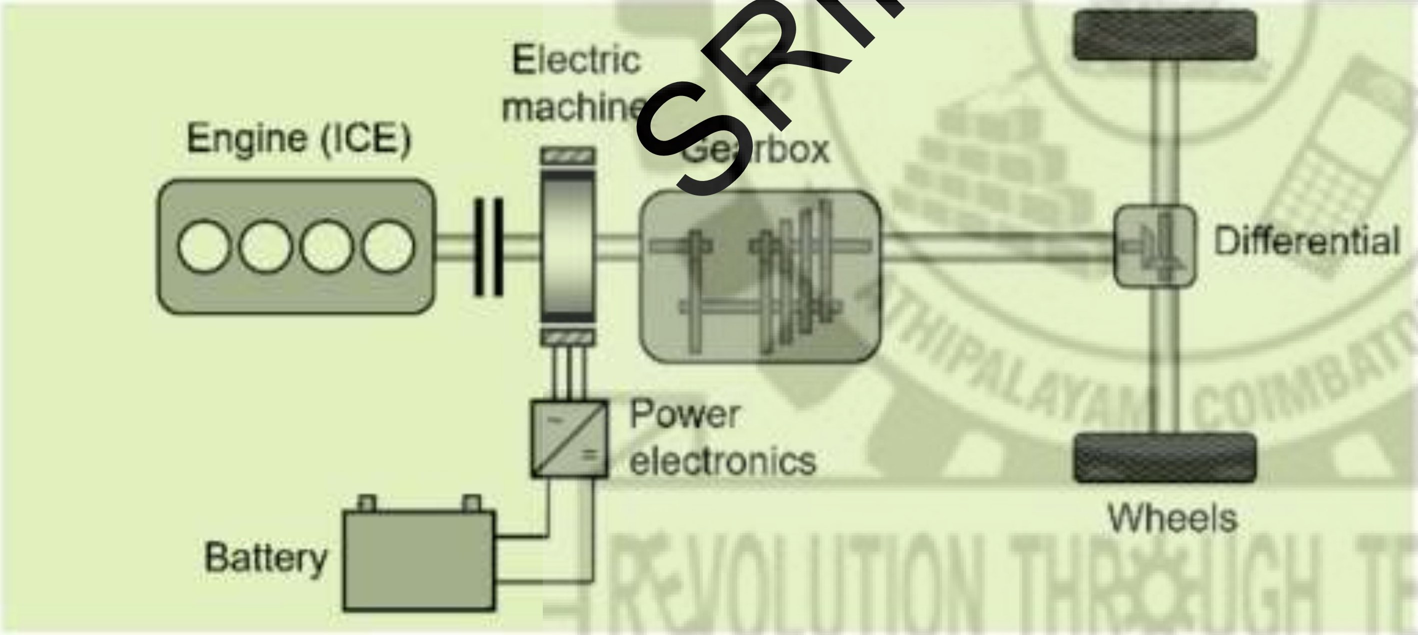
P4 – Drive at rear axle
- Highest potential for recuperation

C0 – Starting clutch
C1 – Decoupler

Hybrid Topologies & features



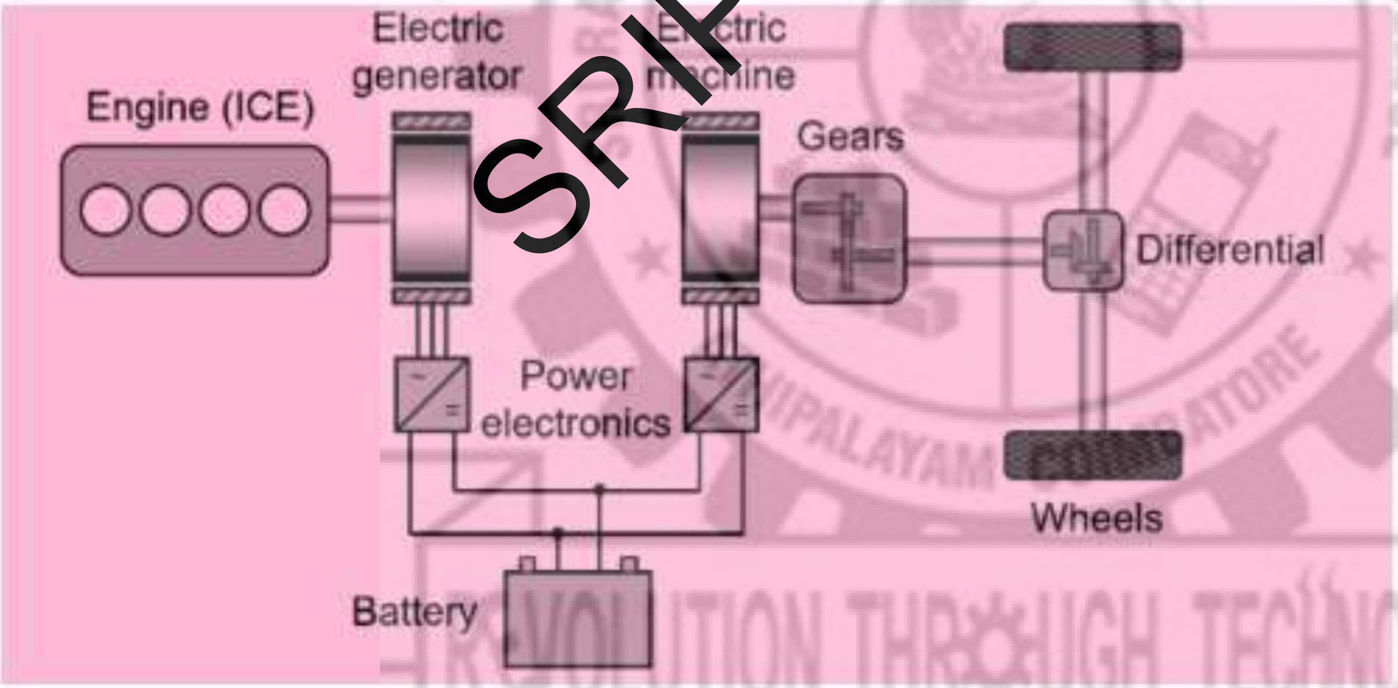
PARALLEL HYBRID PT



Advantages
- Long range
- Good overall efficiency
- Downsizing
- Regenerative braking
- Design similar to conventional vehicles
- Lower cost (compared to series hybrid)
- Low emissions

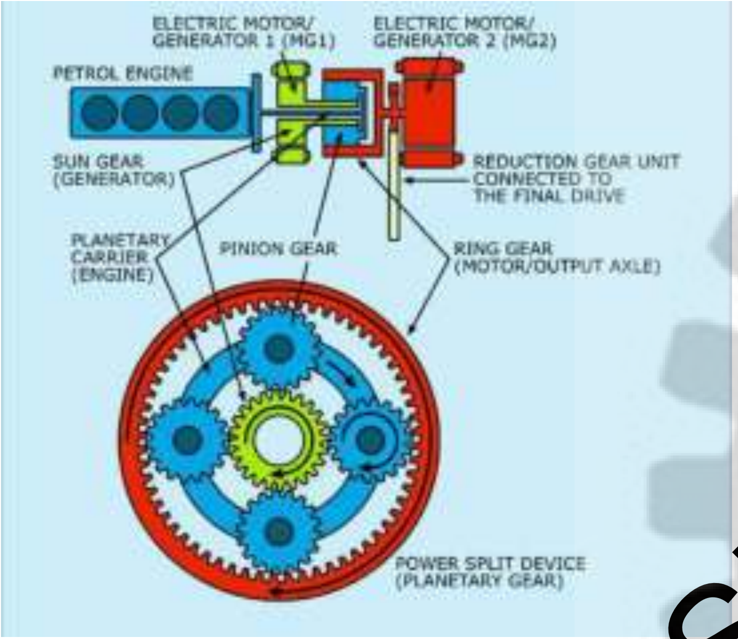
Disadvantages
- Limited regenerative braking
- Higher cost (compared to CON)

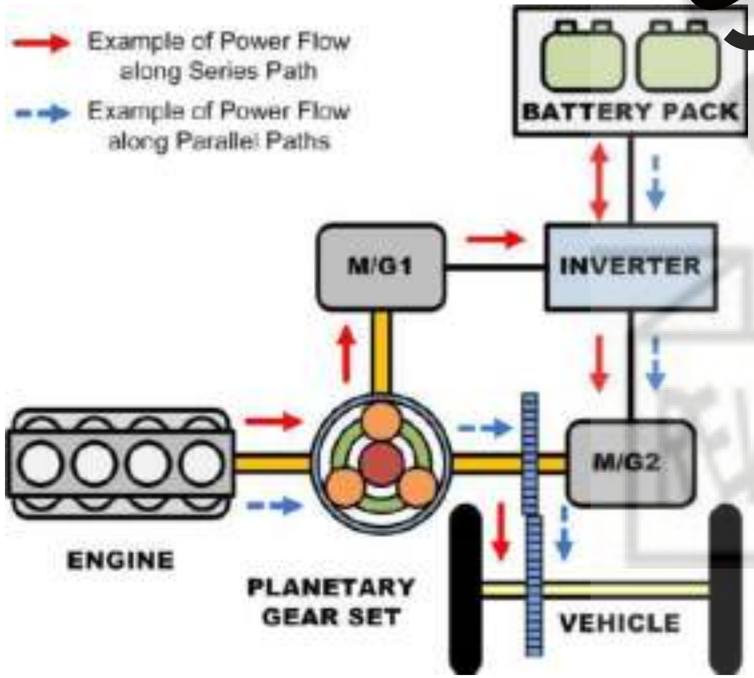
SERIES HYBRID PT



Advantages
- Long range
- Regenerative braking
- Low emissions

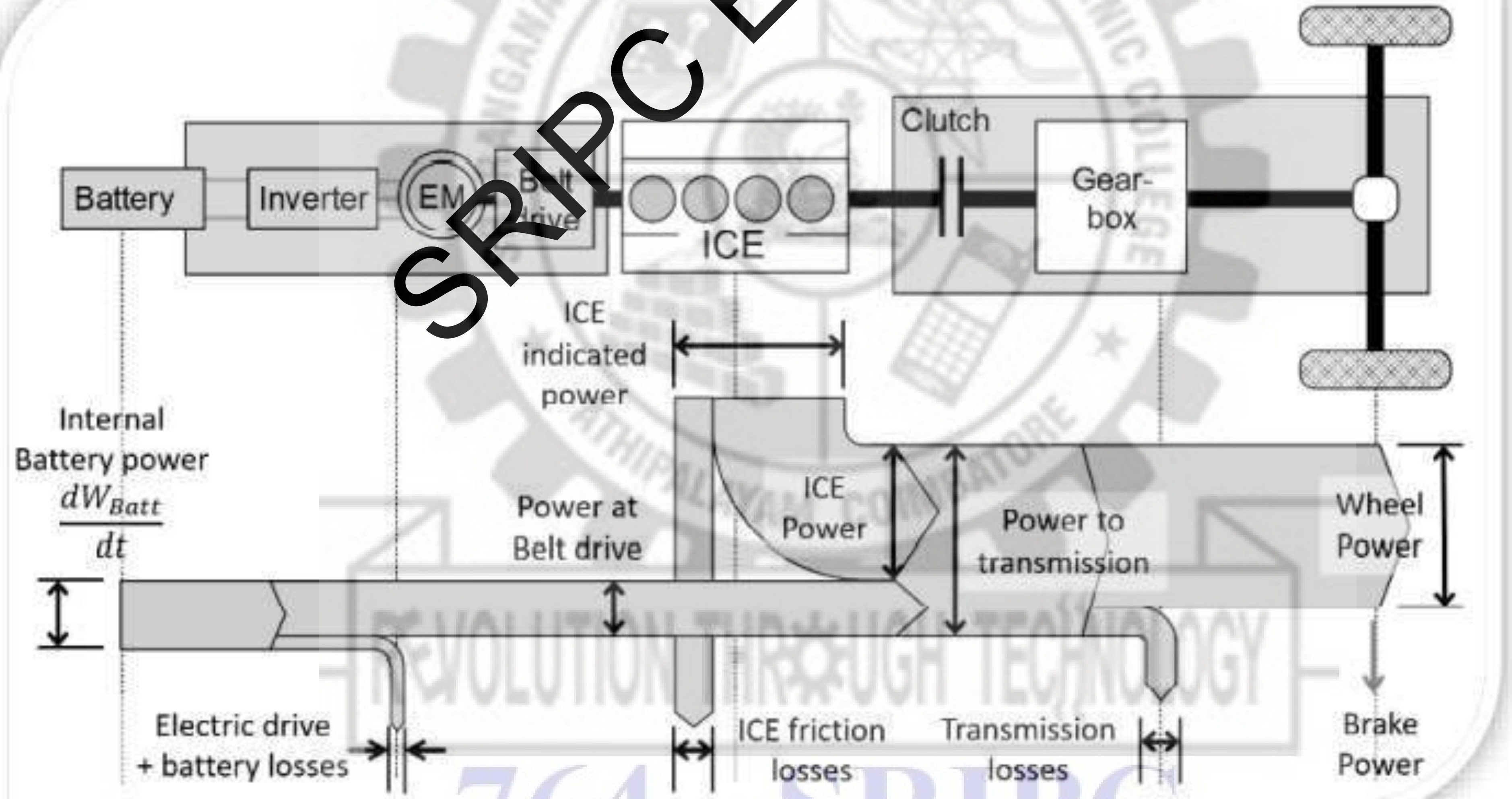
Disadvantages
- Low efficiency
- High system cost



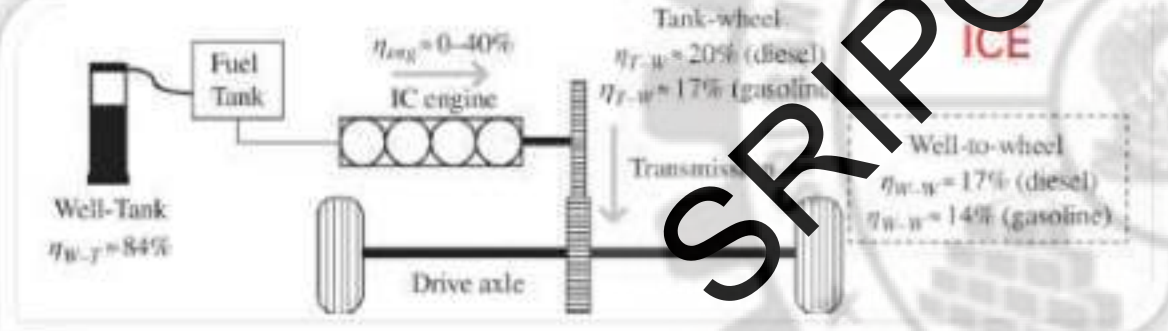


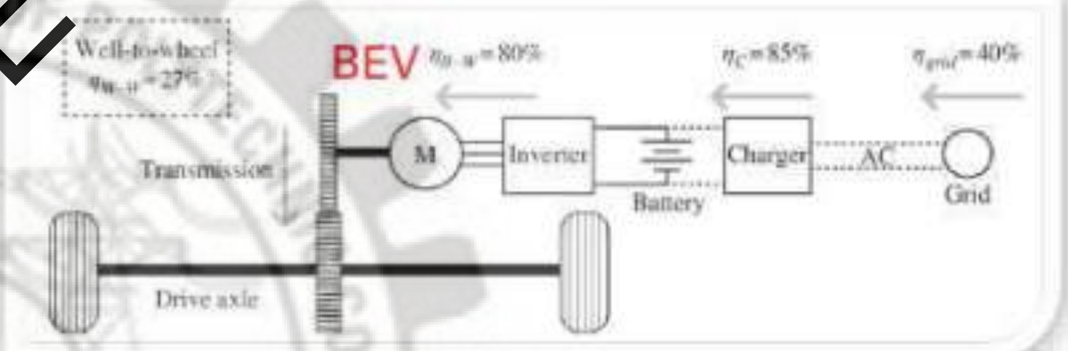
Power Split Hybrid

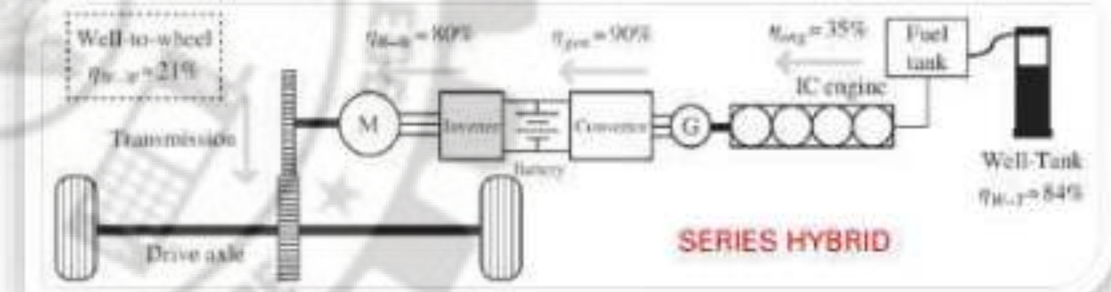
POWER/ENERGY FLOW DIAGRAMS / SANKEY

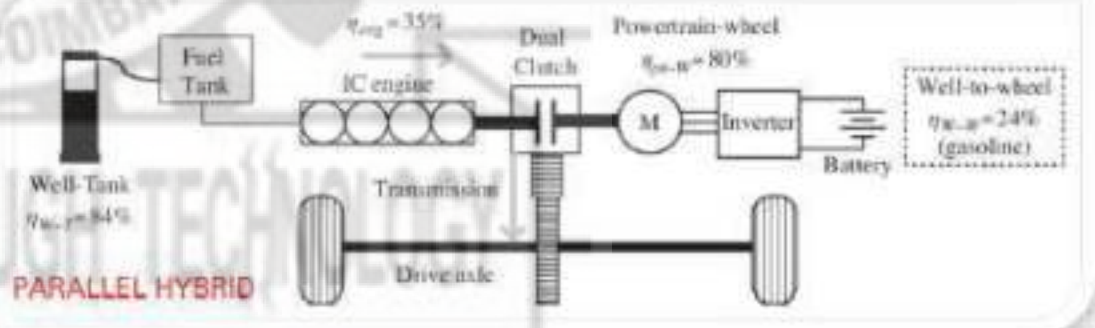


EFFICIENCY COMPARISON



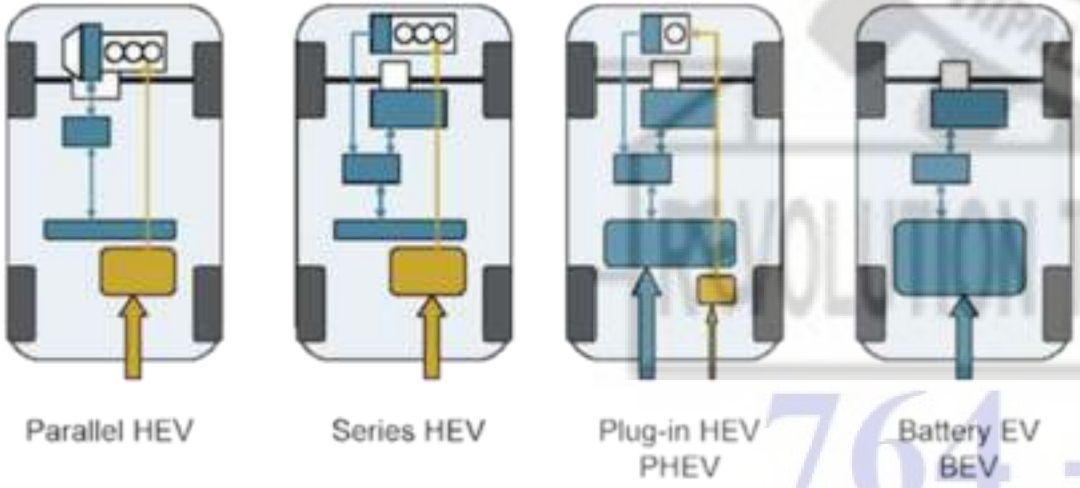


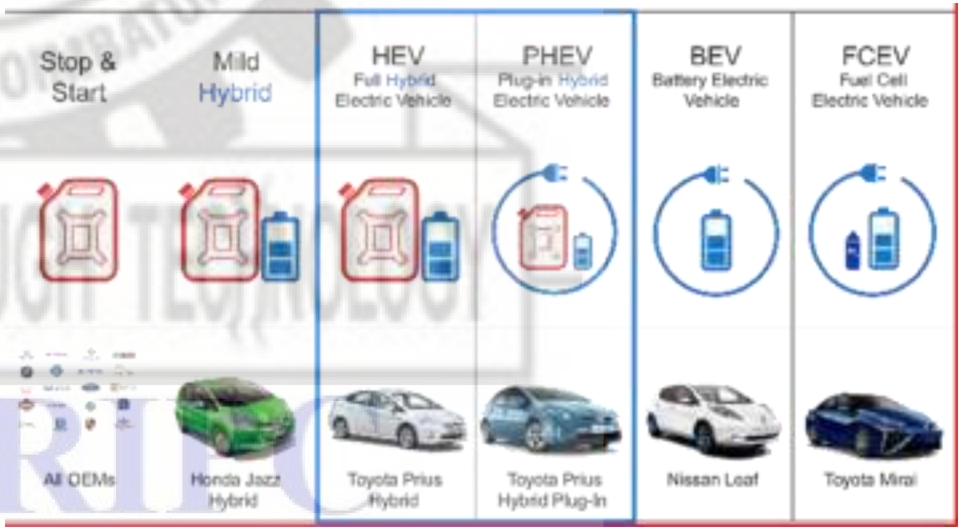




Fuel	Powertrain efficiency (%)	Well-to-wheel efficiency (%)
Gasoline SI	17	14
Diesel CI	20	17
BEV	80	27
Gasoline Series HEV	25	21
Gasoline Parallel HEV	28	24
Hydrogen FCEV	45	27


Hybrid
e.g. Toyota Prius
Plug-in Hybrid EV
e.g. Toyota Plug-in Prius
Battery EV
e.g. Nissan Leaf
Range Extended EV
e.g. BMW i3
Hydrogen Fuel Cell
e.g. Hyundai ix35


Parallel HEV
Series HEV
Plug-in HEV PHEV
Battery EV BEV

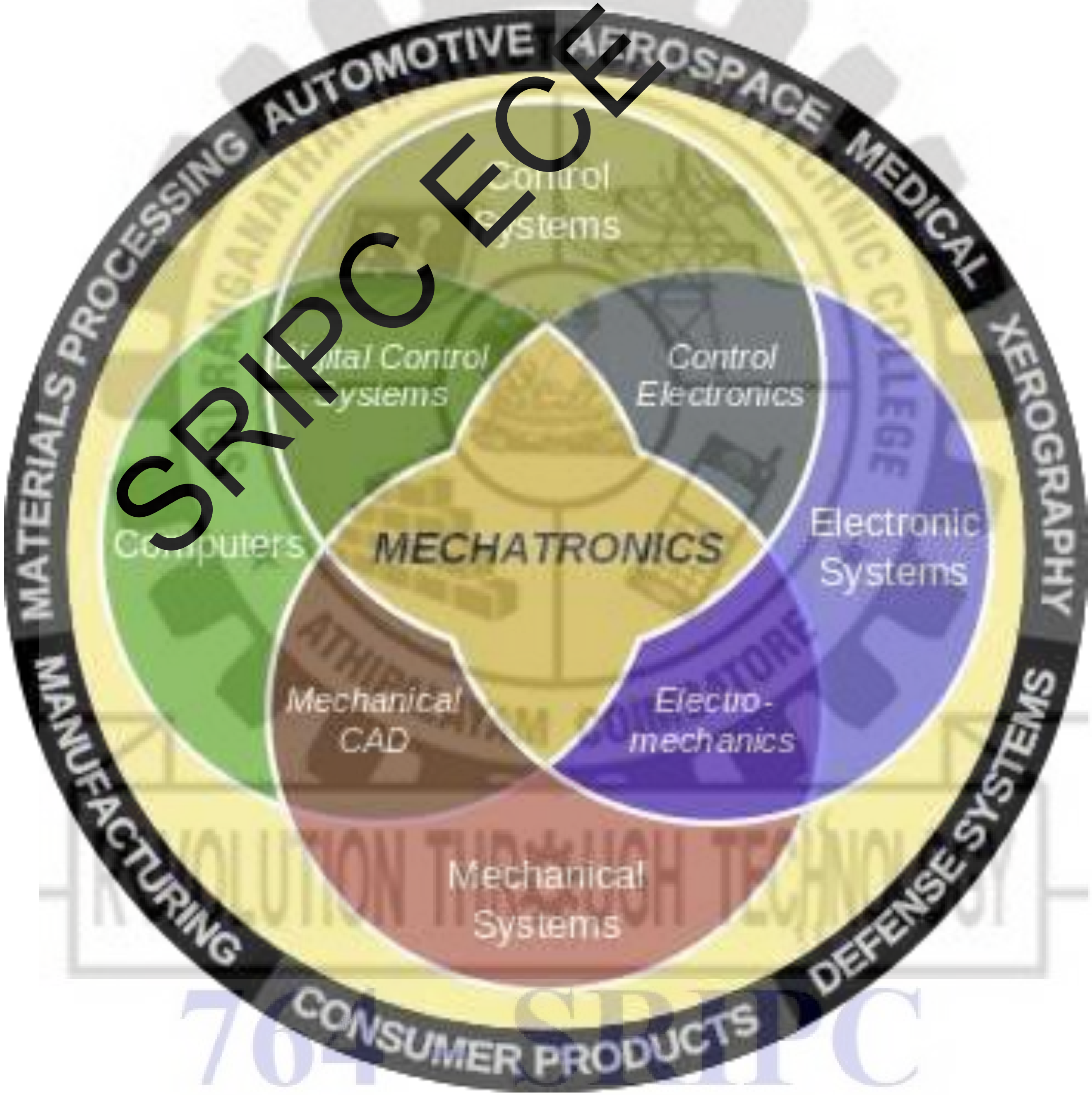

Stop & Start
Mild Hybrid
HEV
Full Hybrid Electric Vehicle
PHEV
Plug-in Hybrid Electric Vehicle
BEV
Battery Electric Vehicle
FCEV
Fuel Cell Electric Vehicle
All OEMs
Honda Jazz Hybrid
Toyota Prius Hybrid
Toyota Prius Hybrid Plug-In
Nissan Leaf
Toyota Mirai

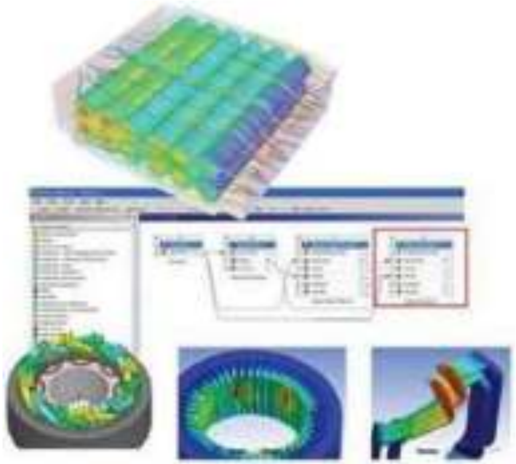
SUMMARIZING THE HV SCENARIO VS TYPES

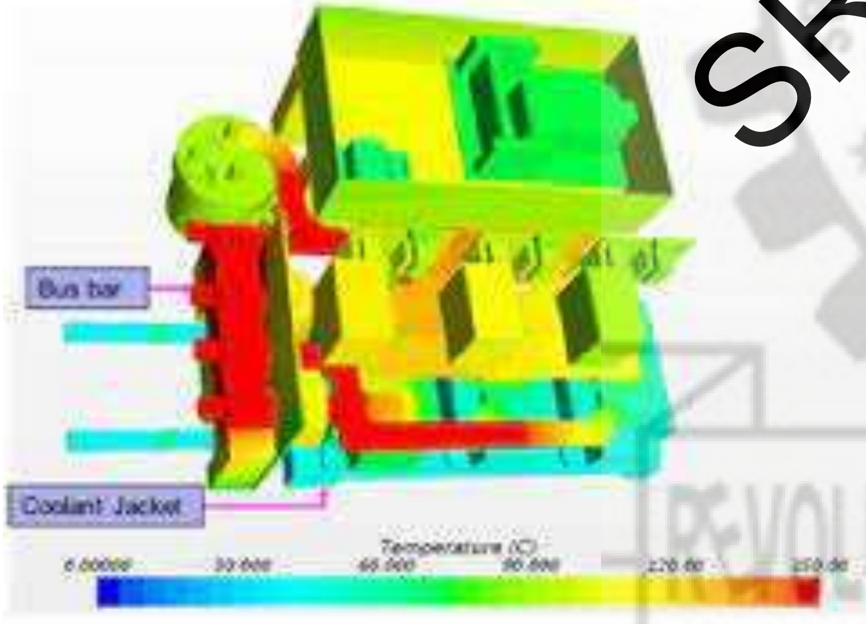
- Just meet strict fuel consumptions standards -> Mild Hybrid
- Incentives / demands for high fuel economy -> Full Hybrid
- Ultra high fuel economy / all-electric at low cost -> PHEV
- Full EV, limited charging infra -> BEV+REX
- Full EV, good charging infra -> BEV

Electric Propulsion Systems

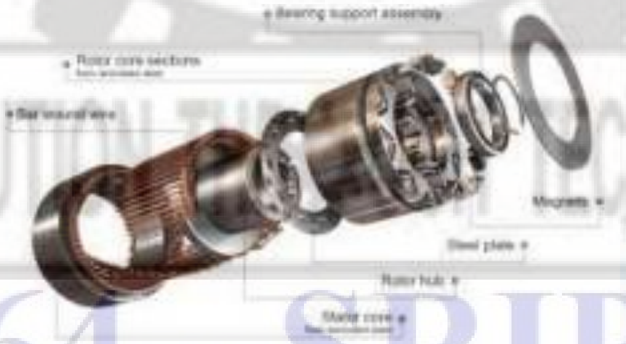
- Types of EV motors
- DC motor drives
- Permanent Magnetic Brush Less -DC Motor Drives (BLDC)
  - – Principles, Construction and Working
- Hub motor Drive system
- Merits and Demerits of DC motor drive, BLDC motor drive

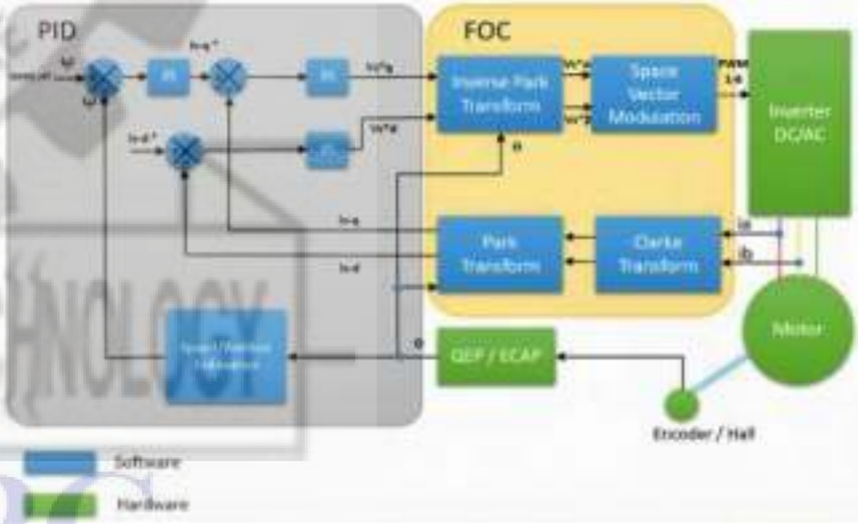

AUTOMOTIVE
AEROSPACE
MEDICAL
XEROGRAPHY
DEFENSE SYSTEMS
CONSUMER PRODUCTS
MANUFACTURING
MATERIALS PROCESSING
Control Systems
Digital Control Systems
Control Electronics
Computers
MECHATRONICS
Electronic Systems
Mechanical CAD
Electro-mechanics
Mechanical Systems



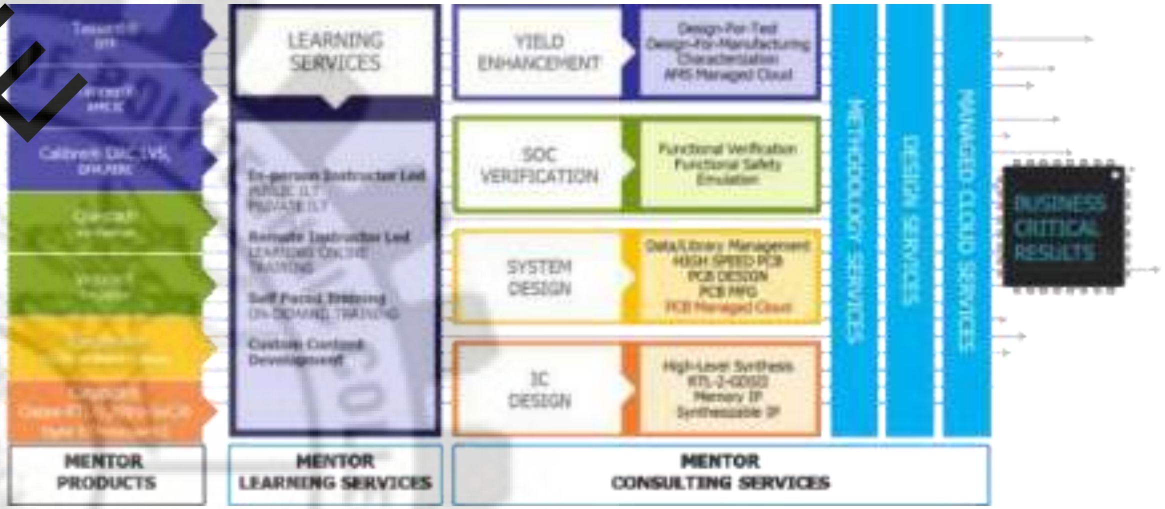


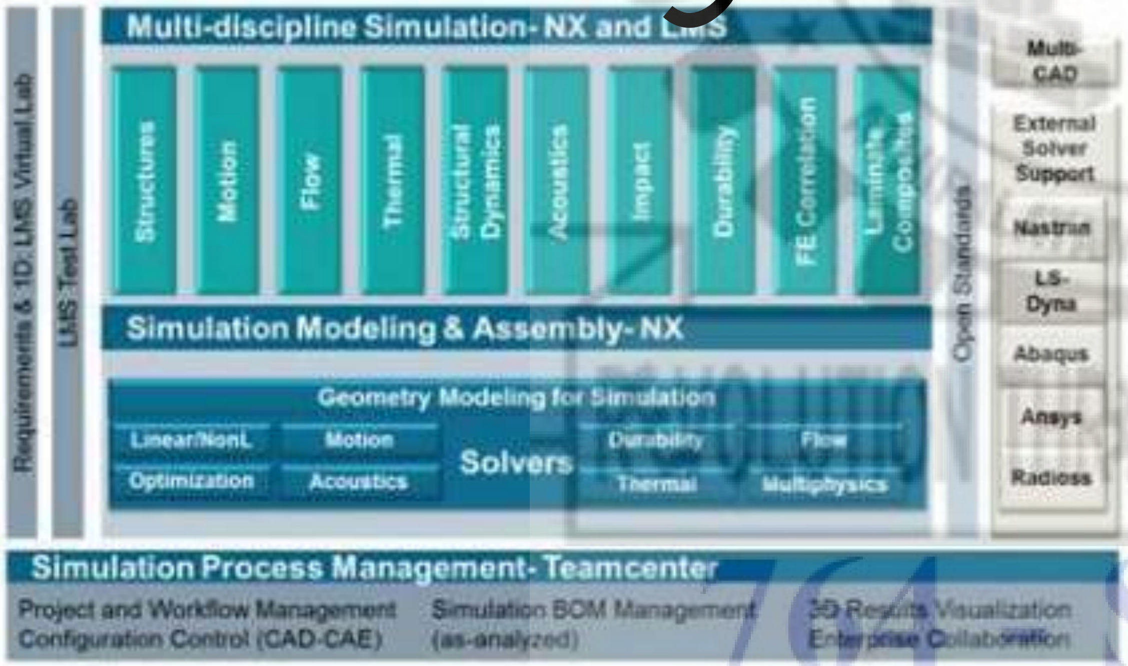
Inverter - Temperature Distribution

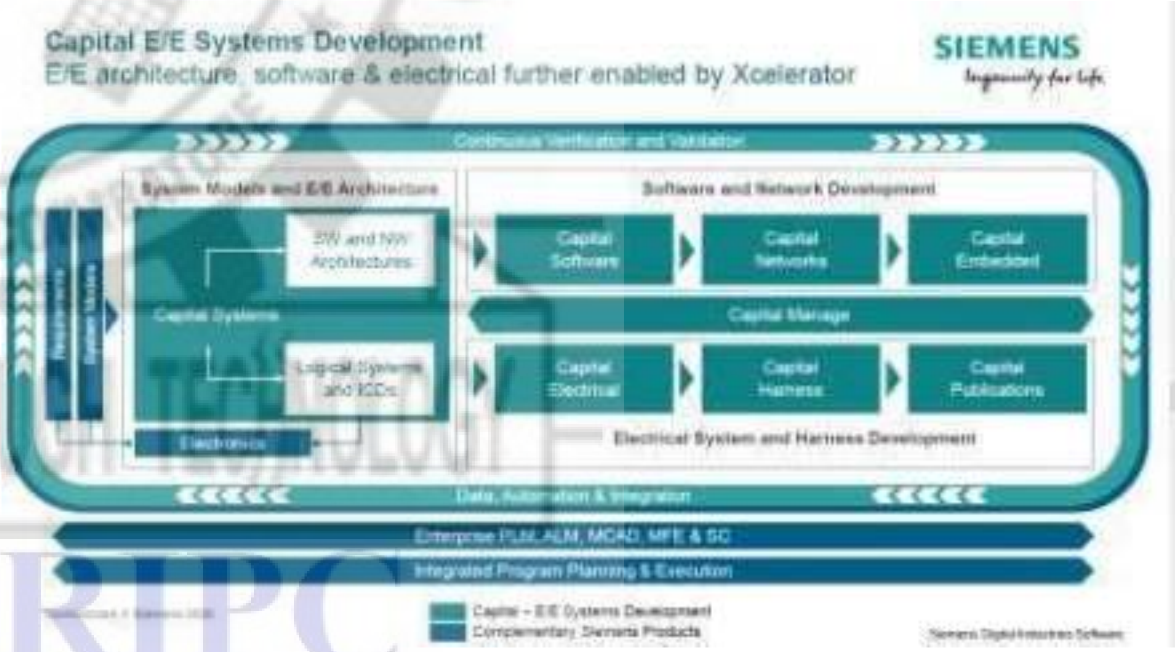




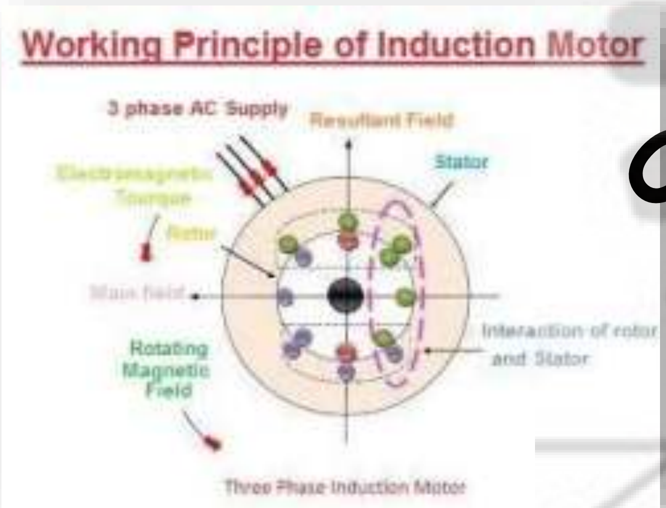
Digital Validation - Multiphysics







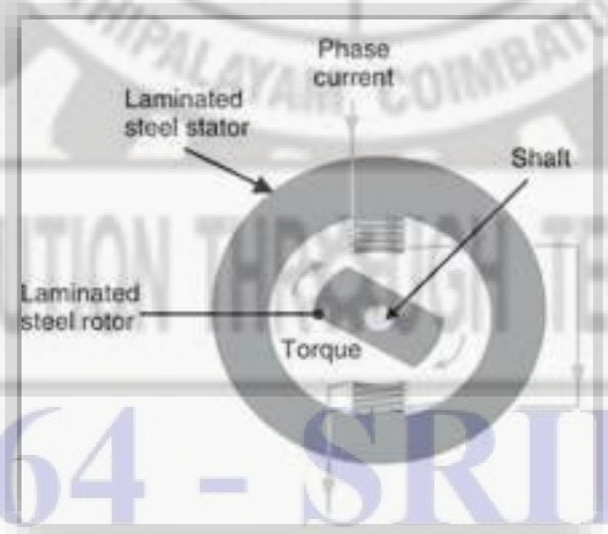
Motor Types



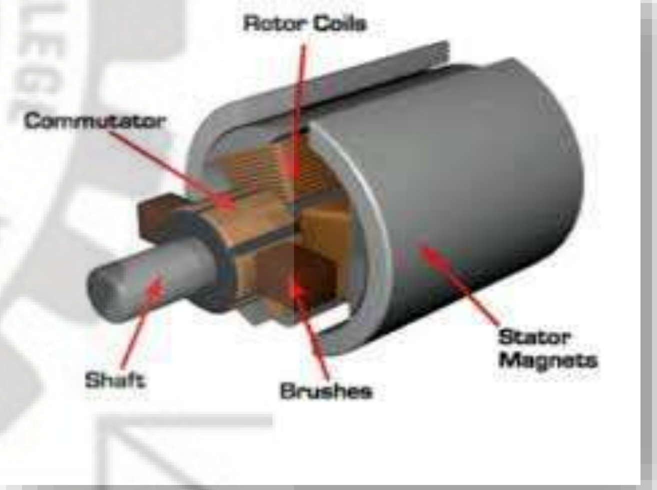
Induction Motor

Permanent Magnet Motor

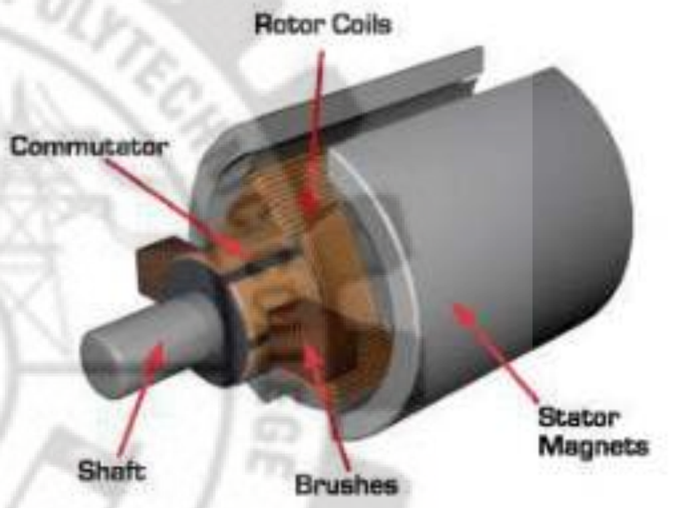
Reluctance Motor



D.C. Motor

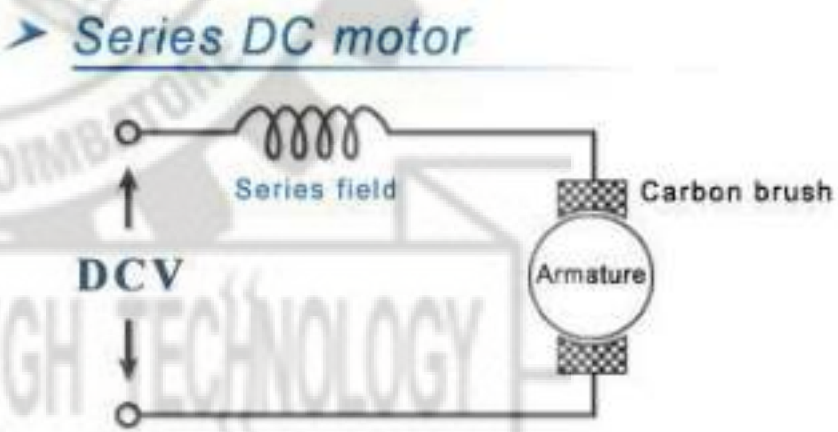


SERIES DC MOTOR



- ✓ Falls under the category of self-excited DC motors, and it gets its name from the fact that the field winding in this case is connected internally in series to the armature winding.

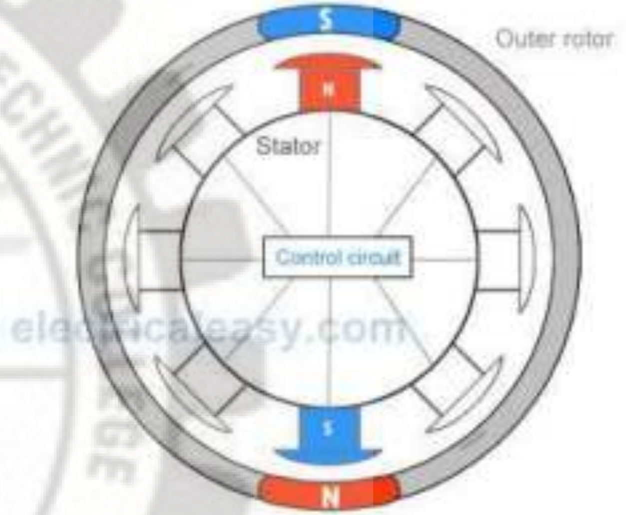
- ✓ PRINCIPLE : Whenever the magnetic field is formed approximately, a current carrying conductor cooperates with an exterior magnetic field, and then a rotating motion can be generated.



DC MOTOR : WORKING

https://www.youtube.com/watch?v=LAtPHANEfQo

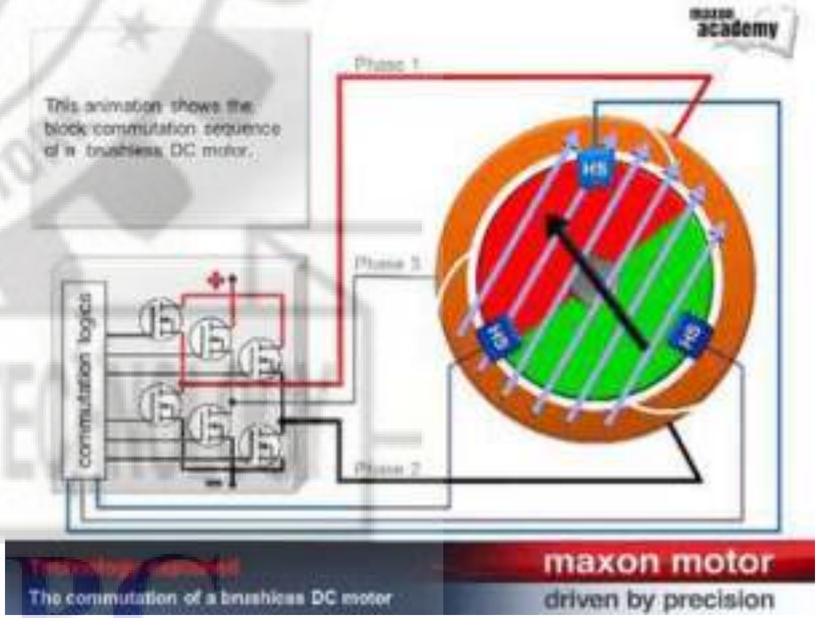
BRUSHLESS DC MOTOR



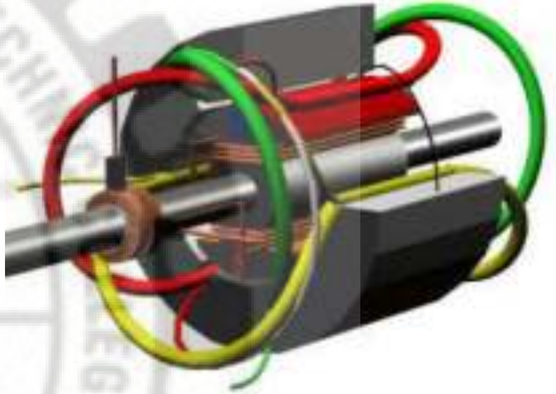
- ✓ A brushed DC motor has permanent magnets on the outside of its structure(STATOR), with a spinning armature on the inside (ROTOR containing electromagnet).
- ✓ A brushless DC motor is essentially flipped inside out, eliminating the need for brushes to flip the electromagnetic field.
- ✓ The control of the speed and torque is done by an 'electronic controller'.

BLDC MOTOR : WORKING

https://www.youtube.com/watch?v=bCEiOnuODac

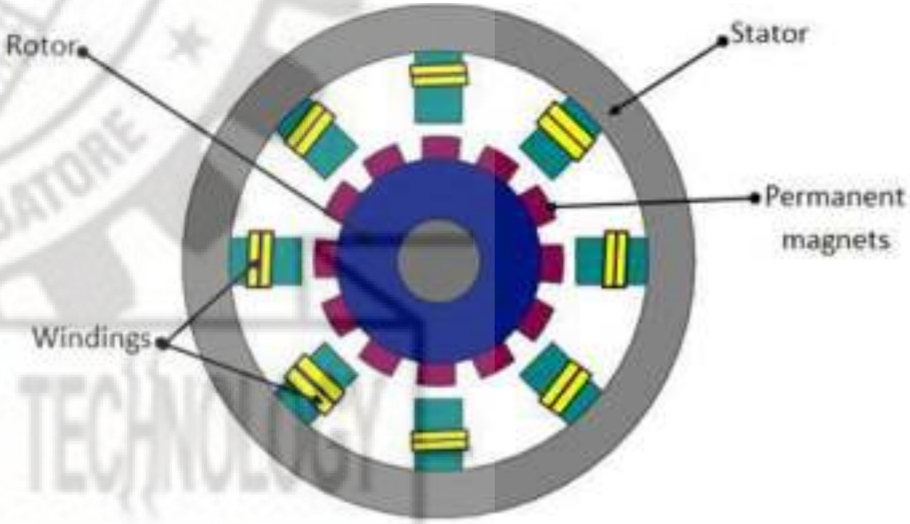


PM SYNCHRONOUS MOTOR



- ✓ The principle of operation of a synchronous motor is based on the interaction of the rotating magnetic field of the stator and the constant magnetic field of the rotor.

- ✓ The magnetic field of the rotor, interacting with the synchronous alternating current of the stator windings, according to the Ampere's Law, creates torque, forcing the rotor to rotate.

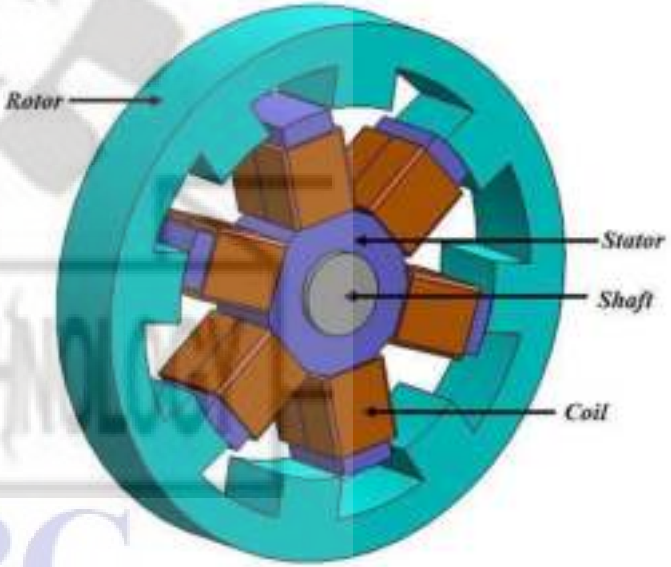


PMSM : WORKING

https://www.youtube.com/watch?v=Vk2jDXxZIhs

SWITCHED RELUCTANCE MOTOR

- ✓ Based on the variable reluctance principle.
- ✓ By changing the air gap between the rotor and stator, we can change the reluctance of the motor.
- ✓ Reluctance is nothing but a resistance to the magnetic flux. (Opposes the magnetic flux)
- ✓ As the magnetic flux have a tendency to flow through lowest reluctance path, therefore rotor always tends to align along the minimum reluctance path.



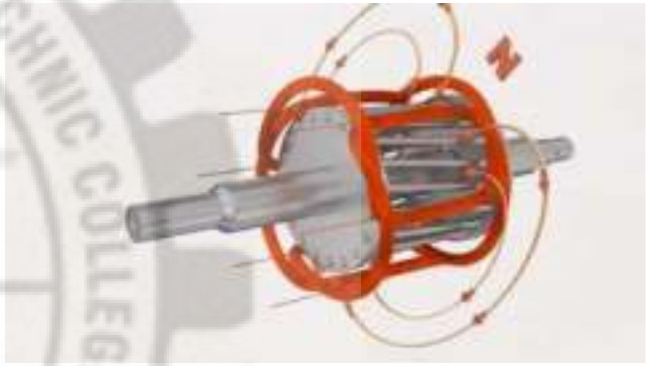
SR MOTOR : WORKING

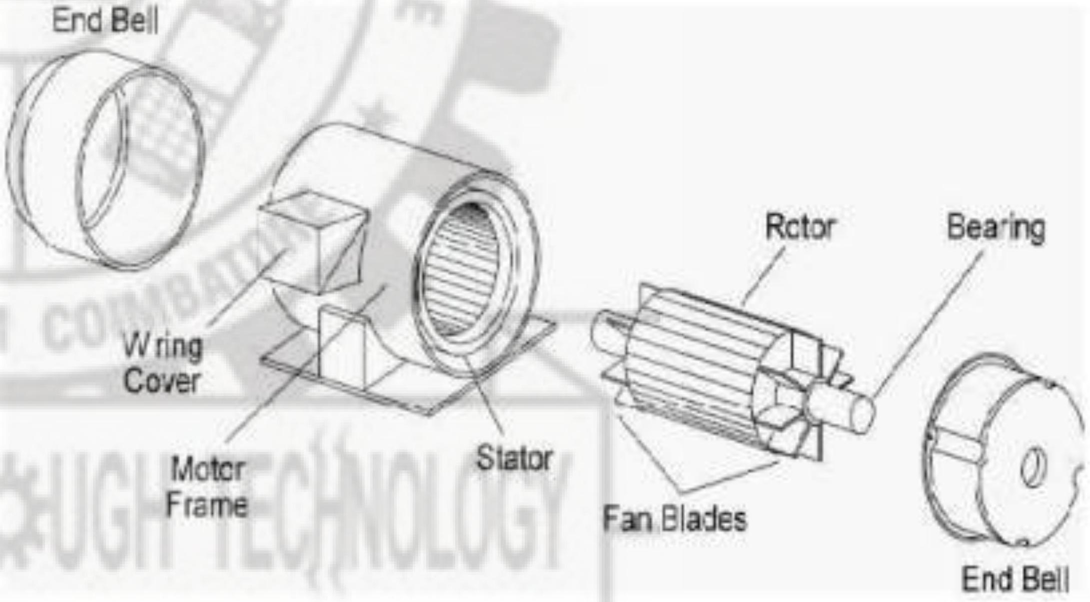
https://www.youtube.com/watch?v=23i0prqMfT0

INDUCTION MOTOR

- ✓ Based on the principle of electromagnetism. It is called a 'squirrel cage' motor because the rotor inside of it – known as a 'squirrel cage rotor' – looks like a squirrel cage.

- ✓ The main difference is that there is no electrical connection from the rotor winding to any source of supply. The required current and voltage in the rotor circuit are provided by induction from the stator winding. This is the reason to call is as an induction motor.



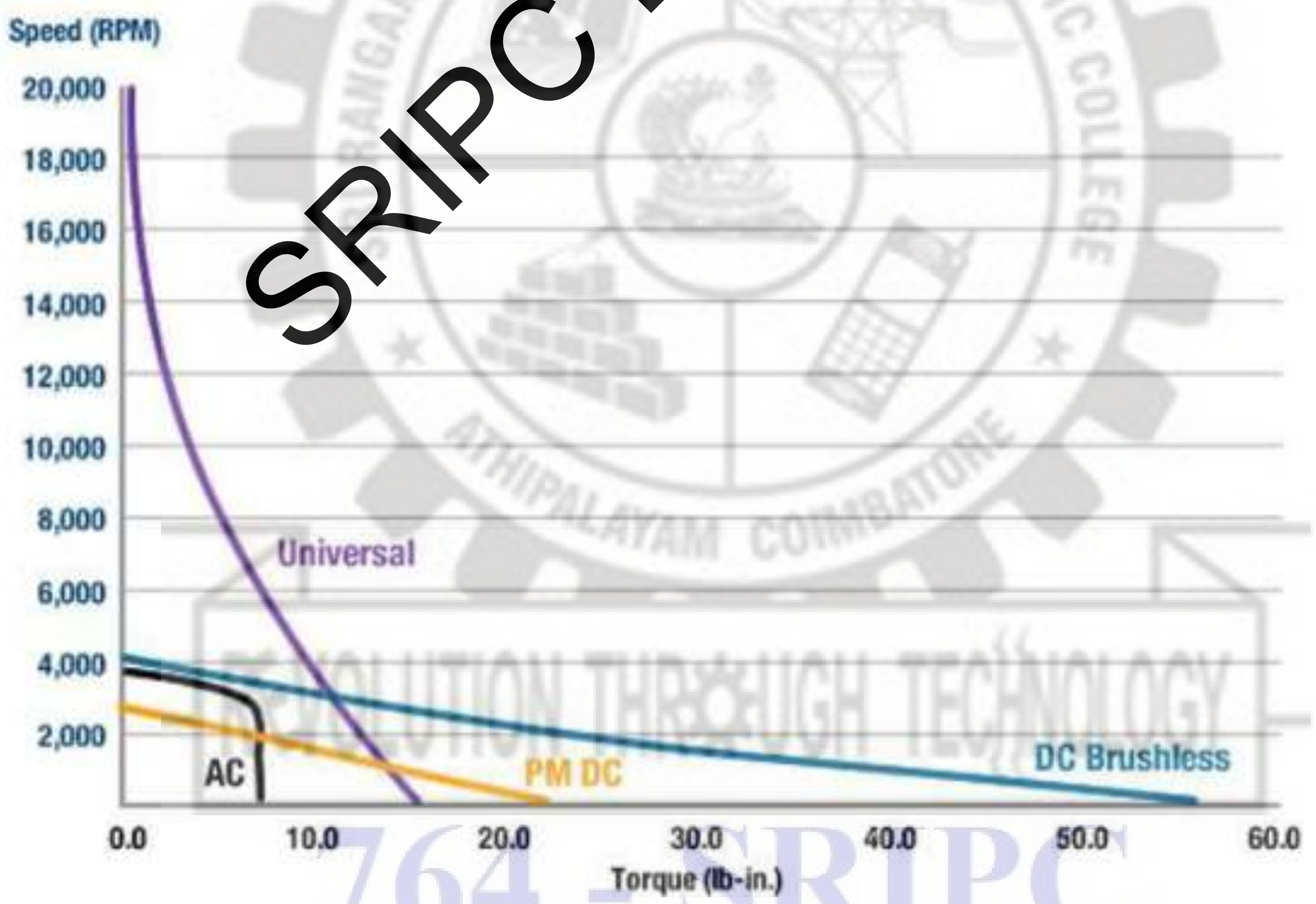


INDUCTION MOTOR: WORKING

https://www.youtube.com/watch?v=AQqyGNOP_3o

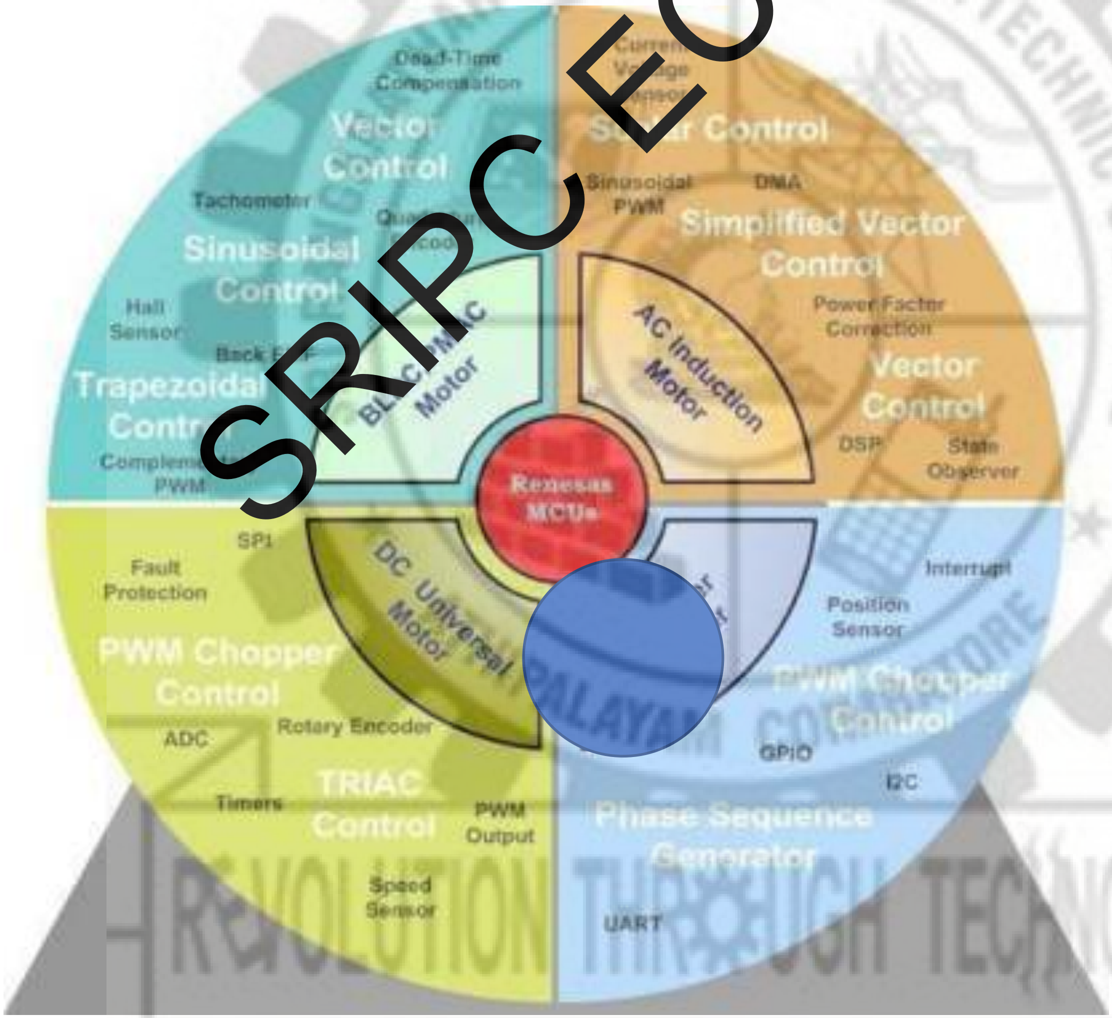
CONTROL ALGORITHMS FOR MOTORS

N vs T

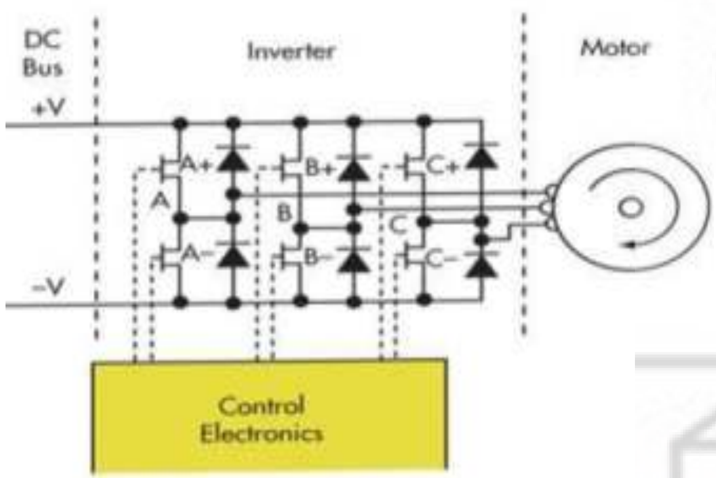


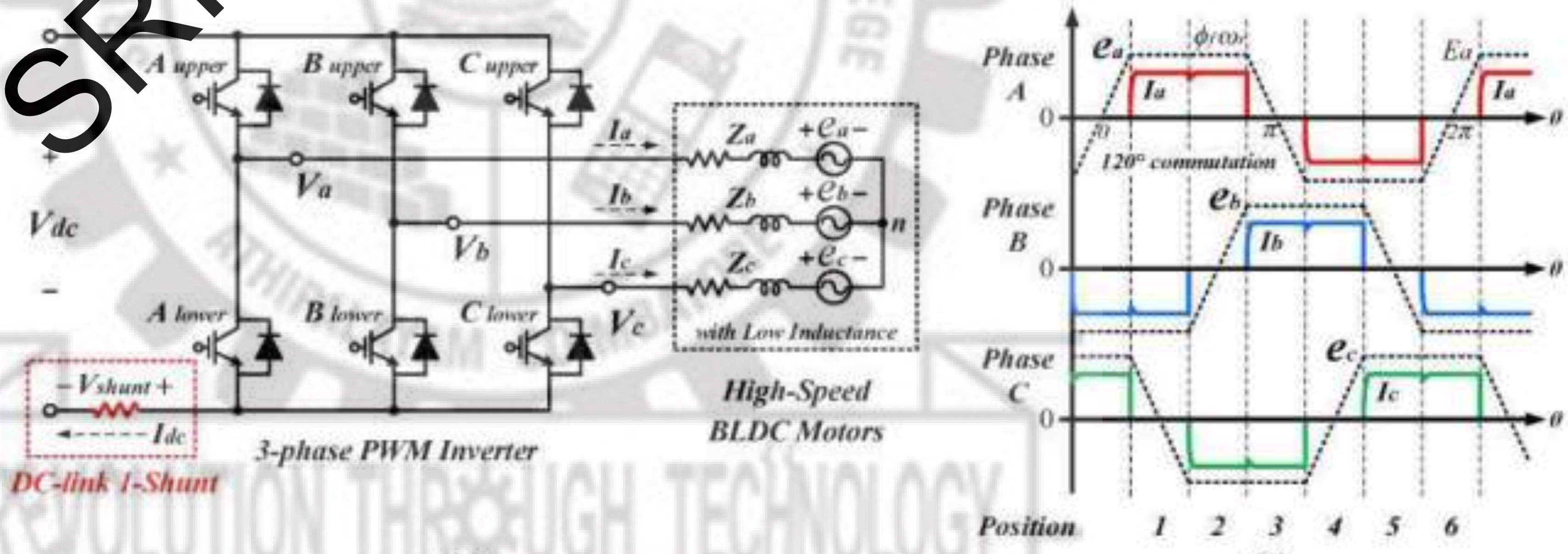
1lb-in=0.1129 N.m

Control Methods for Motors



Trapezoidal Control





(a) (b)

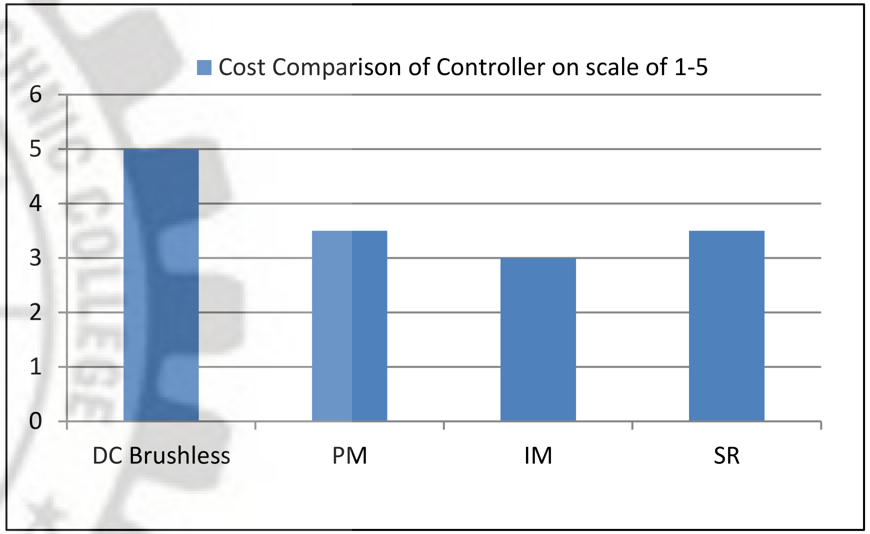
PERFORMANCE COMPARISON OF MOTOR DRIVE TECHNOLOGIES

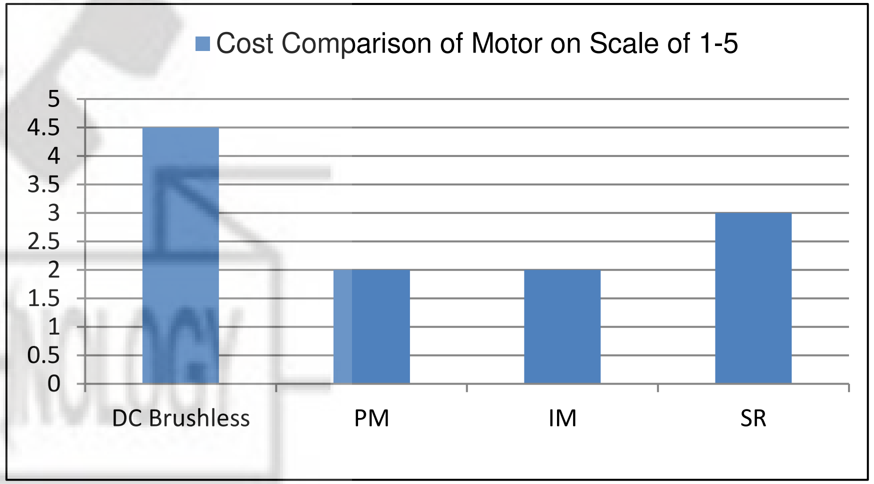
- EV applications demand high efficiency, high torque density, high reliability, and wide speed range while reducing weight, complexity, efficiency and cost.

Motor Drives	Pros	Cons	Application
DC Motors	✓ Uses DC supply from the battery in vehicles ✓ Motor drives, speed and torque control is simple	✓ Large and inefficient, maintenance requirements ✓ Limited regenerative braking capacity	✓ Danavolt of Peugeot Citroen
Induction Motors	✓ Renowned for their simplicity, ruggedness, cheapness and reliability	✓ Low efficiency, low power factor, and low inverter usage	✓ Silverado of Chevrolet ✓ Durango of Daimler Chrysler, ✓ X5 of BMW ✓Kangoo of Renault
Permanent Magnet Motors	✓ High torque and power density, high controllability, low weight and size	✓ Limited reserve and high cost of rare earth materials	✓ Tino of Nissan ✓ Insight of Honda ✓ Prius of Toyota
Reluctance Motors	✓ High reliability and speed potential ✓ Can withstand high temperatures and mechanical stresses	✓ High torque ripples, acoustic noise, and high Electromagnetic Interference	✓ Commodore of Holden

Summary of Performance Comparison

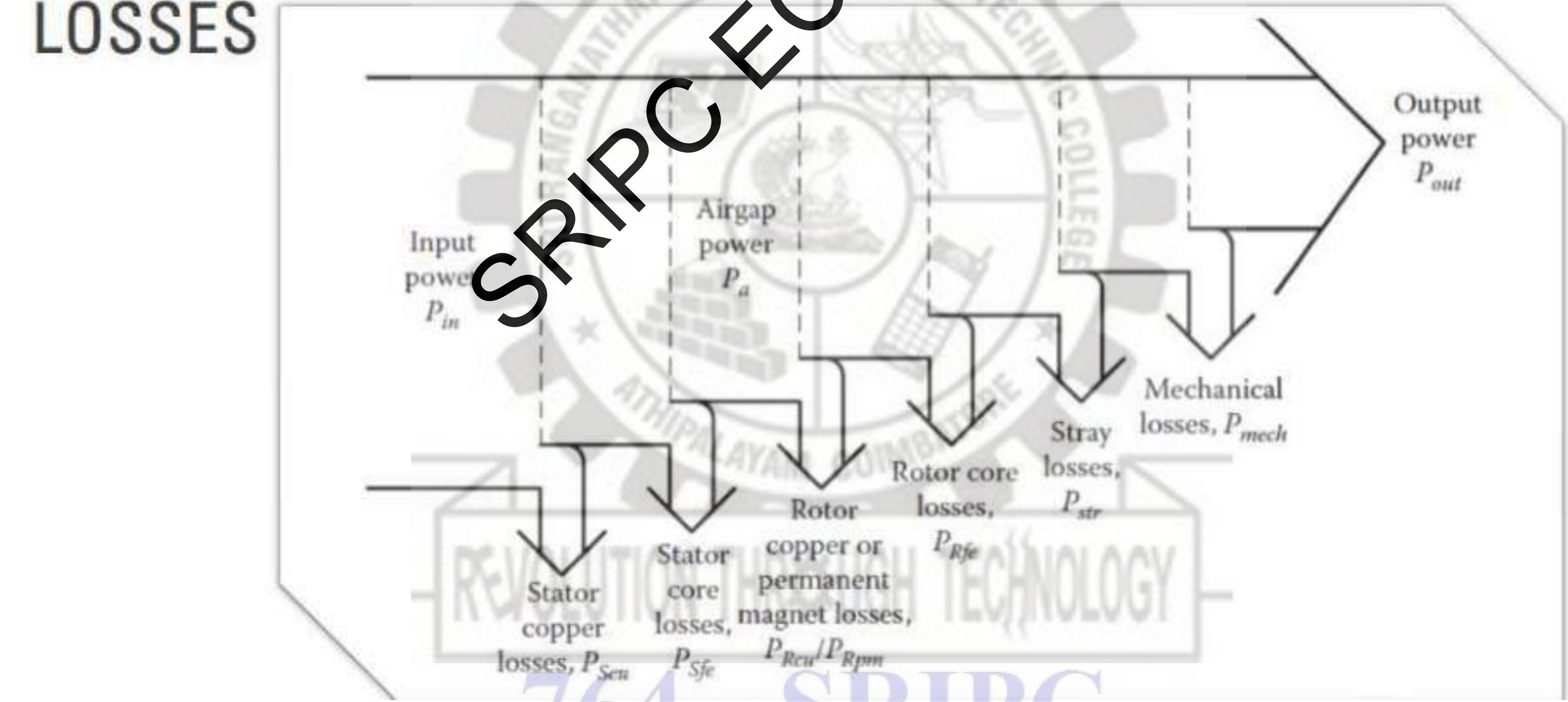
Performance	DC	PM	IM	SR
Power Density	Low	High	Low	Medium
Torque Ripple	Low	Medium	Low	High
Acoustic Noise	Medium	Low	Low	High
Overload Capacity	High	Medium	High	Low
Controllability	High	Medium	High	Low
Max Speed	Medium	Low	High	Very High
Speed Range	Medium	Low	Medium	High
Size	Medium	Small	Medium	Large
Reliability	Low	Medium	High	High
Efficiency	Low	High	Medium	Medium





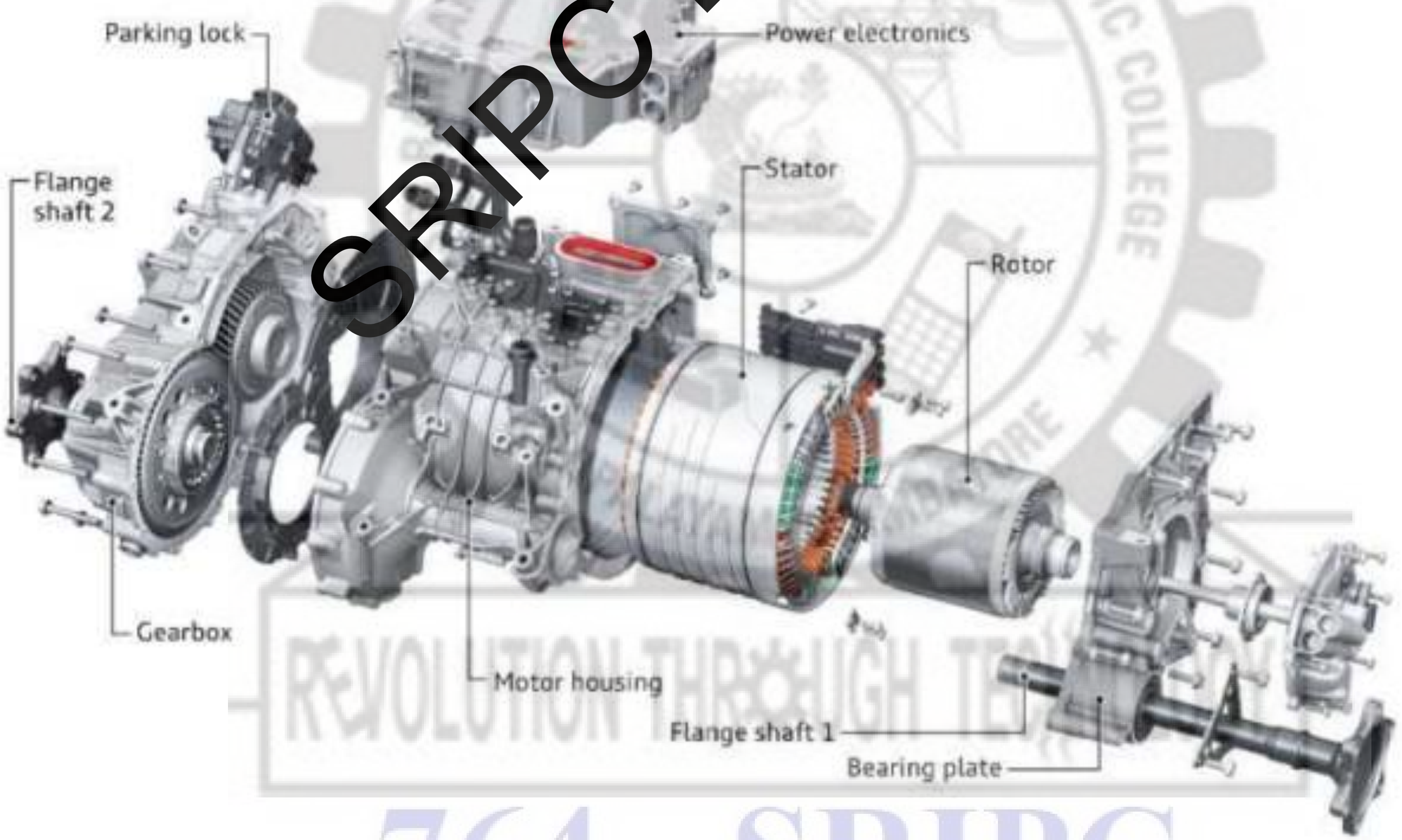
Hub Motor

ELECTRIC MACHINE LOSSES

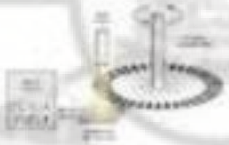
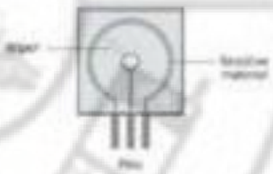



High power density
High torque density
Wide speed range
High efficiency
Wide constant-power
High intermittent overload capability
Better NVH
High reliability
Reasonable cost

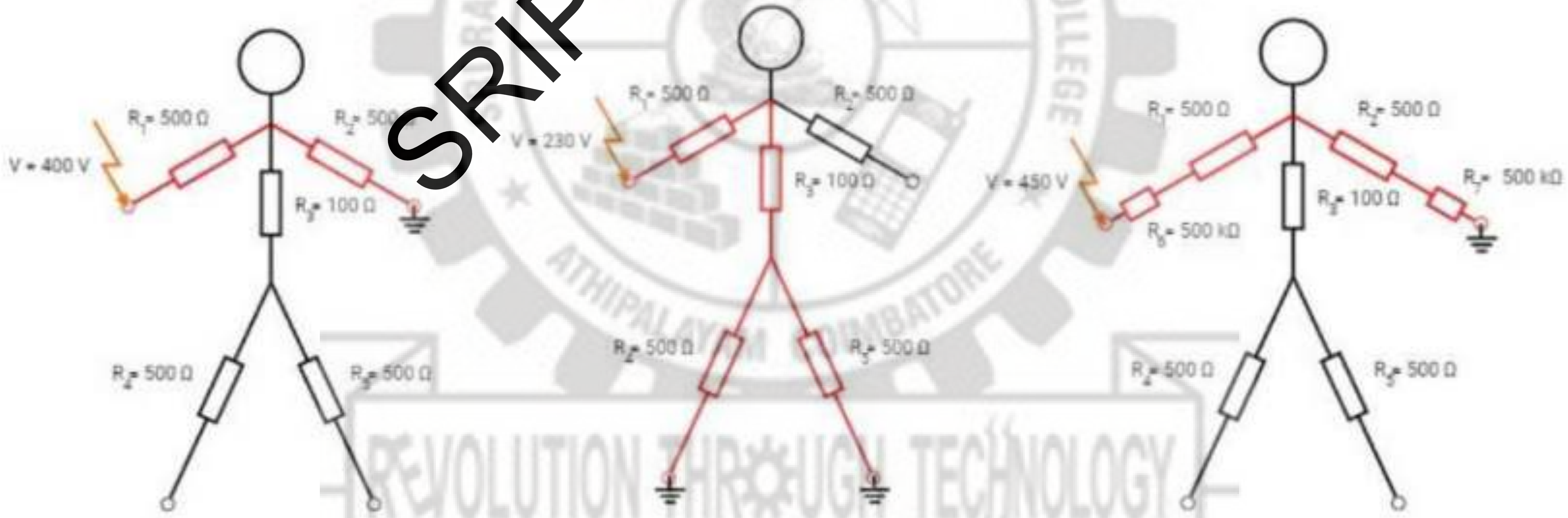
E-Drive System Architecture



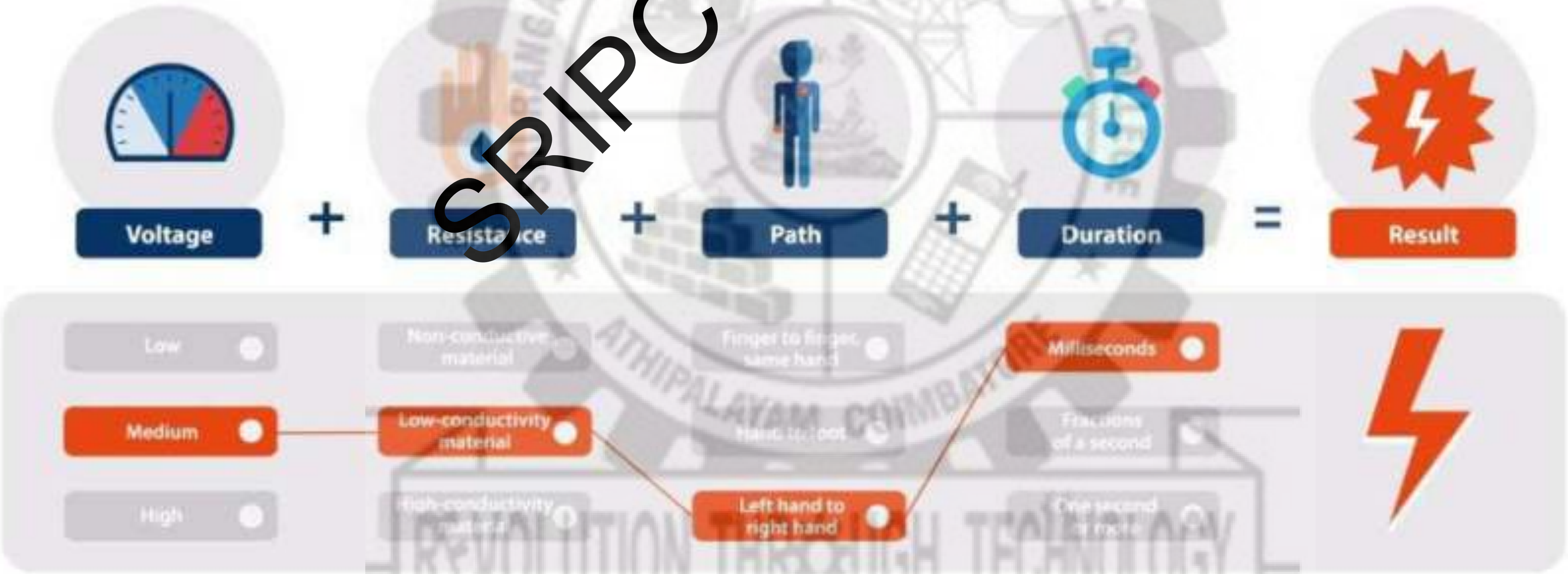
Typical Position Sensing Techniques

	Inductive	Resolver	Optical Encoder	Resistive Potentiometer	Hall-Effect Latch	Magnetic Encoder IC
Sensor Type						
Size and Weight	Low	High	Med	Very Low	Very Low	Low
System Costs	Med	High	High	Low	Low	Med
Power	Low	High	Med	Low	Low	Low
Accuracy	Very High	Very High	Very High	Low	Med	High
RPM Rates	Very High	Very High	Very High	Low	Med	High
Strayfield Immune	Yes	Yes	Yes	Yes	No	No / (ams Yes)
Dirt/Dust Susceptible	No	No	Yes	No	No	No
Functional Safety Redundancy option	Possible	Not possible (Physically and Economically)	Not possible (Physically and Economically)	Possible	Not Possible (Too complex due to so many devices required)	Possible

Electrical resistance of the human body

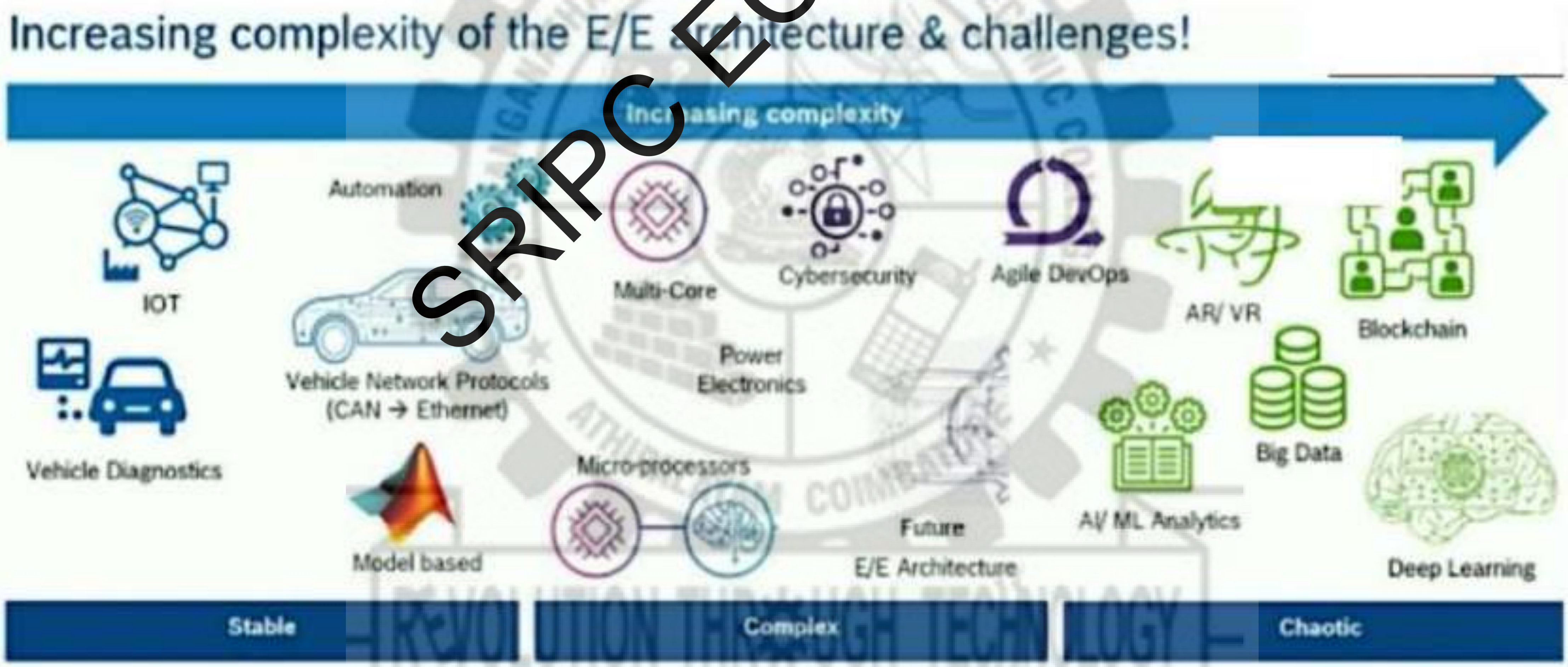


Factors affecting an Electrocution



Personal Protective Equipment

Increasing System Complexity



Functional Safety is a key element to product development in the new era of Mobility

Top EV Cars

- https://www.topgear.com/car-news/electric/top-gears-top-20-electric-cars

End of Session-4

Any Questions?


Thank You!

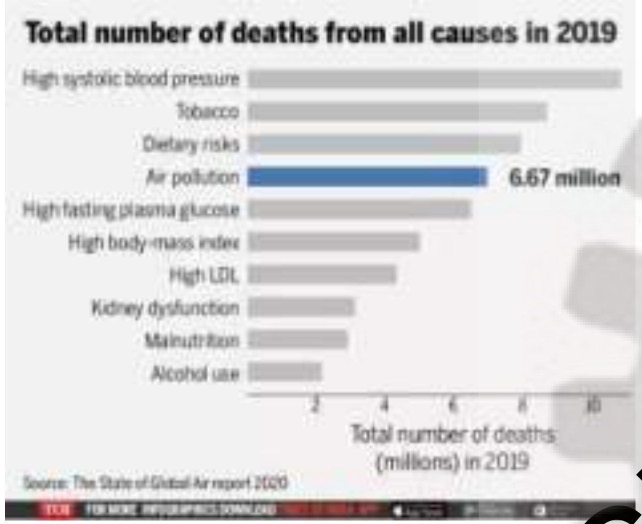
Program on EV Technology and Policy – Day 2

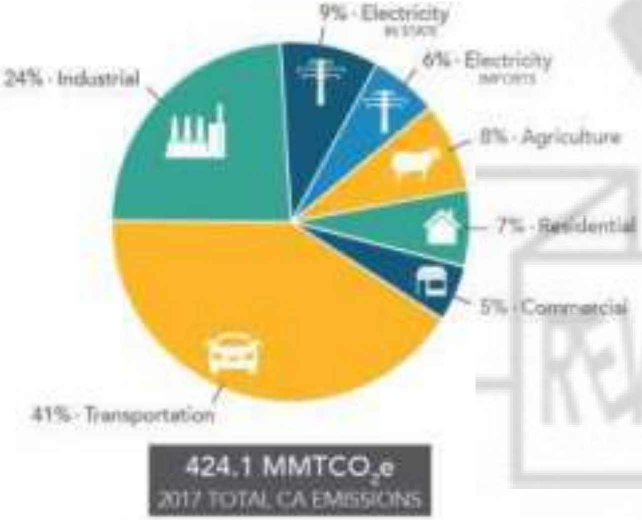
14th May 2022

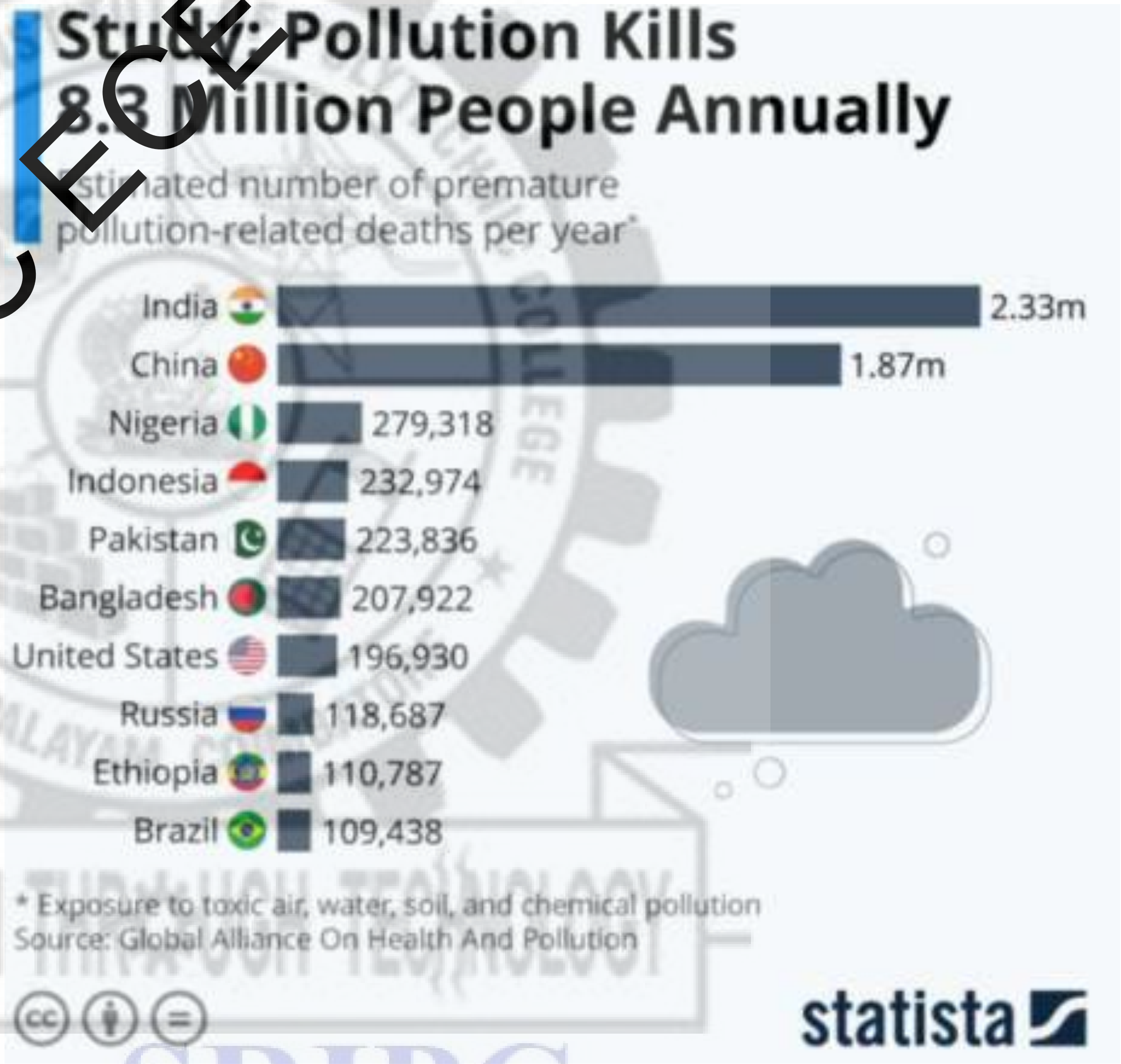
R.Muruganandam, VP-R&D
Sona Comstar Automotive Technology, Chennai

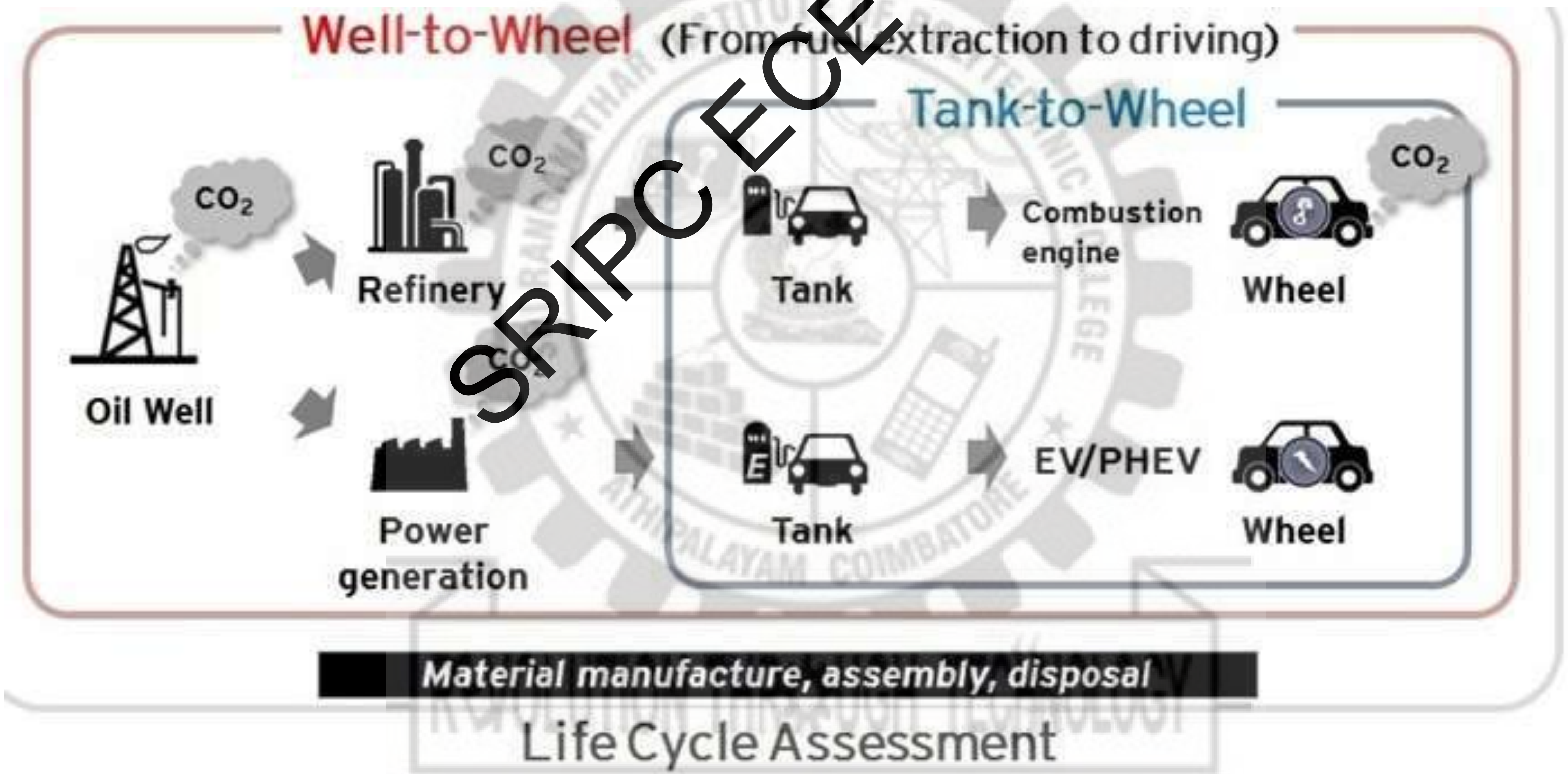
LAST WEEK

in review

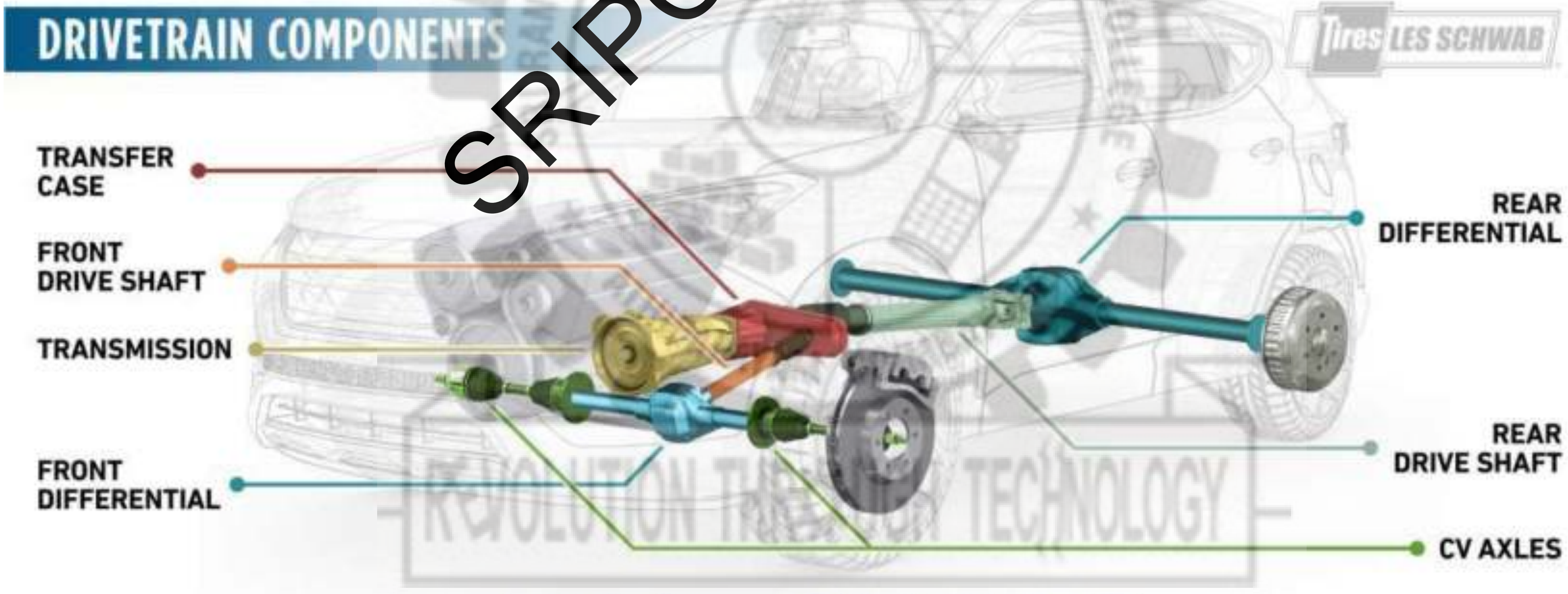

Total number of deaths from all causes in 2019
High systolic blood pressure
Tobacco
Dietary risks
Air pollution
6.67 million
High fasting plasma glucose
High body-mass index
High LDL
Kidney dysfunction
Malnutrition
Alcohol use
2
4
6
8
10
Total number of deaths (millions) in 2019
Source: The State of Global Air report 2020


9% - Electricity
6% - Electricity
24% - Industrial
8% - Agriculture
7% - Residential
5% - Commercial
41% - Transportation
424.1 MMTCO$_2$e
2017 TOTAL CA EMISSIONS

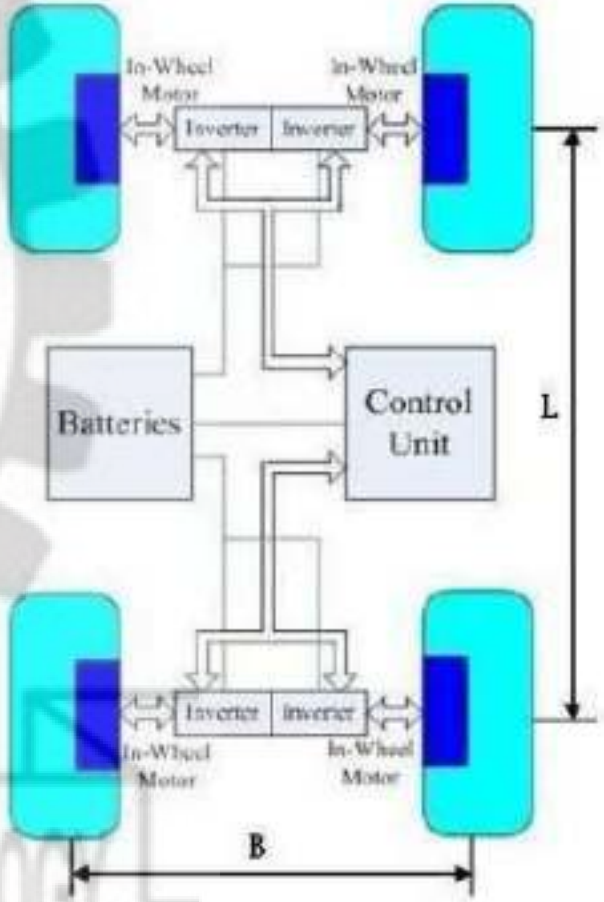

Study: Pollution Kills 8.3 Million People Annually
Estimated number of premature pollution-related deaths per year*
India 2.33m
China 1.87m
Nigeria 279,318
Indonesia 232,974
Pakistan 223,836
Bangladesh 207,922
United States 196,930
Russia 118,687
Ethiopia 110,787
Brazil 109,438
* Exposure to toxic air, water, soil, and chemical pollution
Source: Global Alliance On Health And Pollution
statista

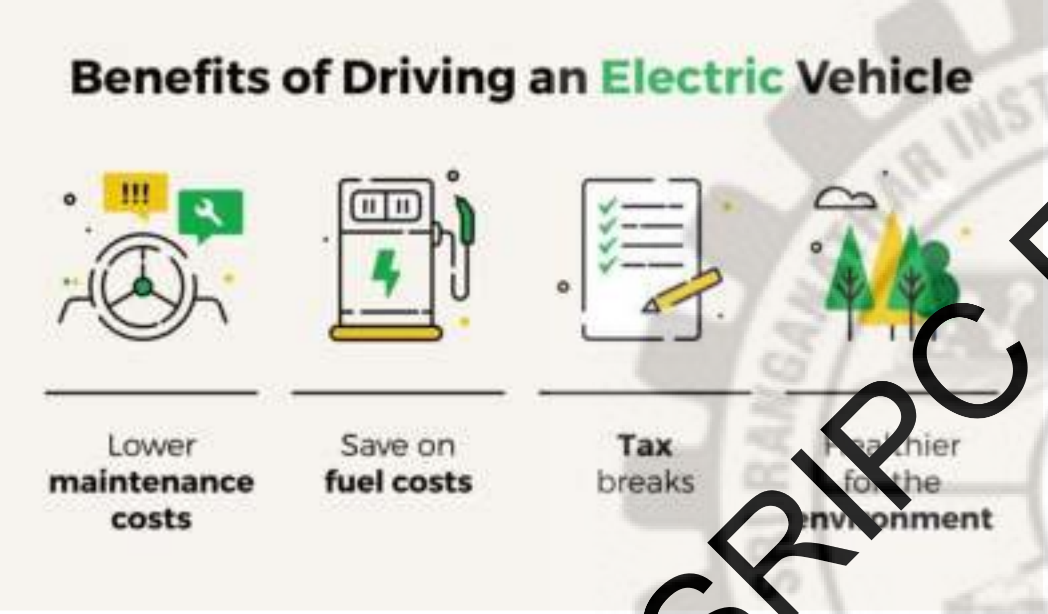

Well-to-Wheel (From fuel extraction to driving)
Tank-to-Wheel
CO_2
CO_2
CO_2
CO_2
Oil Well
Refinery
Power generation
Tank
Tank
Combustion engine
EV/PHEV
Wheel
Wheel
Material manufacture, assembly, disposal
Life Cycle Assessment

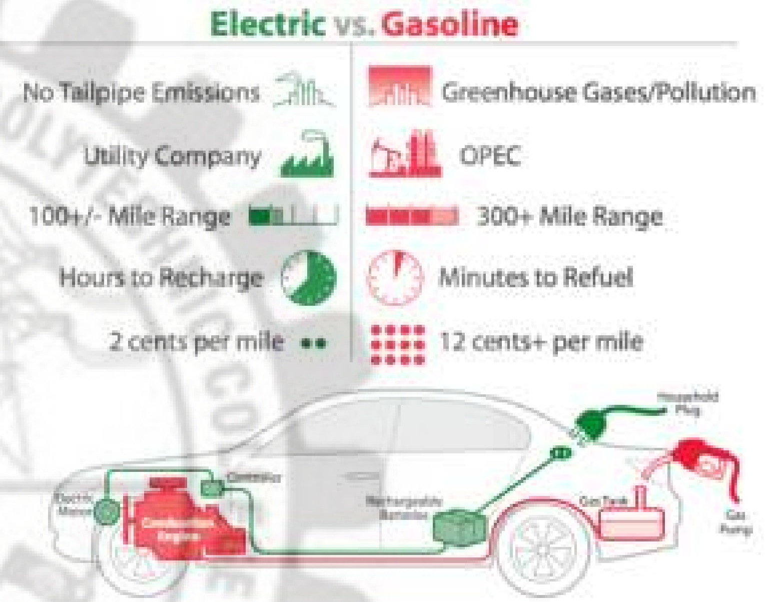
Parts of Drive train system



Introduction to Battery Electric Vehicle




Benefits of Driving an Electric Vehicle
Lower maintenance costs
Save on fuel costs
Tax breaks
Healthier for the environment

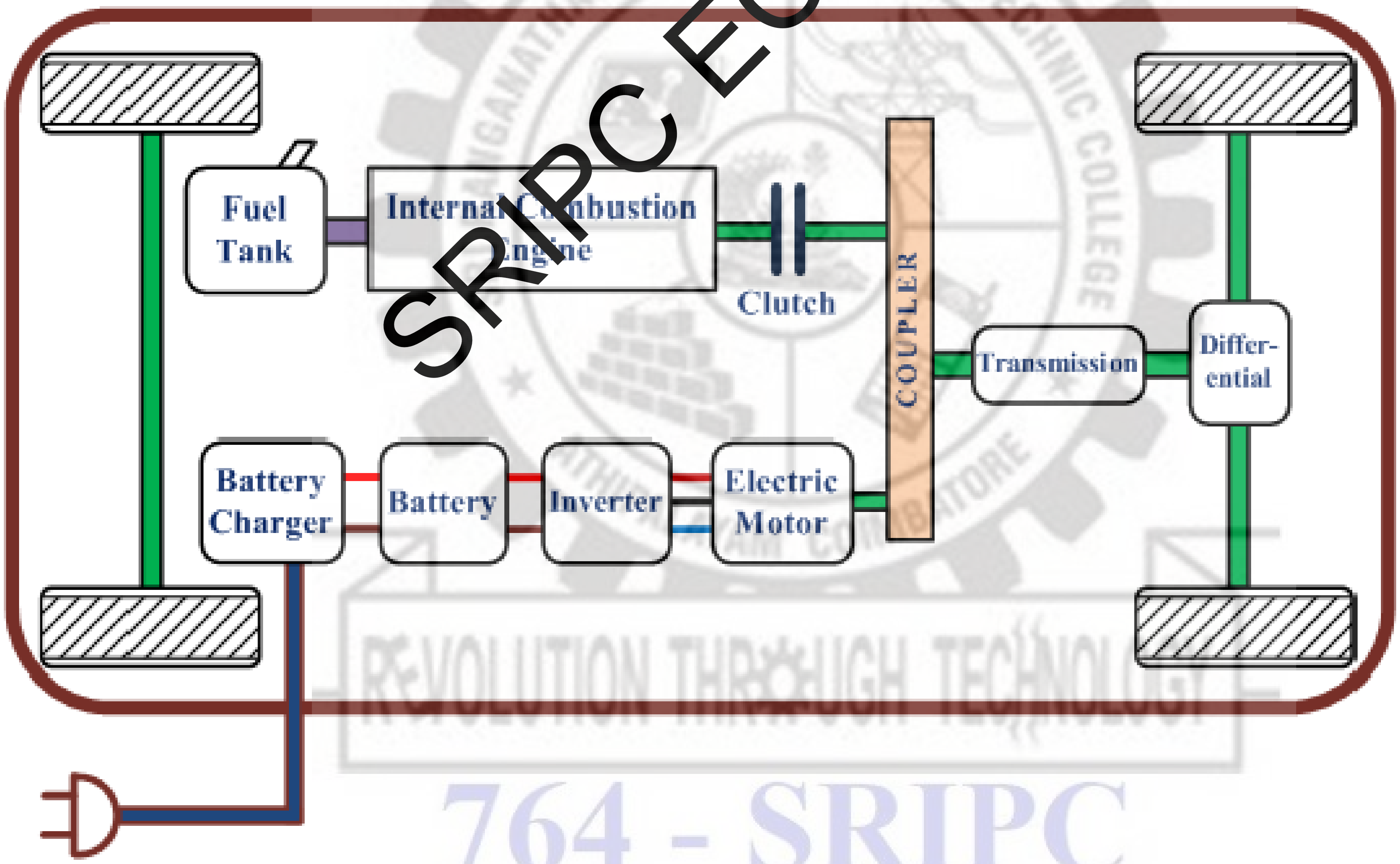

Electric vs. Gasoline
No Tailpipe Emissions
Greenhouse Gases/Pollution
Utility Company
OPEC
100+/- Mile Range
300+ Mile Range
Hours to Recharge
Minutes to Refuel
2 cents per mile
12 cents+ per mile


analyticSteps
www.analyticsteps.com
Energy Efficiency
Curtailing Noise Pollution
Fewer Particulates
Advantages of Electric Car
Night charging leads to cleaner energy
CO_2
Cleaner CO2 emission
Zero tailpipe emissions


Benefits of Electric Vehicles
Lower noise pollution
Lower repair & maintenance costs
Faster acceleration
Higher energy conversion efficiency
No idling
Smaller, lighter engine

Figure 2. Historical fleet CO_2 emissions performance and current standards (gCO_2/km normalized to NEDC) for passenger cars

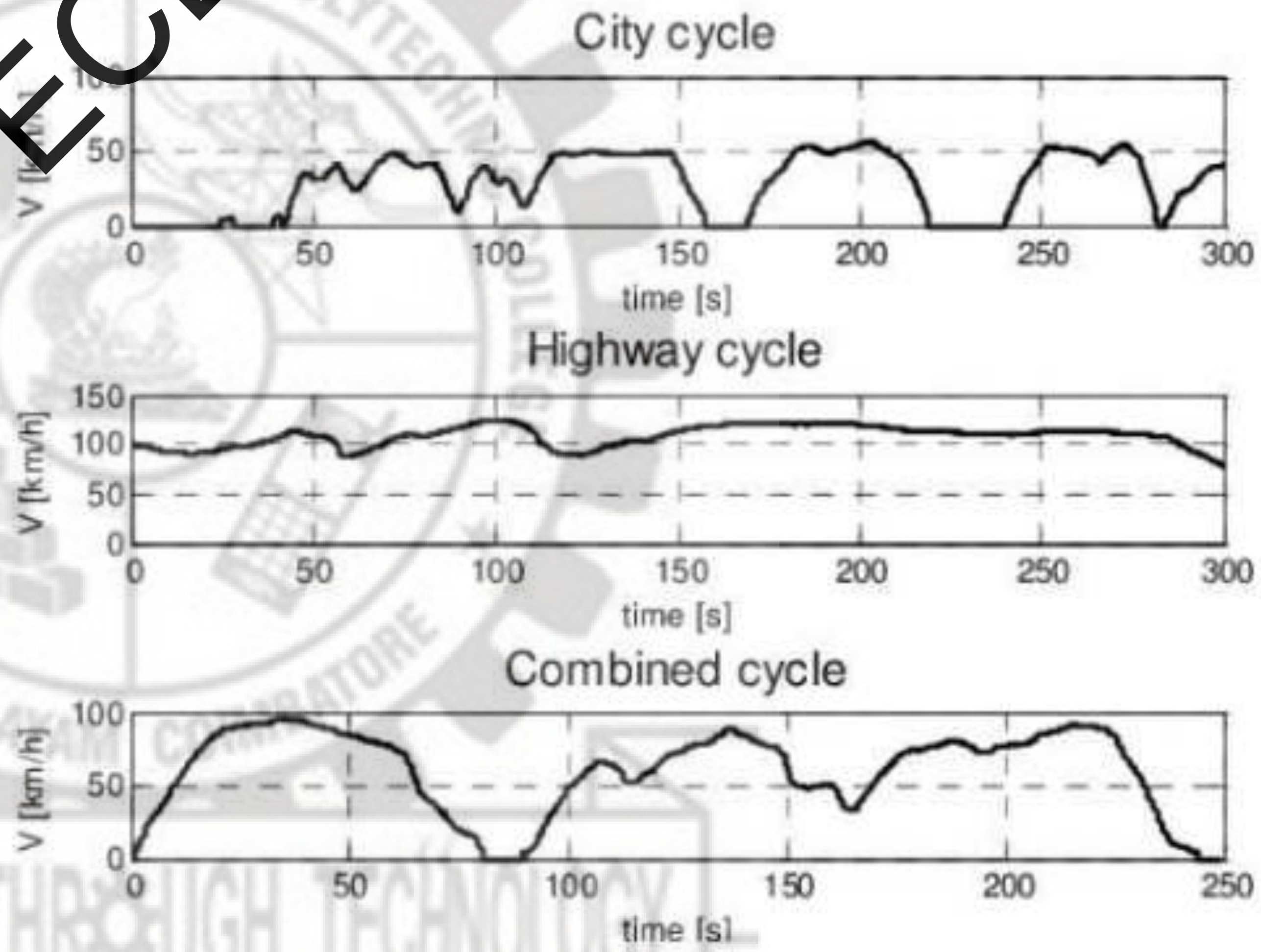
Hybrid electric Vehicle(HEV)



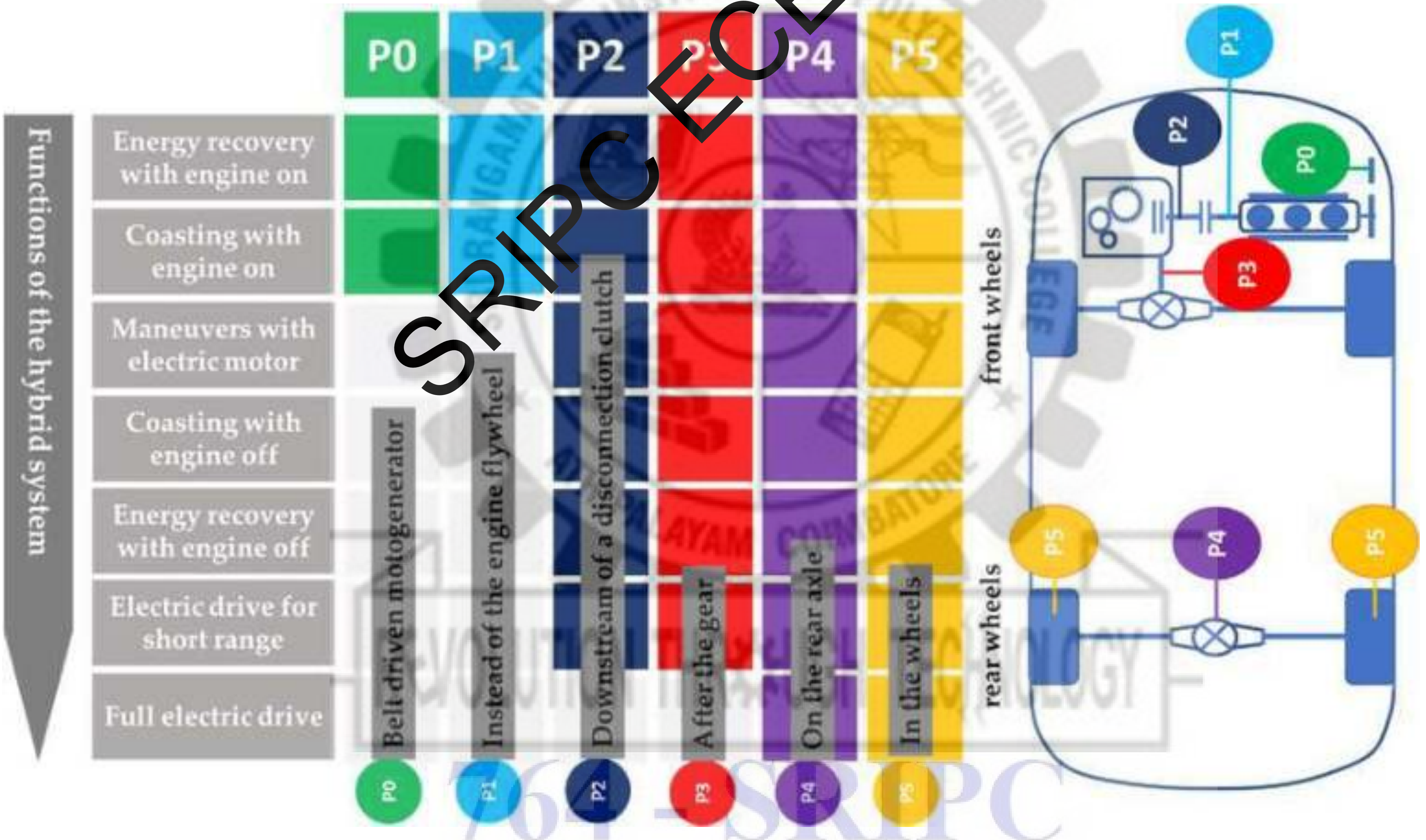
Tractive Effort in Normal Driving

DRIVE CYCLES

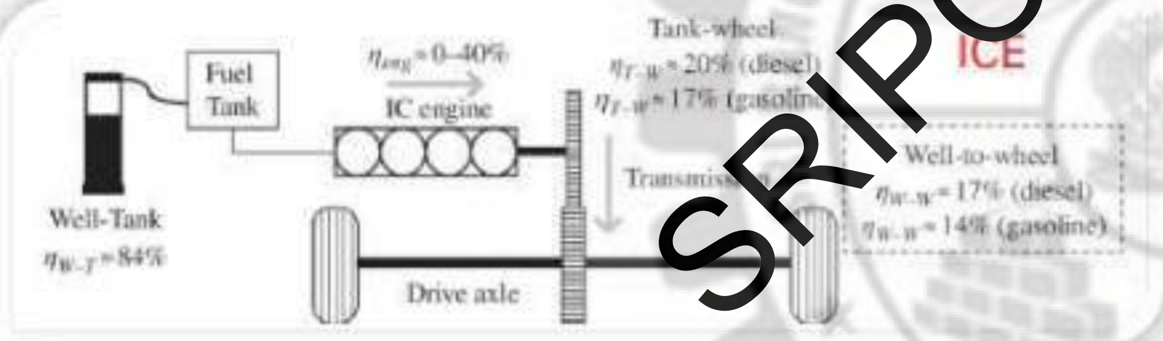
- A standardized drive profile which can be used to benchmark and compare fuel economy and emissions
- A driving cycle is a series of data points representing the speed of a vehicle versus time
- Driving cycles are produced by different countries and organizations to assess the performance of vehicles in various ways, as for example fuel consumption and polluting emissions



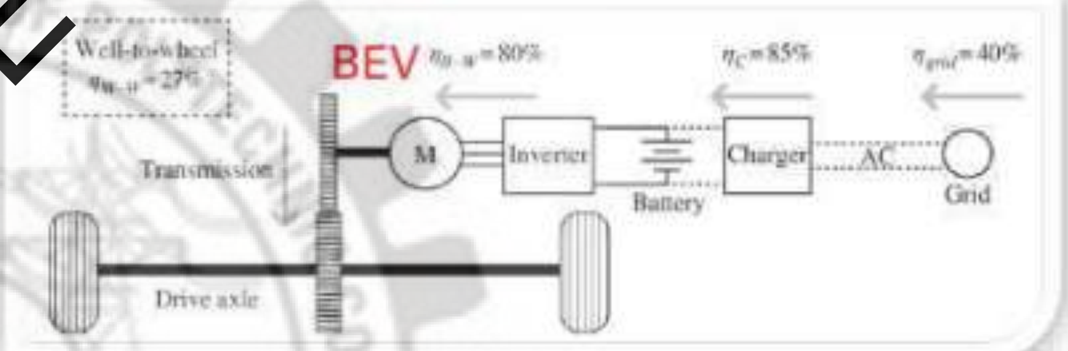
Hybrid Topologies & features

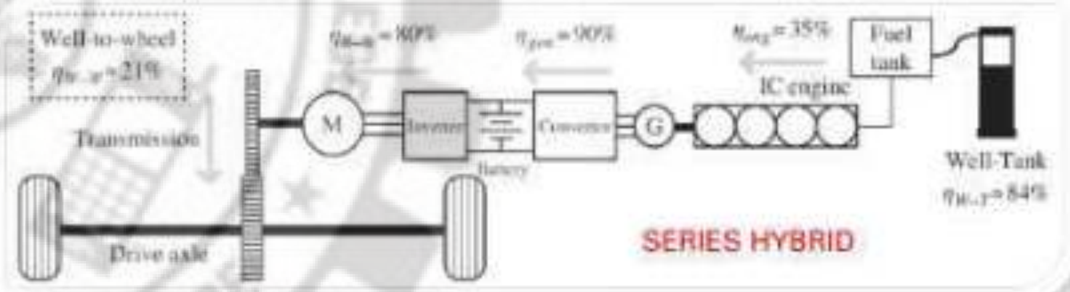


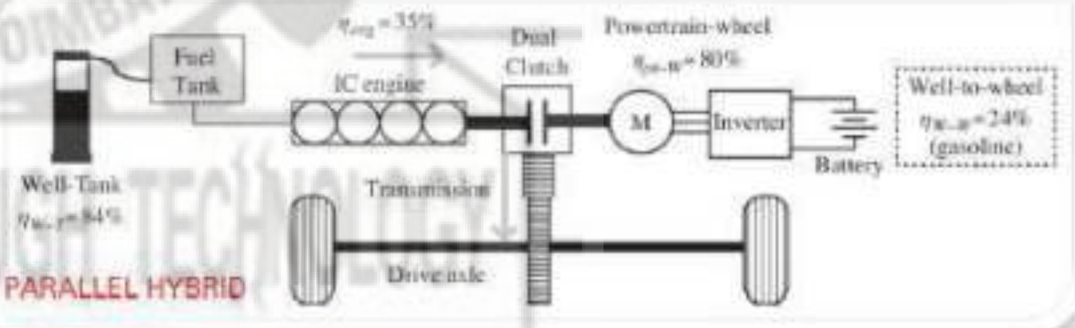
EFFICIENCY COMPARISON



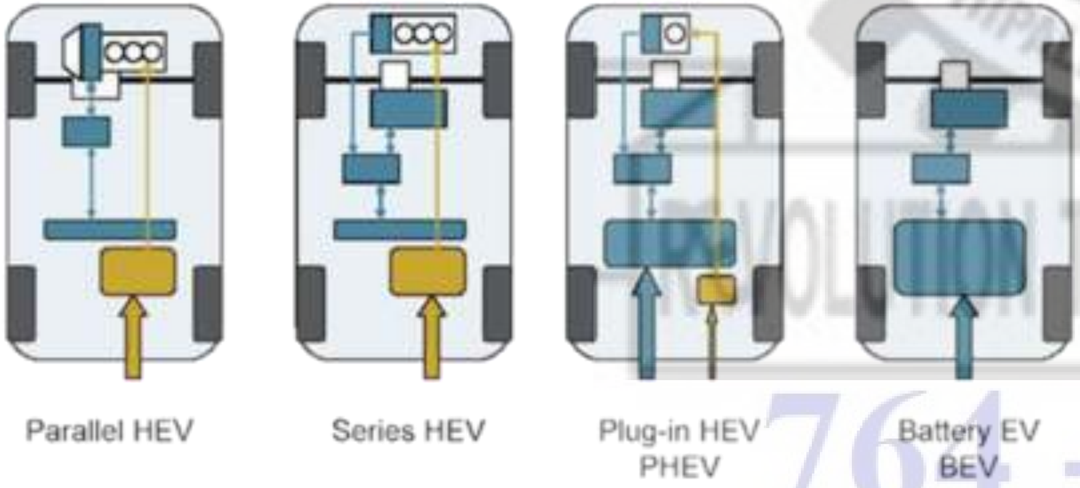
Fuel	Powertrain efficiency (%)	Well-to-wheel efficiency (%)
Gasoline SI	17	14
Diesel CI	20	17
BEV	80	27
Gasoline Series HEV	25	21
Gasoline Parallel HEV	28	24
Hydrogen FCEV	45	27

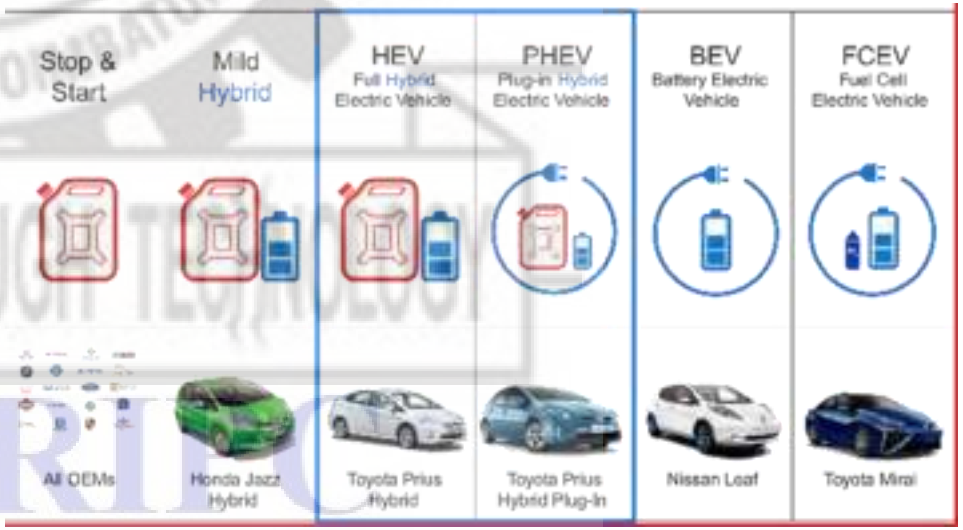




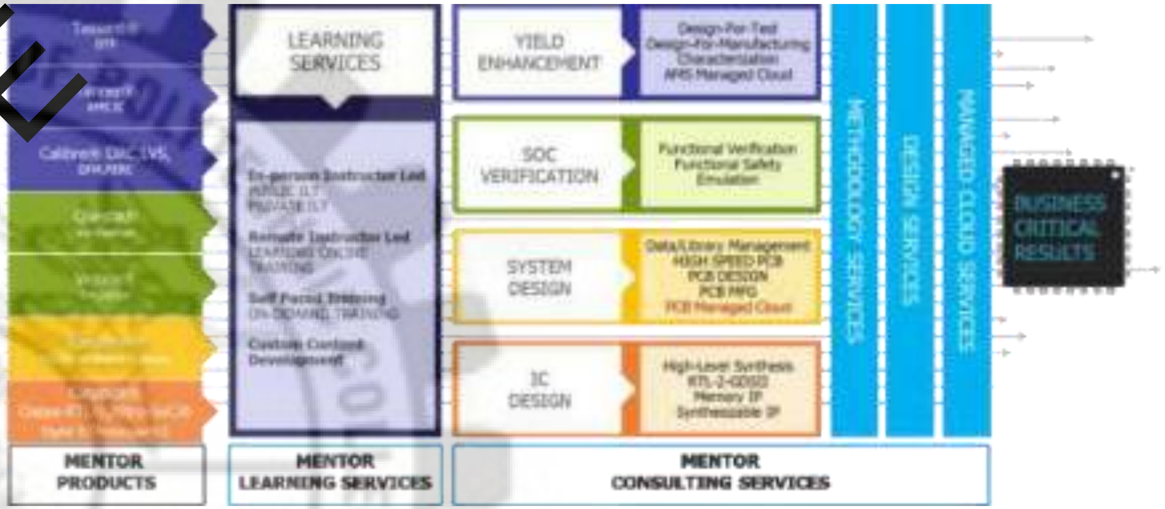


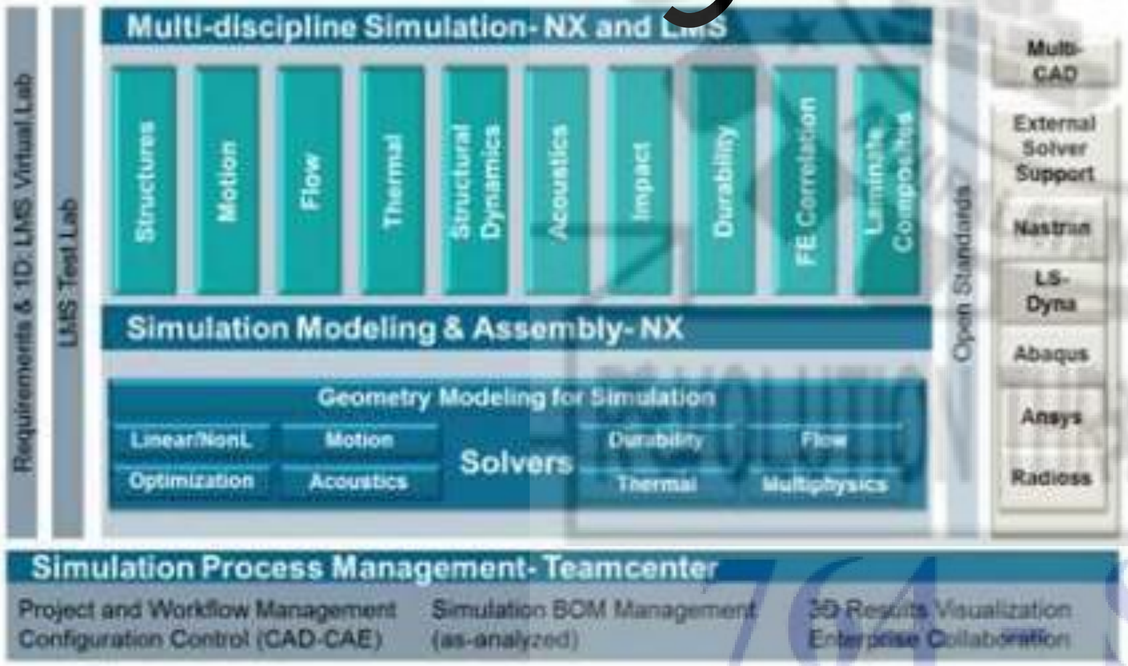

Hybrid
e.g. Toyota Prius
Plug-in Hybrid EV
e.g. Toyota Plug-in Prius
Battery EV
e.g. Nissan Leaf
Range Extended EV
e.g. BMW i3
Hydrogen Fuel Cell
e.g. Hyundai ix35

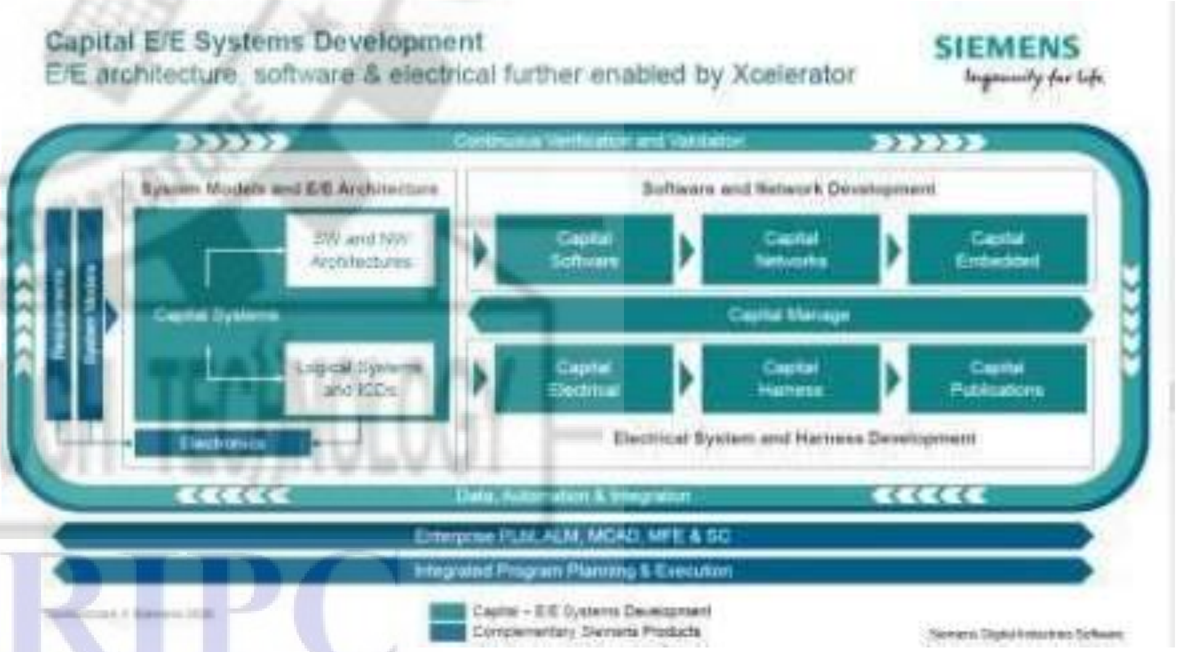

Parallel HEV
Series HEV
Plug-in HEV PHEV
Battery EV BEV


Stop & Start
Mild Hybrid
HEV Full Hybrid Electric Vehicle
PHEV Plug-in Hybrid Electric Vehicle
BEV Battery Electric Vehicle
FCEV Fuel Cell Electric Vehicle
All OEMs
Honda Jazz Hybrid
Toyota Prius Hybrid
Toyota Prius Hybrid Plug-In
Nissan Leaf
Toyota Mirai

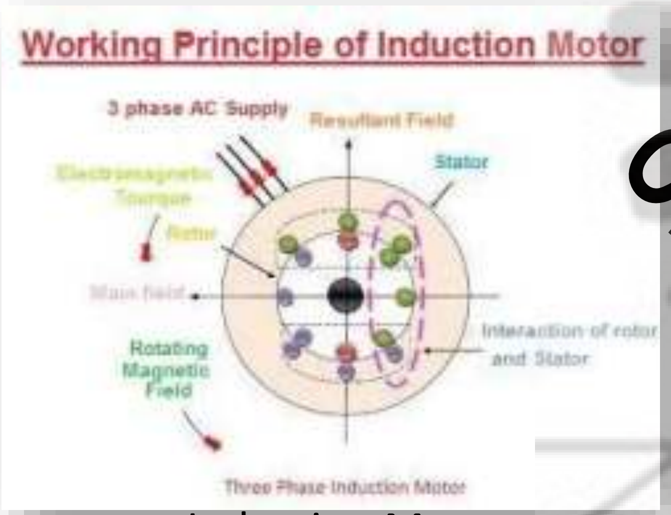
Digital Validation - Multiphysics







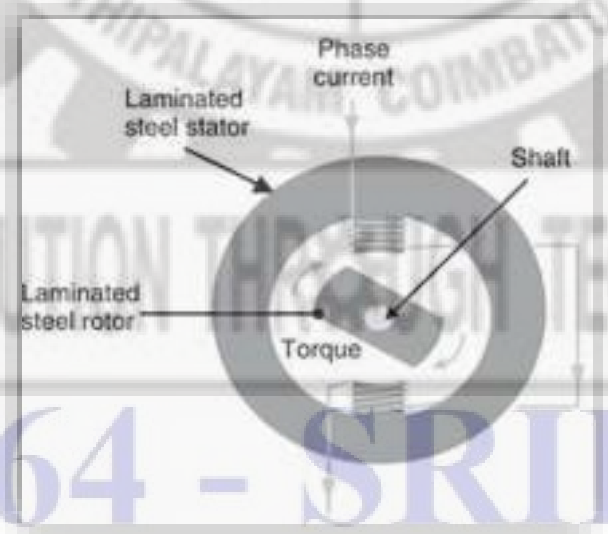
Motor Types



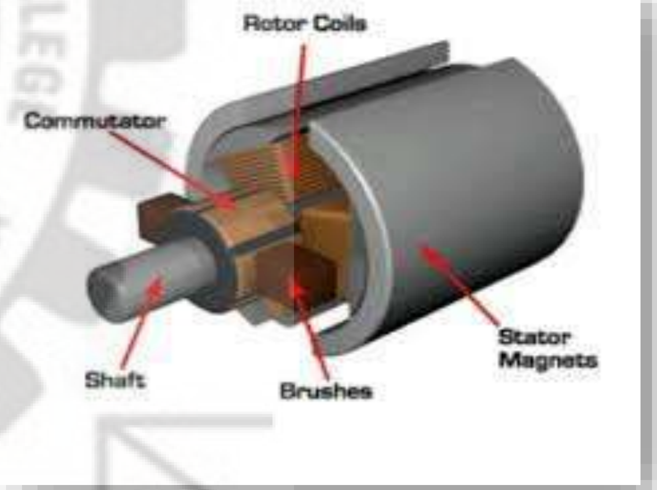
Induction Motor

Permanent Magnet Motor

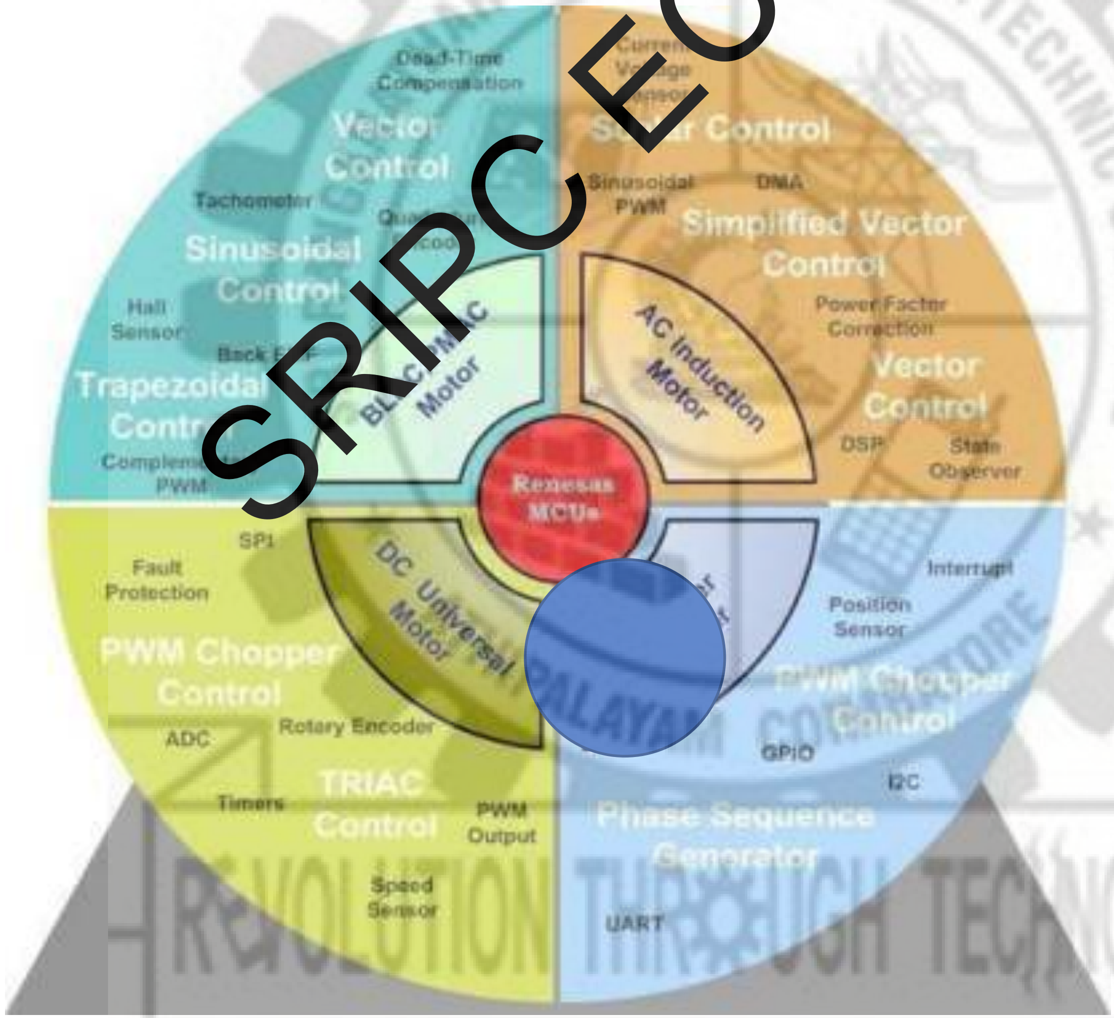
Reluctance Motor



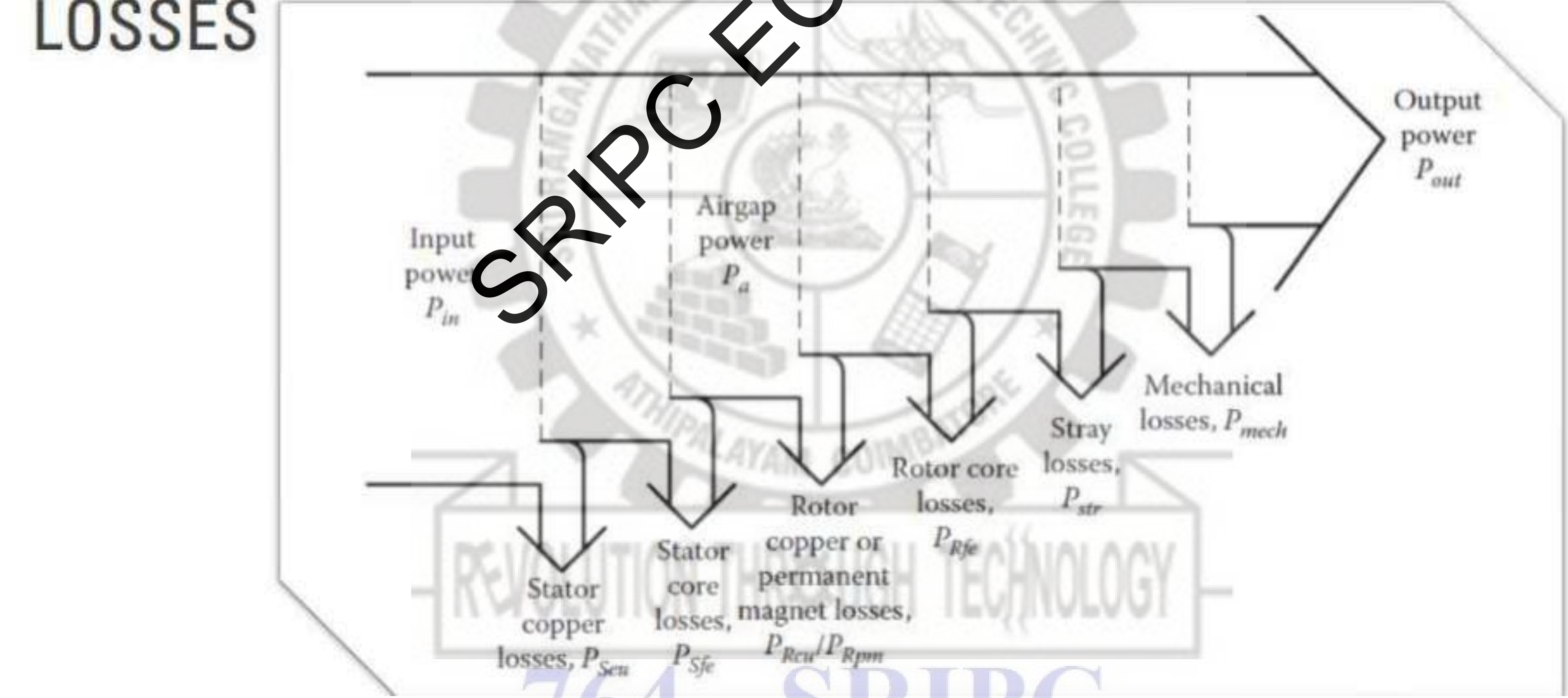
D.C. Motor



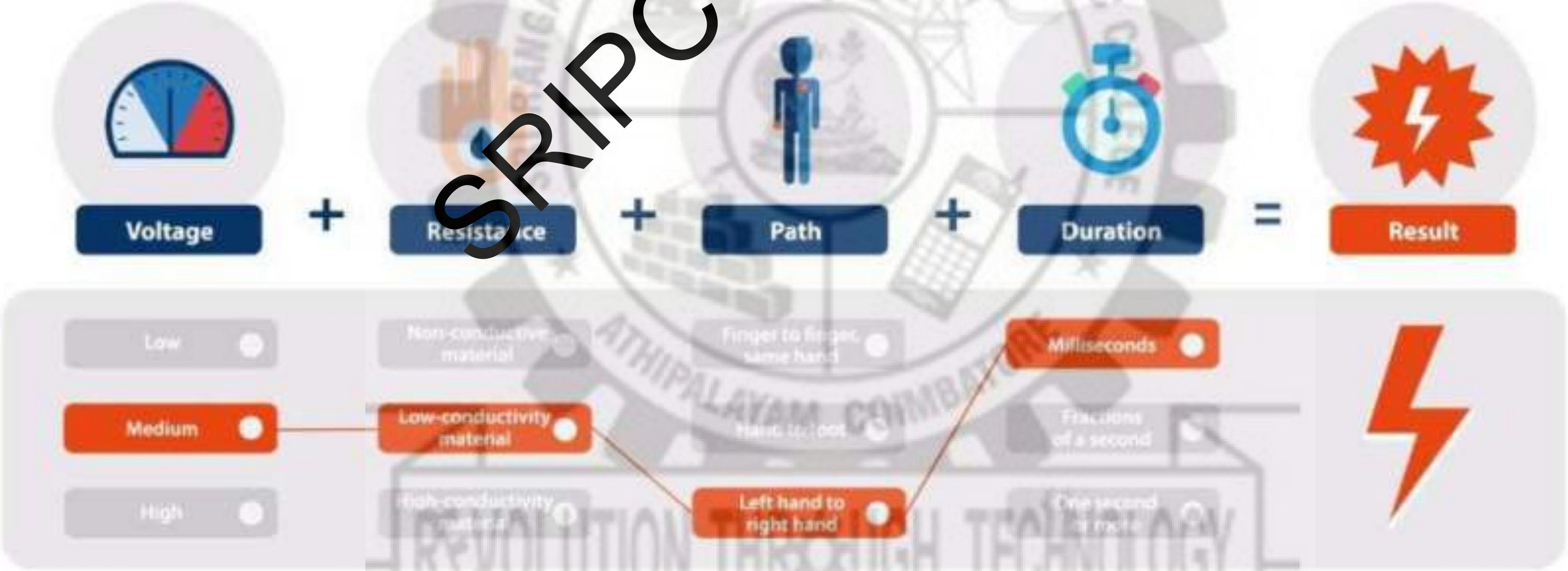
Control Methods for Motors



ELECTRIC MACHINE LOSSES



Factors affecting an Electrocution



Tesla – fully autonomous Car

- https://www.youtube.com/watch?v=tlThdr3O5Qo

Session 4

Unit No	Topics
I	Environmental impact and history, Types of Electric vehicles
II	Electric vehicle, Electrical Propulsion System
III	Energy Storages, Charging System, Effects and Impacts
IV	Electric Mobility Policy Frame Work
V	Tamilnadu E-Vehicle Policy 2019

Energy Storages

- Electrochemical Batteries
- Battery Technologies
- Construction and working of Lead Acid Batteries
- Nickel and Lithium Based Batteries
- Role of Battery Management System (BMS)
- Battery pack development Technology
- Cell Series and Parallel connection to develop battery pack

Charging

- Battery Charging techniques
- Constant current and Constant voltage, Trickle charging
- Battery Swapping Techniques
- DC charging
- Wireless charging
- Maintenance of Battery pack
- Latest development in battery chemistry

Effects and Impacts

- Effects of EV
- Impacts on Power grid
- Impacts on Environment
- Impacts on Economy

BATTERY TERMINOLOGY-1

Cell Voltage	The difference in standard electrode potential of the cathode and anode.
Current	Number of electrons moved between the electrodes in 1 second.
Battery Capacity	The amount of energy that can be stored in the battery in Joules, or technically, Wh (Watt-hours). Quite simply, it is the product of the voltage, current and the number of hours the battery is being used.
Current-Rating	Manufacturer specification. Expressed in mAh, it is the current delivered by the battery if it is going to be used for one hour. If you extract 10A from a 10Ah (10000 mAh) battery, it will be depleted in one hour.
C-Rate (Charge or Discharge Rate)	Expressed in C (example-2C or 4C or 0.7 C), it is the current input or output of the battery expressed in terms of the current rating definition. If you are drawing a current of 20A from a 10Ah battery, you are essentially drawing a 2C rate. For the same battery, a 5A current discharge would constitute a 0.5C rate.
Theoretical Energy Density (Gravimetric and Volumetric)	The theoretical value of the ratio of the battery capacity to the mass (gravimetric energy density) or the volume (volumetric energy density) of the electrodes.
Actual Energy Density (Gravimetric and Volumetric)	This calculation takes into account the mass of passive components as well.
Power Density (Gravimetric and Volumetric)	The rate of energy delivered by the battery per unit time per kg (gravimetric) or liter (volumetric) of battery.
Ampere-hour	A common unit of measurement for the capacity of a battery. The product of instantaneous current and the duration for which it is present for the entire discharge cycle.

BATTERY TERMINOLOGY-2

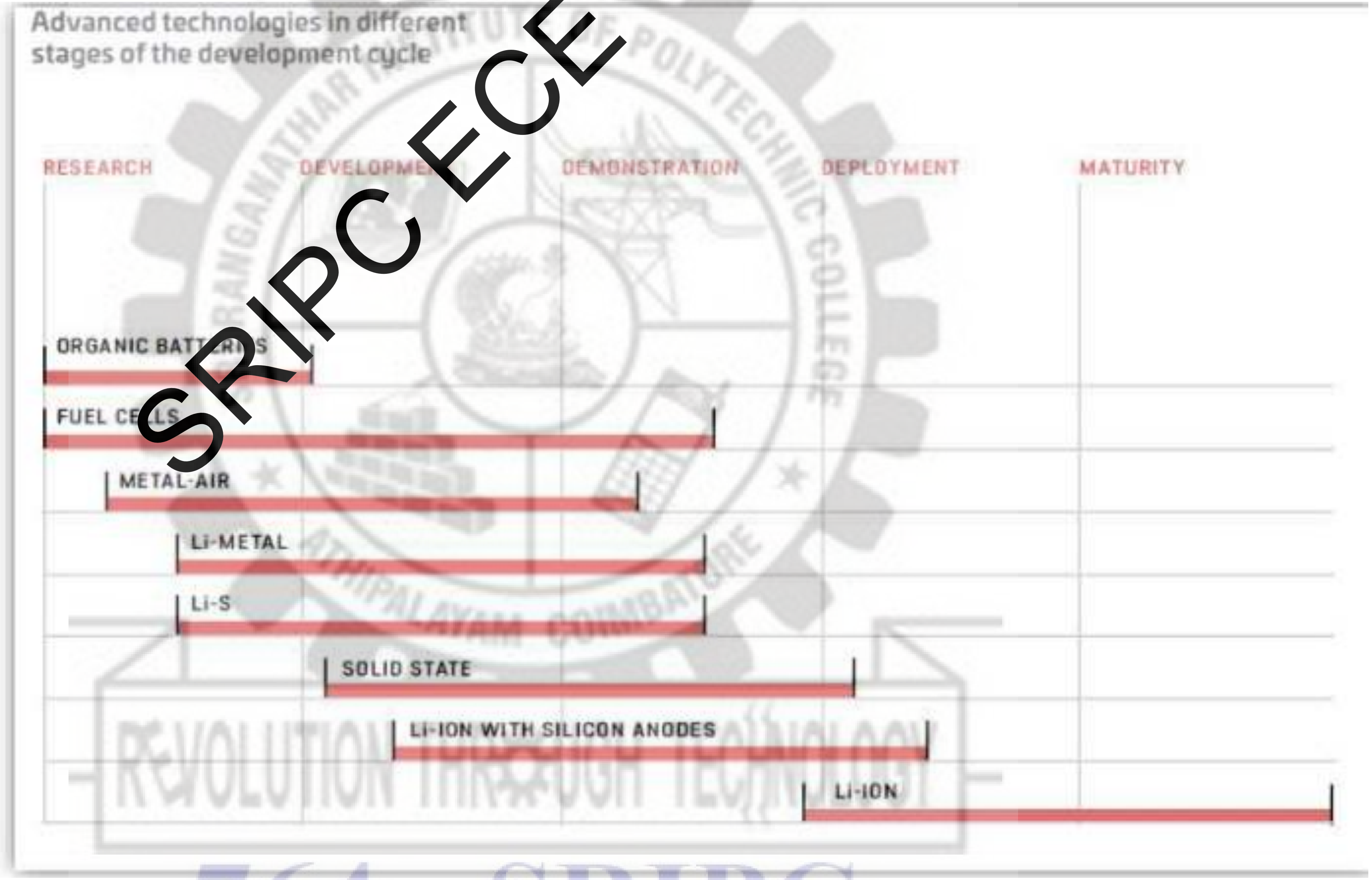
Open Circuit Voltage	The voltage measured between the two electrodes when the terminals of the battery are not connected to an external circuit (no current flowing between the electrodes).
Cut-off Voltage	The voltage that is available between the terminals when the state of charge is almost zero. The lowest voltage at the end of the battery discharge cycle.
Deep and Shallow Cycling	When the battery is discharged to 80% and more of its discharge state, it is deep-discharging. When the battery is not allowed to approach its cutoff voltage, it is shallow-discharging.
Internal Resistance	The resistance to the flow of current within the cell.
Self-discharge	Discharge that takes place in the open-circuit condition.
Short-circuit	A zero to low resistance path unintentionally created between the terminals causing a high current influx.
Thermal Runaway	A self-destructive path that the cell takes due to mechanical, electrochemical failure.
Operating Temperature Range	The ideal temperature range at which the output of the cell is optimal – not poor performance o kinetics leading to thermal runaway.
Intercalation	The process by which smaller atoms occupy spaces in the lattice structure of bigger crystal struc

WHY DIFFERENT BATTERY TYPES

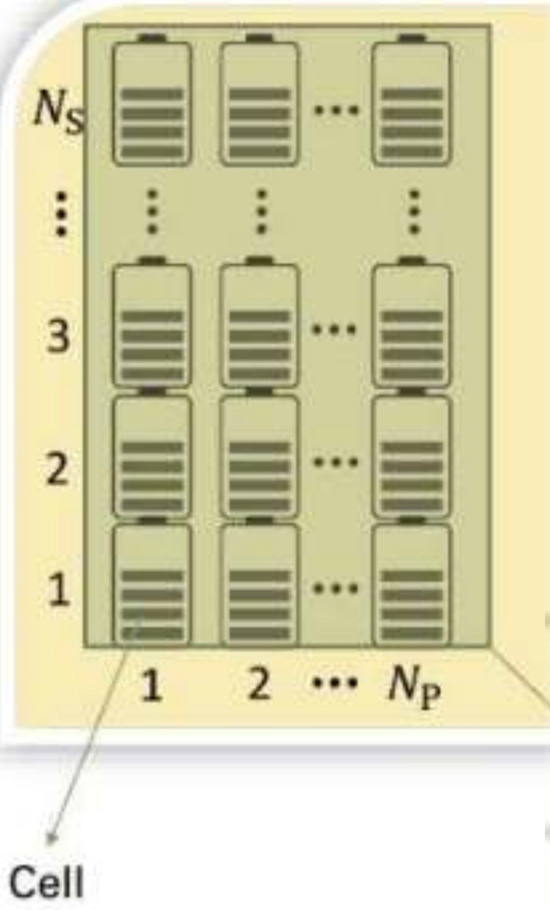
Typical Considerations driving the need for battery types:

- Peak Power
- Continuous Power
- Energy Capacity
- Battery Pack Voltage
- Durability
- Cost

WHERE ARE WE?


Advanced technologies in different stages of the development cycle
RESEARCH
DEVELOPMENT
DEMONSTRATION
DEPLOYMENT
MATURITY
ORGANIC BATTERIES
FUEL CELLS
METAL-AIR
Li-METAL
Li-S
SOLID STATE
Li-ION WITH SILICON ANODES
Li-ION

SERIES & PARALLEL



$$N_S = \frac{U_{BattPack}}{U_{BattCell}}$$

$$N_P \geq \frac{W_{BattPack}}{N_S \; W_{BattCell}}$$

- When building a complete battery pack from a given type of battery cell, the only way is to tailor the battery pack size is to change the number of cells in series and in parallel
- The number of series connected cells determine the battery pack voltage and thus the number of cells in series has to be selected to match the desired pack voltage
- The number of parallel branches can be used to vary the total capacity of the battery
- As a result, the number of parallel branches will have to be at least equal to the required battery pack energy capacity divided by the number of cells in series times the energy capacity of each cell

POWER / ENERGY / C-RATE

$$C = \frac{I_{\text{MaxCell}}\,(A)}{Q_{\text{Cell}}\,(\text{Ah})} \approx \frac{P_{\text{MaxCell}}}{W_{\text{Cell}}}$$

Example

Powertrain type	Peak power (kW)	Energy capacity (kWh)	Ideal C-Rate
Mild hybrid	10	0.1	100
Full hybrid	25	0.25	100
Plug-in hybrid	50	10	5
BEV with REX	100	20	5
BEV	100	30	3.3

Cells for different powertrain types

Different
- Cell capacity
- C-Rate

- Thermal properties
- Durability

WHY BATTERY MANAGEMENT

- Optimal Charging and Discharging
- Dissipating heat from battery cells
- Optimizing battery life
- Cell Balancing
- Proper battery monitoring and control
- Battery Pack Safety

Thermal Management Block

Reads temperature and starts cooling or heating operation to maintain the temperature in the optimal range.

Also, it sends signals to ECU if the temperature goes beyond allowable limits. These systems can include both passive and active cooling systems.

Battery Algorithm Block

Estimates state of health and state of charge. Based on the measured values, it calculates current stage with respect to full charge, which is essential for ensuring that the battery is not overcharged.

Measurement Block

Measures cell temperature, current voltage at different places and the ambient temperature.

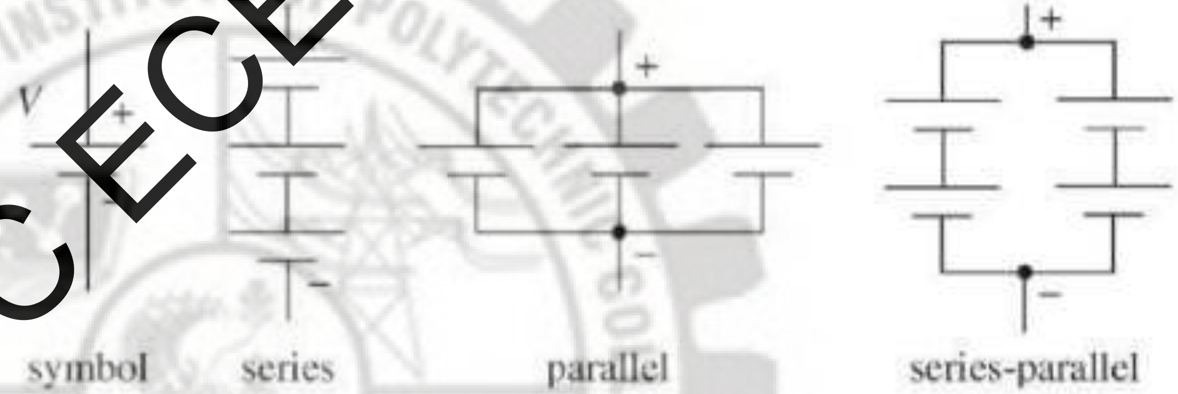
Capability Estimation Block

Sends information of the safe levels of charge or discharge to ECU and charger unit.

Cell Equalization Block

Compares the highest and lowest cell voltages to apply cell balancing techniques.

BATTERIES



A battery is a device that converts chemical energy into electrical energy and vice versa

The **anode** is the solid metal connection or electrode within the battery at which oxidation occurs during discharge. The anode is at the **negative** terminal of the battery. By definition, an anode is an electrode through which current flows into a device (during discharge in the case of the battery).

The **cathode** is the solid metal connection or electrode within the battery at which reduction occurs during discharge. The cathode is the **positive** electrode of the battery.

An **electrolyte** is a substance which contains ions and allows the flow of ionic charge. A **cation** is an ion with a positive charge, and an **anion** is an ion with a negative charge.

An electric **battery** comprises one or more of these electrochemical cells and produces dc current by the conversion of chemical energy into electrical energy.

A **primary** battery is a battery with one or more cells in which an **irreversible** chemical reaction produces electricity.

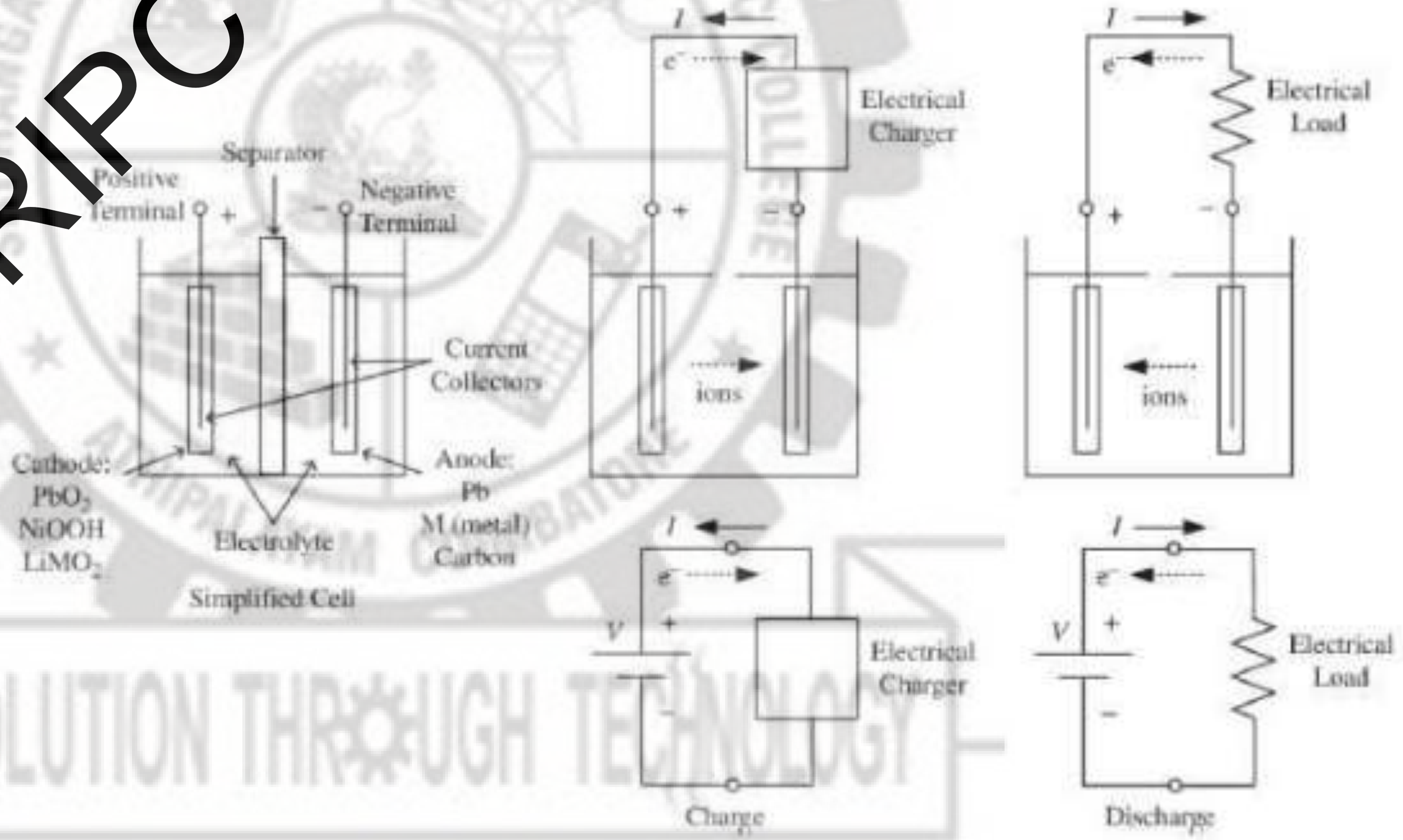
A **secondary** battery is a battery with one or more cells in which a **reversible** chemical reaction produces electricity.

BATTERY BASICS

ENERGY=POWER x TIME (1J=1Ws)

CHARGE=CURRENT x TIME (1C=1As)
(ENERGY STORAGE CAPACITY)

ENERGY=CAPACITY x VOLTAGE
(1J=1As X V)



C- RATE

$$C = \frac{I_{\text{MaxCell}}\ (A)}{Q_{\text{Cell}}\ (\text{Ah})} \approx \frac{P_{\text{MaxCell}}}{W_{\text{Cell}}}$$

- In describing batteries, it is common to use the *C* rate.
- A *C* rate is a measure of how quickly the battery is charged or discharged relative to its maximum capacity
- Example:
  - A **1*C*** rate discharges the battery pack at a fixed given current in one hour, while a 10*C* rate discharges the battery pack at ten times the 1*C* current.
  - A *C*/3 rate discharges the battery pack at one third of the 1*C* current.

Example

Powertrain type	Peak power (kW)	Energy capacity (kWh)	Ideal C-Rate
Mild hybrid	10	0.1	100
Full hybrid	25	0.25	100
Plug-in hybrid	50	10	5
BEV with REX	100	20	5
BEV	100	30	3.3

SOC & DOD

- The state of charge (SOC) is the portion of the total battery capacity that is available for discharge.
  - It is often expressed as a percentage, and can be seen as a measure of how much energy remains in the battery
- The depth of discharge (DOD) is the portion of electrical energy stored in a battery that has been discharged
  - It is often expressed as a percentage

Pack Capacity is 24 kWh and 6 kWh has been discharged, means:
DOD is 6/24 or 25%.
Remaining energy = 18 kWh, i.e. SOC is 18/24 or 75%

Understanding Electric Car Batteries

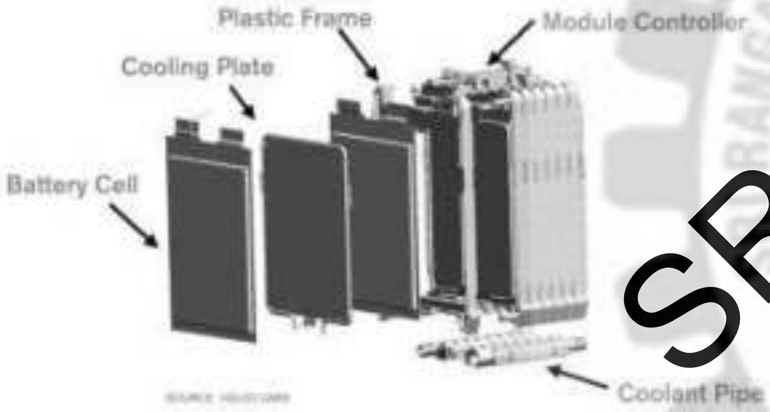
	Lithium Ion	Nickel-Metal	Lead-Acid	Ultracapacitors
Easy Access / Inexpensive	✓	✗	✓	✗
Energy Efficient	✓	✓	✓	✓
Temp. Performance	✓	✗	✗	✓
Weight	✓	✓	✓	✓
Life Cycle	✓	✗	✓	✗

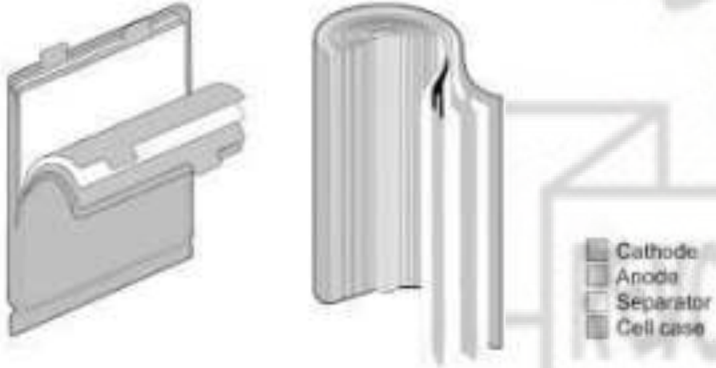
Cell chemistry	Specific Energy kWh/tonne	Specific Power kW/tonne	Charge-discharge efficiency	Cycle life
Lead acid (for reference)	35	40	90%	1000
Li-ion	110-190	1150		2000
NiMH	<80	200	91%	3000
NaS	90	90-150	85%	5200
Bi-polar Pb/SO_4	50	500	91%	
Li-ion phosphate	95-155	1060		1000-5000
Li-ion titanate (nano)	74-83			15,000

Battery type	Nickel-Cadmium (Ni-Cd)	Nickel-metal hydride (Ni-MH)	Lithium-Ion (Li-Ion)
Battery weight (kg)	360	260	180
Specific energy (Wh/kg)	50	70	140
Energy (Kwh)	18	18.2	25
Range (km)	128	145	205
Maximum speed (km/h)	95	110	120

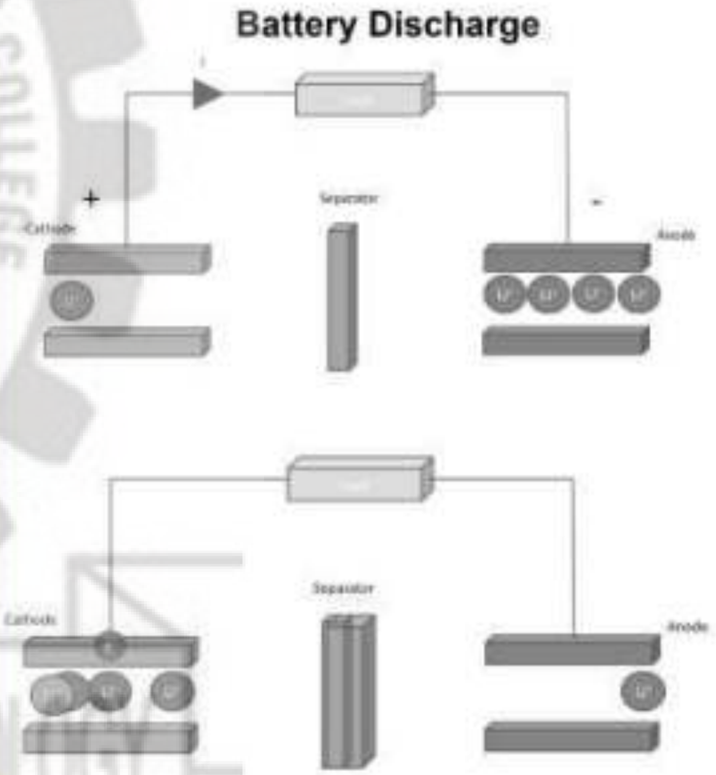
Note: Selected US battery electric vehicles (BEV) only. Positions are representative and do not indicate exact prices or range. Back labels = currently available, green labels = forthcoming models with specifications and timeline released. Blue labels = announced but limited details confirmed. Range is based on manufacturers statements, not on any specific test cycle.

CURRENT FLOW





- Main components of a battery are anode, cathode, and a separator
- Anode is negative charged, and the cathode is positive
- Lithium ions flows in an electrolyte through a separator to the cathode => Results in negative charge of electrodes to the anode
- Connecting a load => electrons travel from the anode to the cathode
- At the anode: oxidation process
- Electrons move only through the load, Electrons cannot move through the separator
- When electrons travel from the anode to the cathode => current directed against the electrons, going from the cathode to the anode

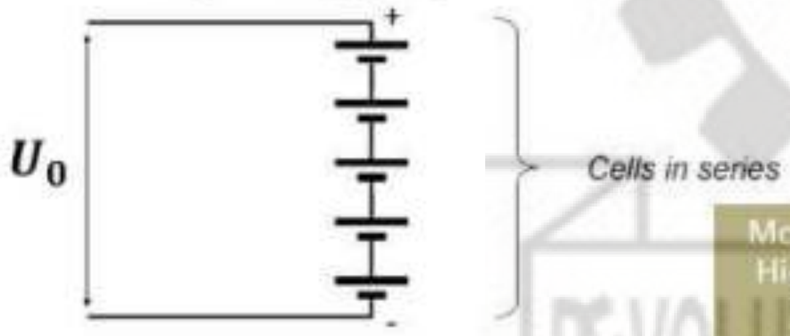


BATTERY TO SUPPORT RANGE

$$E[kWh] = \int_{t_S}^{t_F} P(t)dt$$

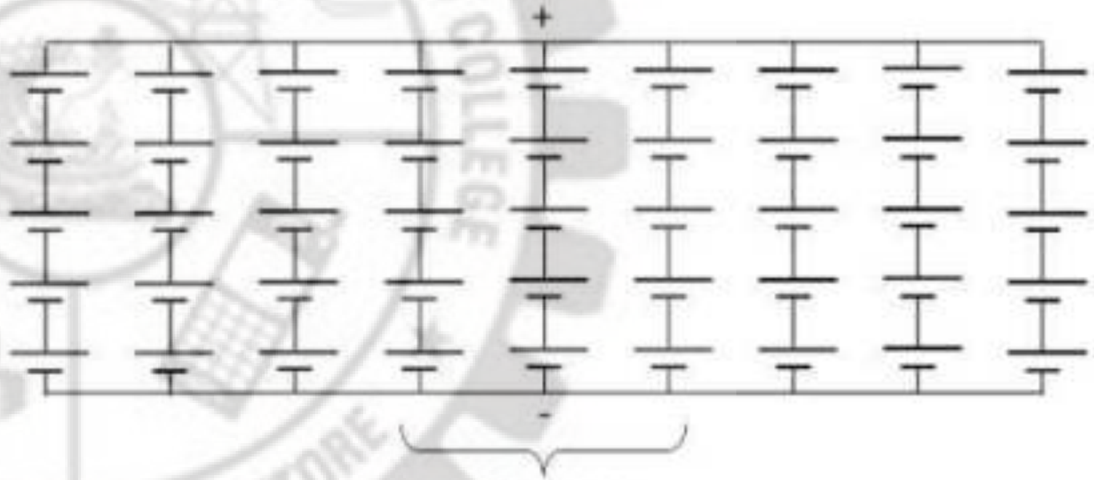
$$E_{batt}[kWh] = E_{cell} n_s n_p$$

$$U_0 = U_{cell} n_s$$



Motor and other needs Higher Voltage, lower losses and more efficiency (~ 400V)

$$E_{batt}[kWh] = E_{cell} n_s n_p$$



100 cells in series each having 100 Wh power capacity = 10 KWh

- Battery delivers almost exactly the same ampere hours as it was charged with
  - =>Charge is measured in Ah, not in KWh
- But the energy it delivers is less than what it was charged with

BATTERY FROM A PT PERSPECTIVE

- *ENERGY=POWER x TIME (1J=1Ws)*
- *CHARGE=CURRENT x TIME (1C=1As) (ENERGY STORAGE CAPACITY)*
- *ENERGY=CAPACITY x VOLTAGE (1J=1As X V)*

- **Capacity**: Maximum charge a battery can store (Ah)
- **State-of-Charge, SoC:** Actual charge divided with battery capacity. (0-100%)
- **C-rate:** Unit for expressing battery current relative to battery capacity. "3 C" is a current which would discharge three times the battery capacity in one hour.
- **Energy Capacity**: Max. energy the battery can store (kWh)

Capacity(Ah) X Battery Voltage(V)

$$C = \frac{I_{\text{MaxCell}}\,(A)}{Q_{\text{Cell}}\,(\text{Ah})} \approx \frac{P_{\text{MaxCell}}}{W_{\text{Cell}}}$$

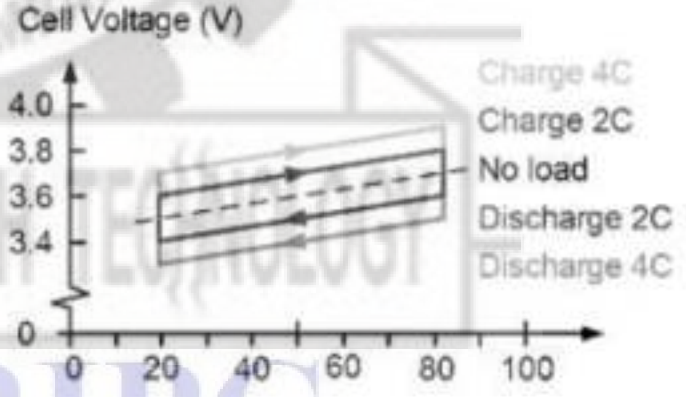
C-rate is a measure of how quickly the battery is charged or discharged relative to its maximum capacity

- Battery delivers almost exactly the same ampere hours as it was charged with
  - =>Charge is measured in Ah, not in KWh

  But the energy it delivers is less than what it was charged with
  - => Because, voltage of the battery increases during charging and decreases during discharge

- Voltage is higher than the no load voltage when the battery is charged, and lower when it is discharged
- Since the Ah are the same, only voltage differs, the energy used to charge the battery is higher than the energy it delivers during discharge
  - => an energy loss both when charging and when discharging
- The voltage during charging and discharging deviates more from the no load voltage if the current is increased as can be seen in the diagram from the voltage difference between a 2 C and a 4 C current
- => the losses increase when high power is used for charging and discharging
- Voltage variation and losses increase with current

Energy Vs Charge



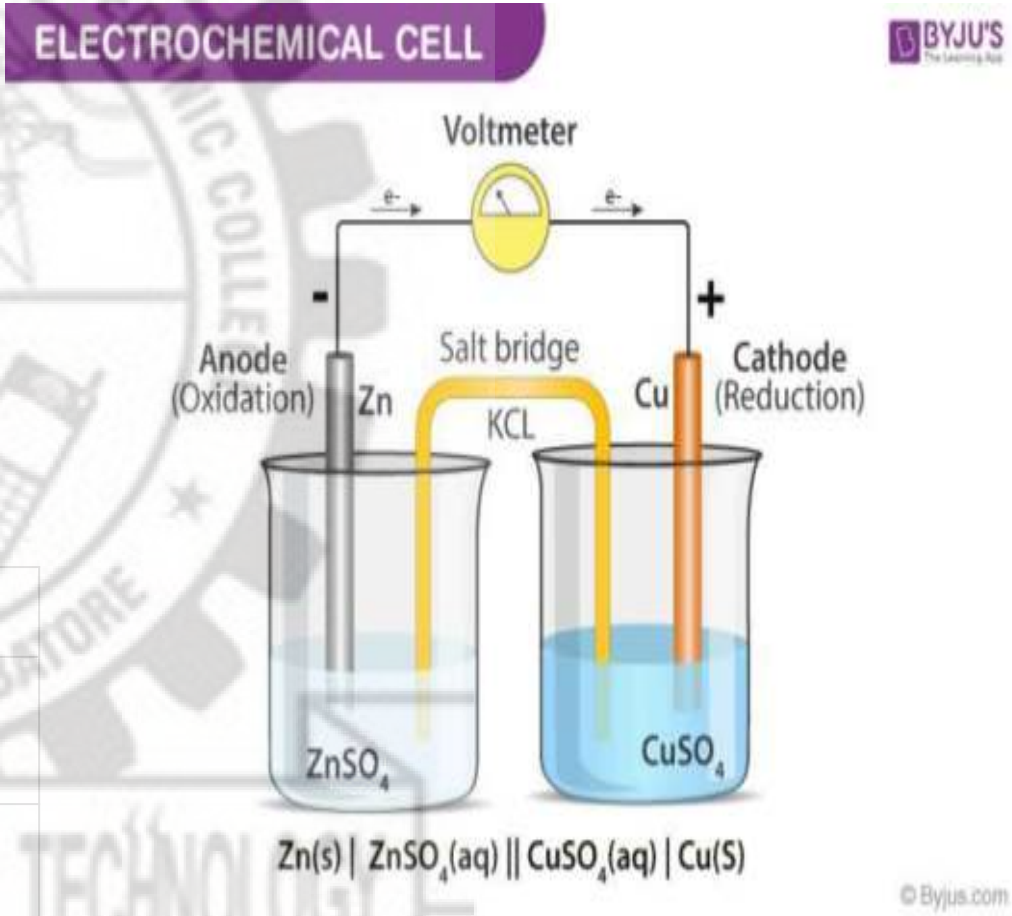
Understanding Electric Car Batteries

	Lithium Ion	Nickel-Metal	Lead-Acid	Ultracapacitors
Easy Access / Inexpensive	✓	✗	✓	✗
Energy Efficient	✓	✓	✓	✓
Temp. Performance	✓	✗	✗	✓
Weight	✓	✓	✓	✓
Life Cycle	✓	✗	✓	✗

Electro Chemical Batteries

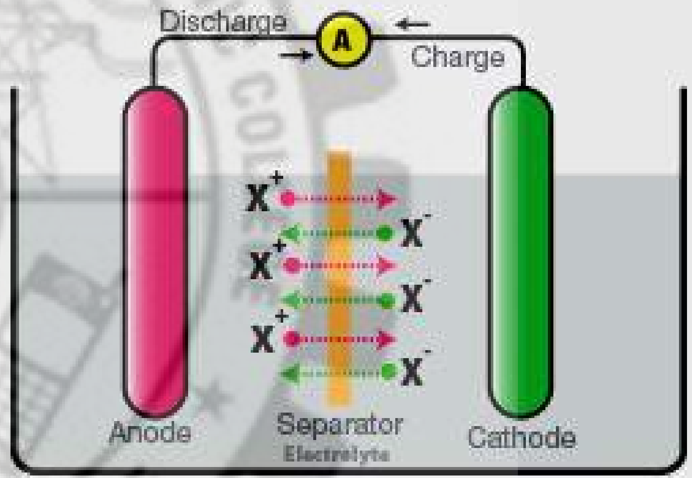
It is a device that can

- generate electrical energy from the chemical reactions
- use the electrical energy supplied to it to facilitate chemical reactions
- These devices are capable of converting chemical energy into electrical energy, or vice versa.
- A common example of an electrochemical cell is a standard 1.5-volt



Cathode	Anode
Denoted by a positive sign since electrons are consumed here	Denoted by a negative sign since electrons are liberated here
A reduction reaction occurs in the cathode of an electrochemical cell	An oxidation reaction occurs here
Electrons move into the cathode	Electrons move out of the anode

DIFFERENCE BETWEEN PRIMARY CELL AND SECONDARY CELL



PRIMARY CELL

A PRIMARY CELL IS A BATTERY THAT IS DESIGNED TO BE USED ONCE AND DISCARDED, AND NOT RECHARGED WITH ELECTRICITY AND REUSED LIKE A SECONDARY CELL IN GENERAL, THE ELECTROCHEMICAL REACTION OCCURRING IN THE CELL IS NOT REVERSIBLE, RENDERING THE CELL UNRECHARGEABLE.

SECONDARY CELL

A SECONDARY CELL IS A TYPE OF ELECTRICAL BATTERY WHICH CAN BE CHARGED, DISCHARGED INTO A LOAD, AND RECHARGED MANY TIMES, AS OPPOSED TO A DISPOSABLE OR PRIMARY BATTERY, WHICH IS SUPPLIED FULLY CHARGED AND DISCARDED AFTER USE.

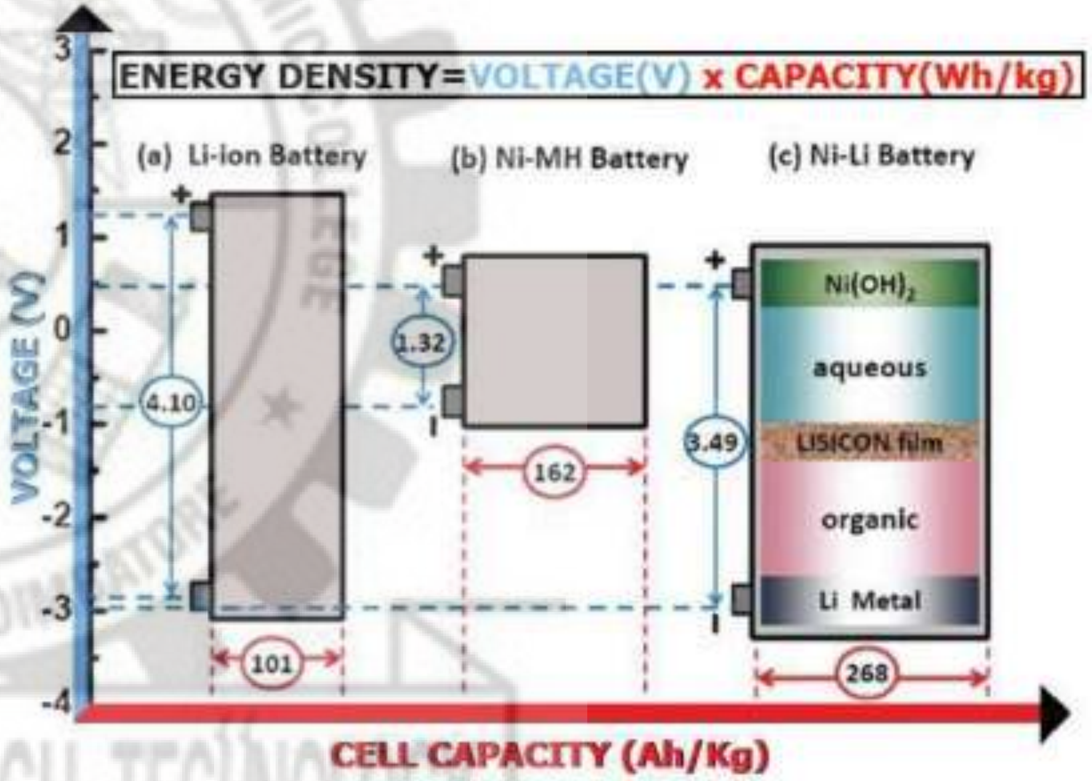
Lead Acid Battery

Theory and working principle

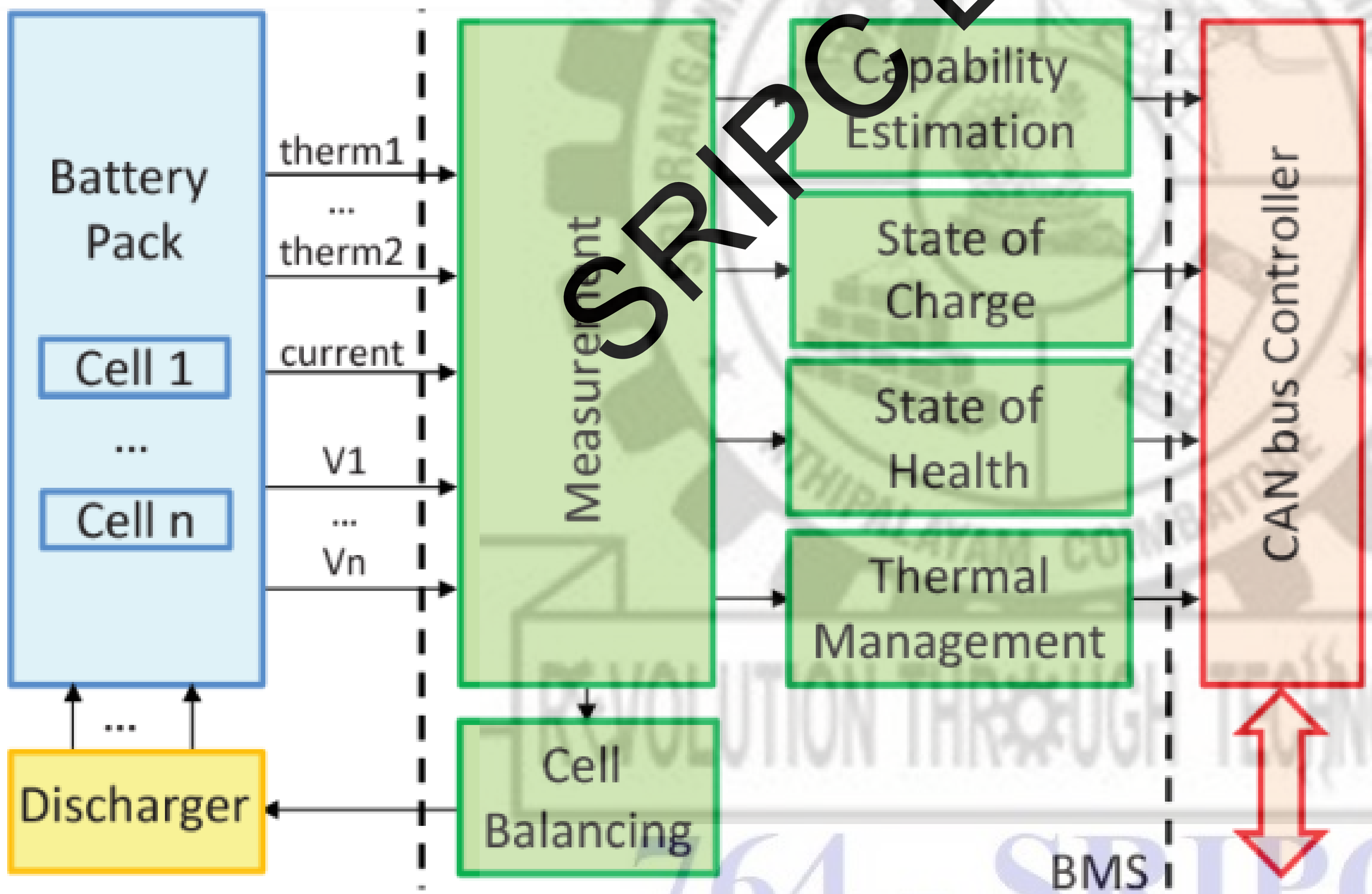
- https://www.youtube.com/watch?v=HhxtfULIO7c

Nickel and Lithium batteries (Ni-Li)

- It is an experimental battery using a
- nickel hydroxide cathode and
- lithium anode.
- The two metals cannot normally be used together in a battery, as there are no electrolytes compatible with both.
- The LISICON design uses a layer of porous glass to separate two electrolytes in contact with each metal.
- The battery is predicted to hold more than three and a half times as much energy per pound as lithium-ion batteries, and to be safer.
- However, the battery will be complex to manufacture and durability issues have yet to be resolved

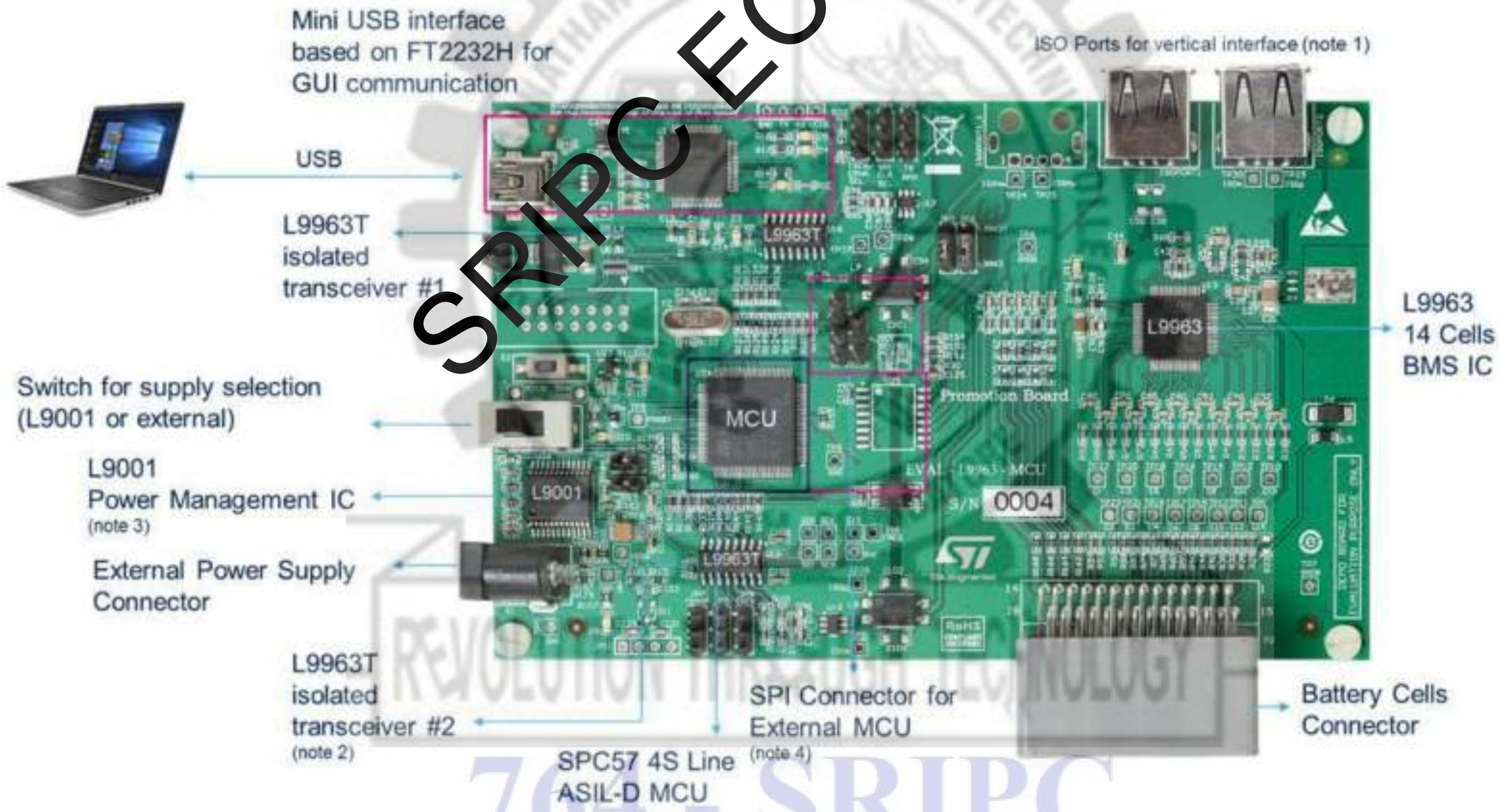


Battery Management System (BMS)

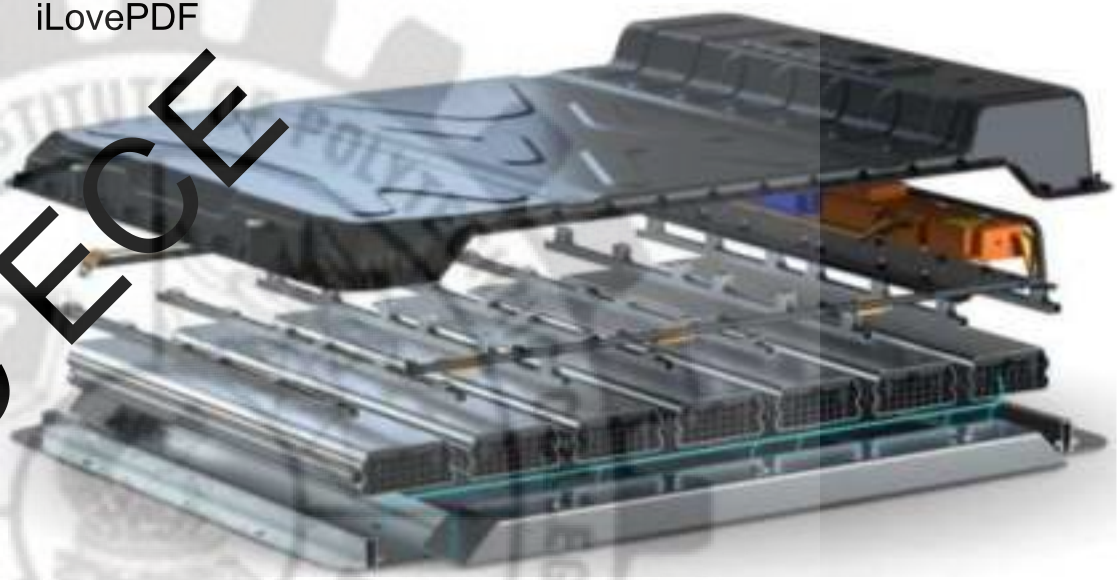


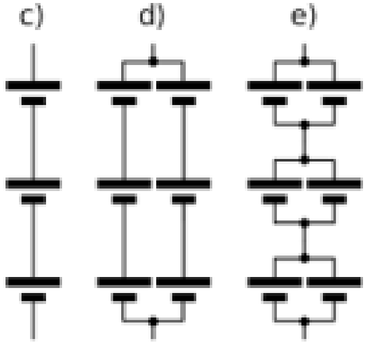
- Safety
  - Higher energy density (265wh/kg)
  - Risk of catching fire – over charging – thermal runaway
- Performance Optimization
  - Tight SOC range control
  - Cell balancing
- Health monitor / Diagnostics
  - SoH / SoC
- Communication
  - OBC
  - Inverter
  - ECUs

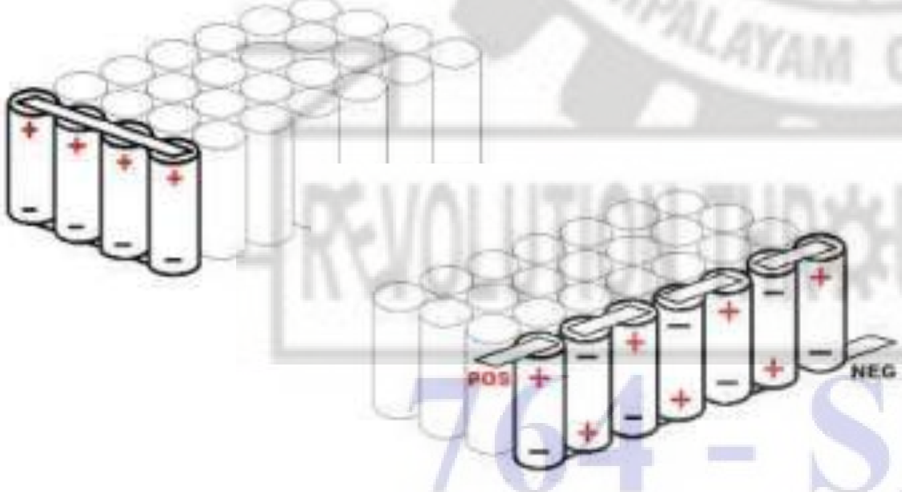
Battery Management System (BMS)

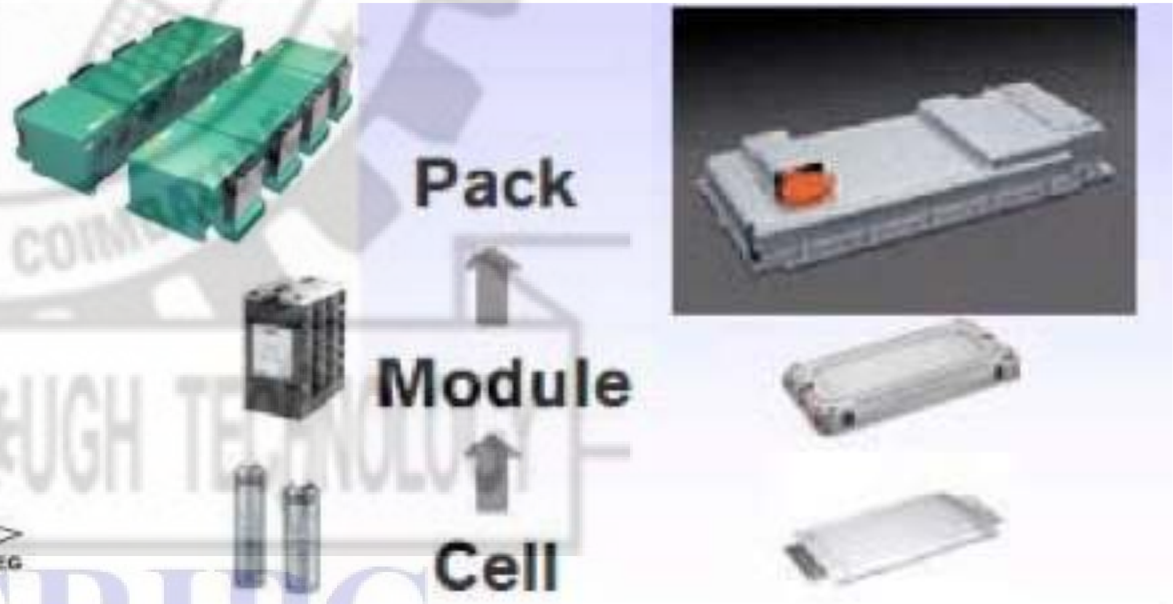


Battery pack







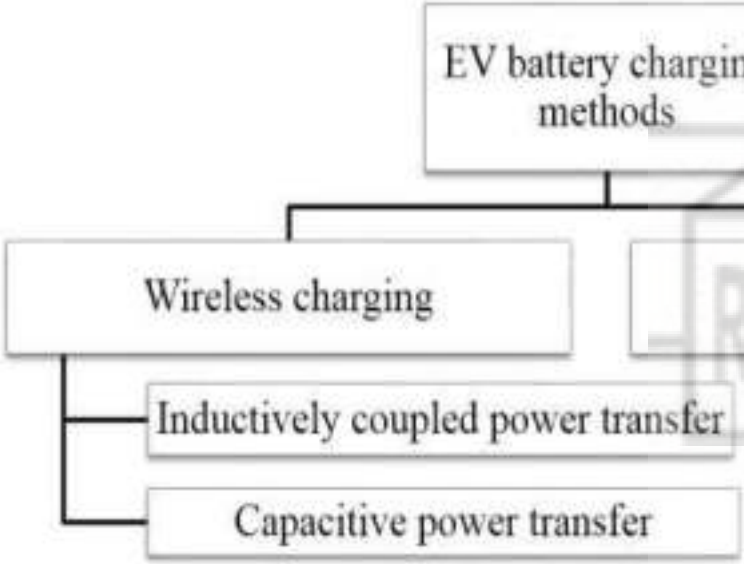


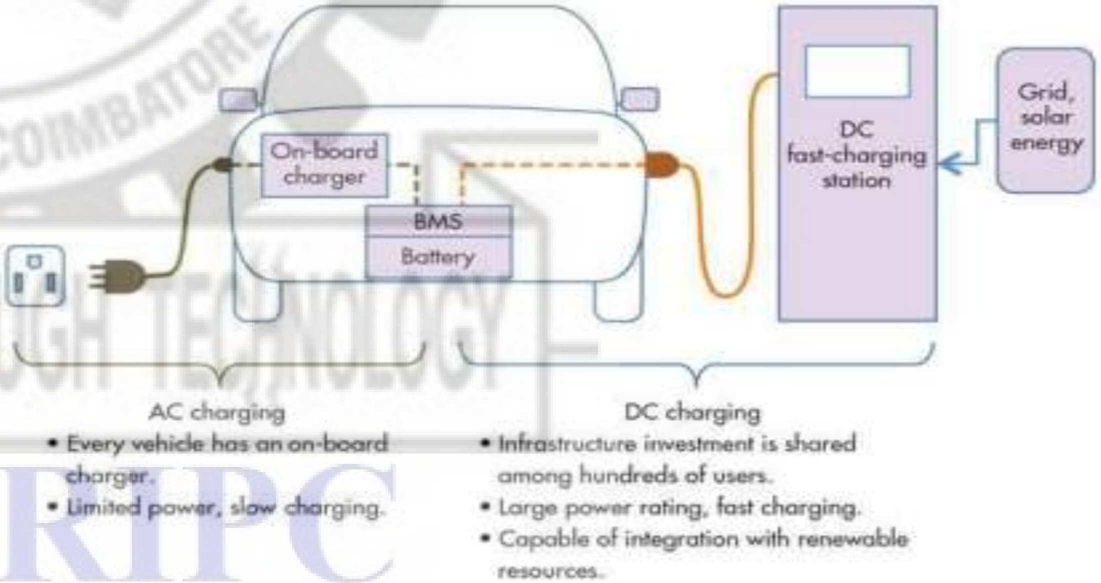
Battery Charging

Method	Advantages	Disadvantages	Key Parameters
Constant Current (CC)	- Easy to implement	- Capacity utilization is low	- Charging current rate
Constant Voltage (CV)	- Easy to implement	- Causing the lattice collapse of battery	- Charging voltage rate
Constant Current Constant Voltage (CC-CV)	- Capacity utilization is high - Stable terminal voltage	- Challenge to balance charging speed, energy loss, temperature variation	- Charging current rate in CC mode - Charging voltage rate in CV mode
Multi-Stage Constant Current (MCC)	- Easy to implement - Fast charging	- Challenge to balance charging speed, capacity utilization and battery lifetime	- The number of CC stages - Charging current rates for each stage

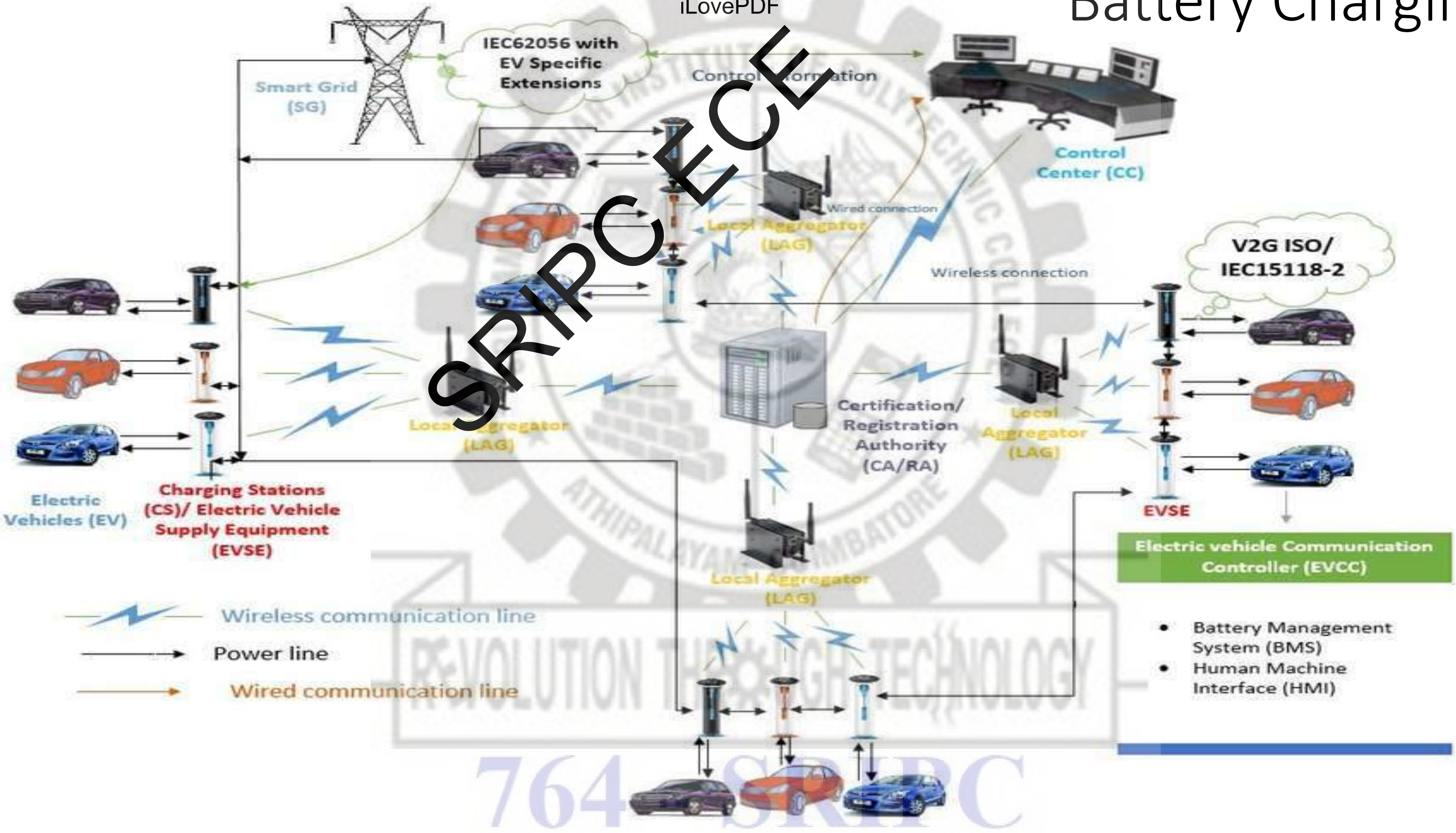
Basic Charging Methods

- **Constant Voltage** — Cheap battery chargers
- **Constant Current** — Switches off at voltage set-point
- **Taper Current** — Unregulated constant voltage
- **Pulsed charge** — Voltage PWM, on/rest/on
- **Negative Pulse Charge** — Short discharge pulse
- **IUI Charging** — Constant I, constant V, equalize
- **IUO Charging** — Constant I, constant V, float
- **Trickle charge** — Compensate for self discharge
- **Float charge** — Constant voltage below gassing V
- **Random charging** — Solar panel, KERS

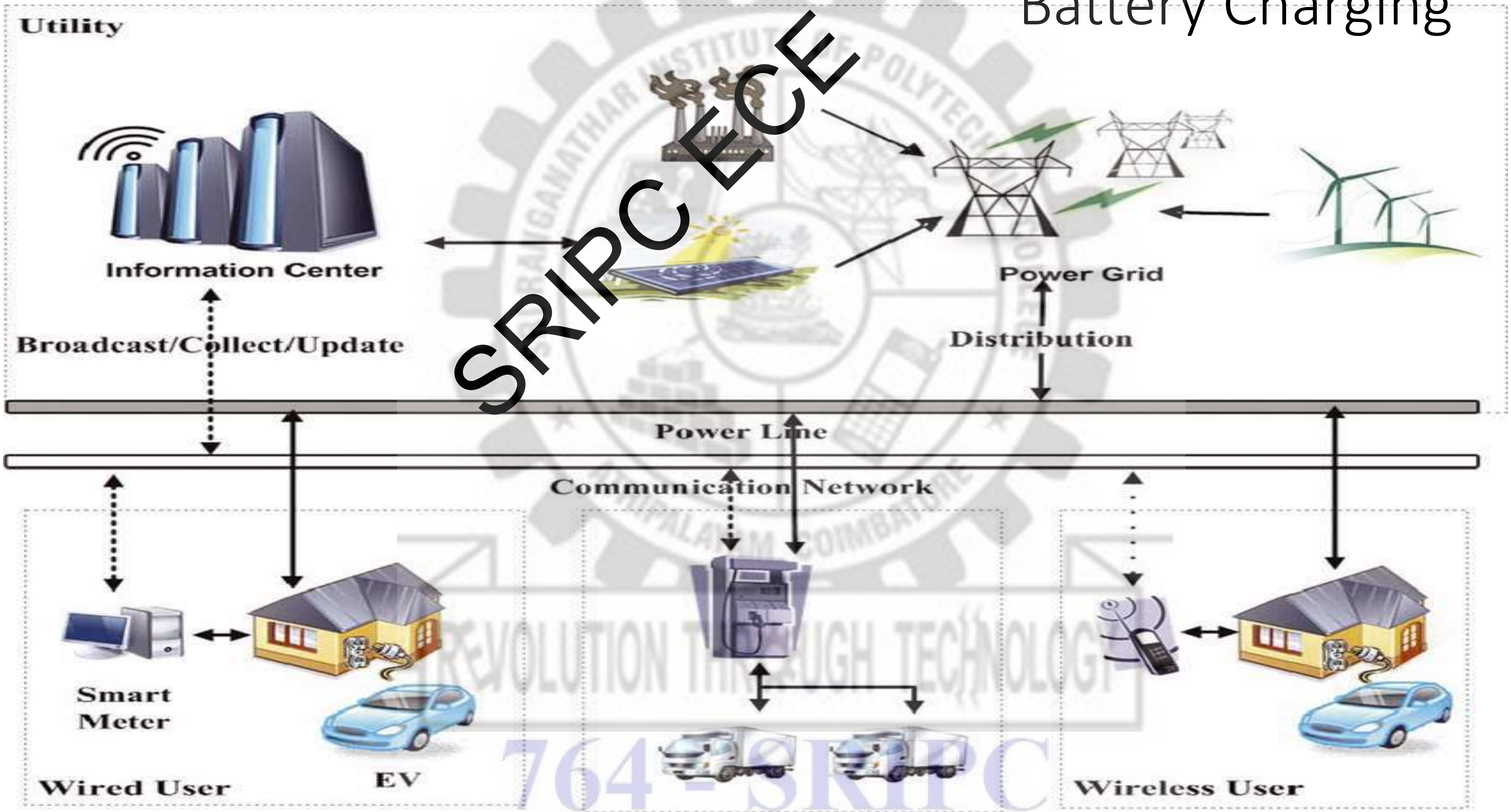




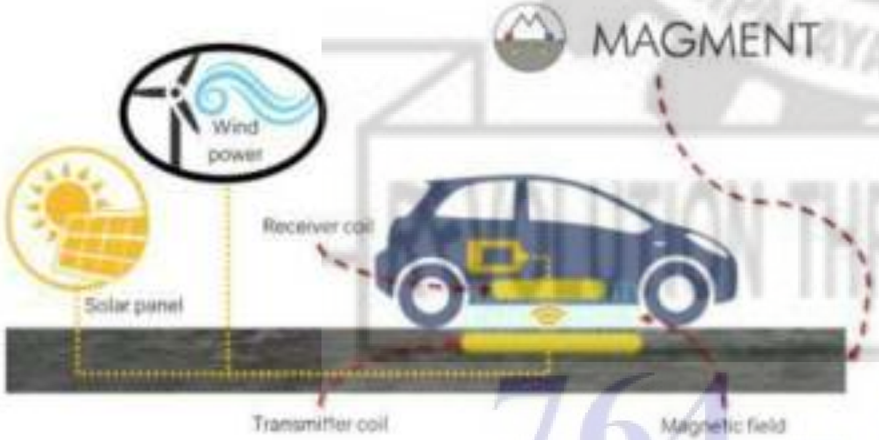
Battery Charging



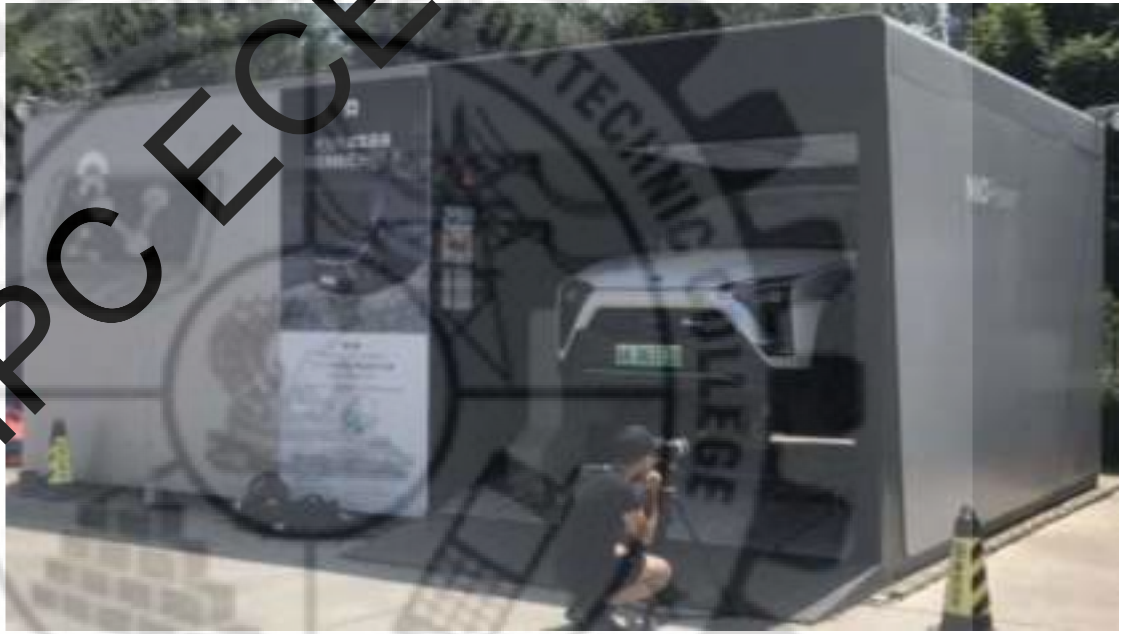
Battery Charging

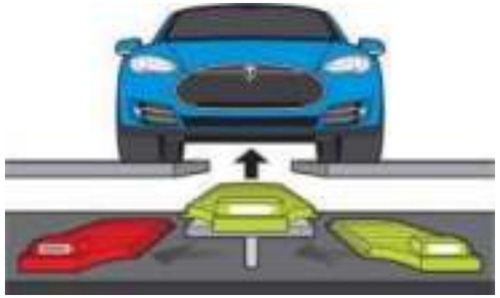


Battery Charging

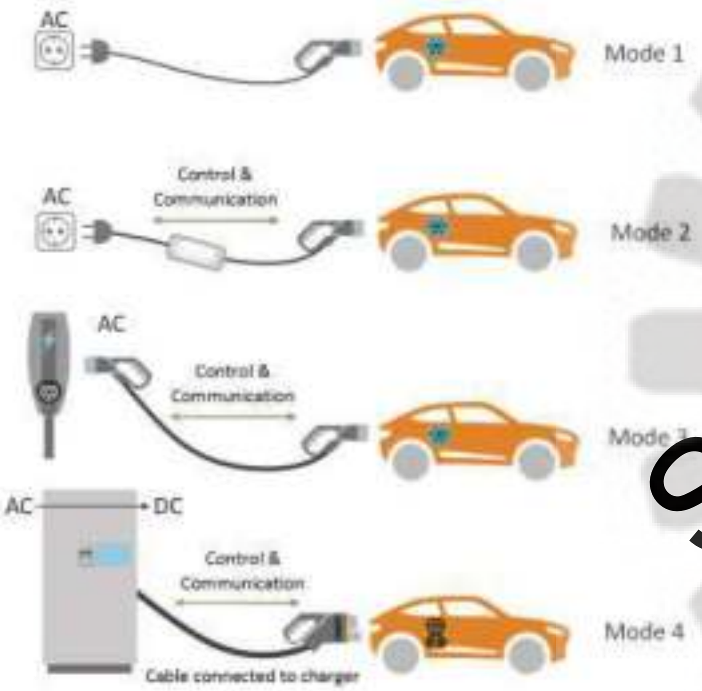


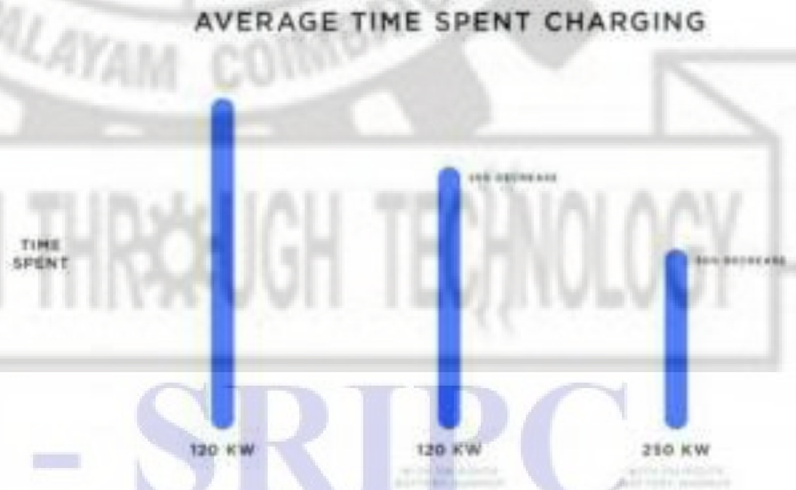
Battery Swapping Technique



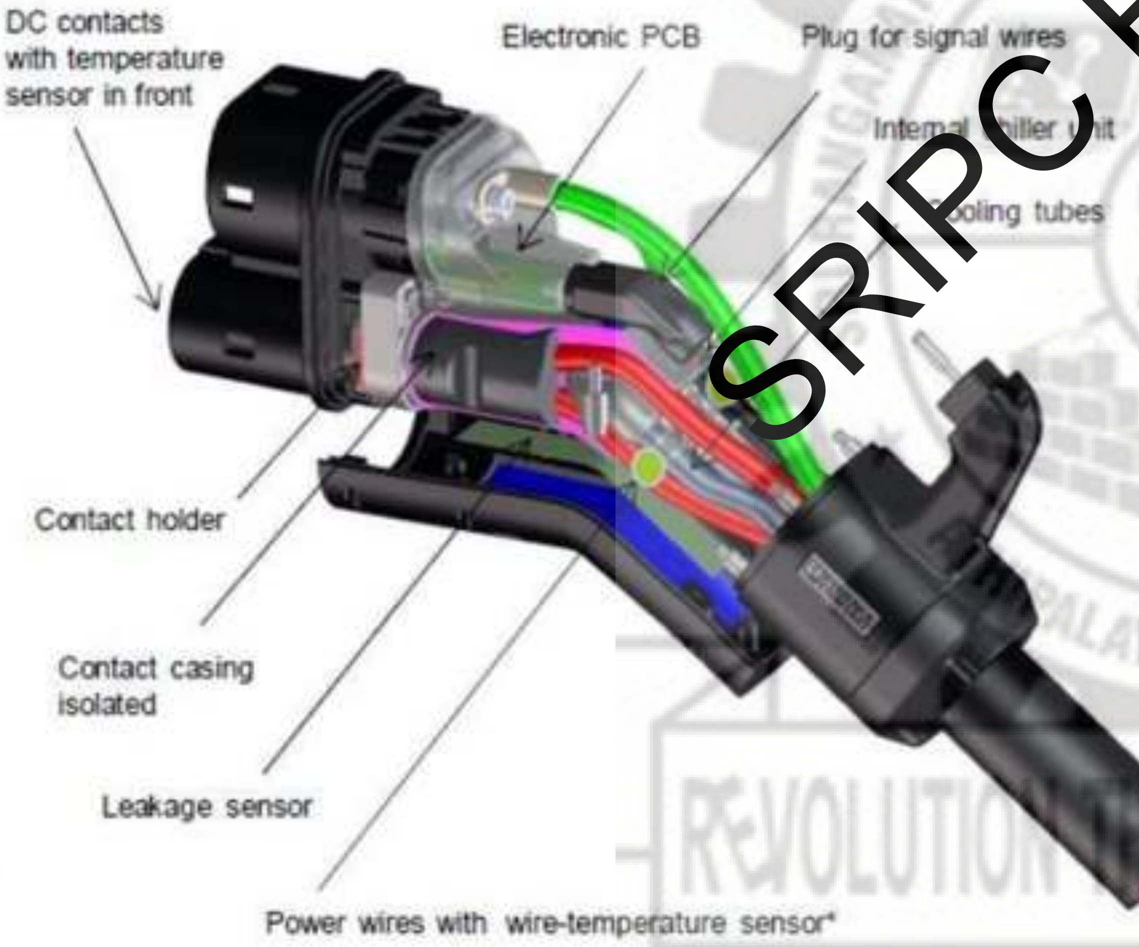


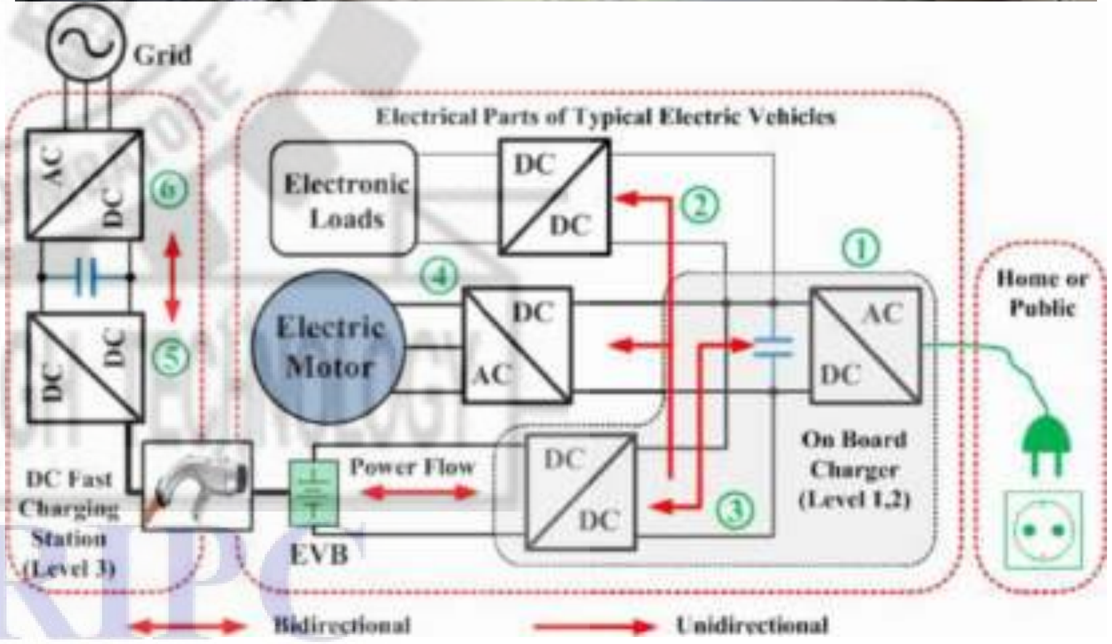
Charging Modes



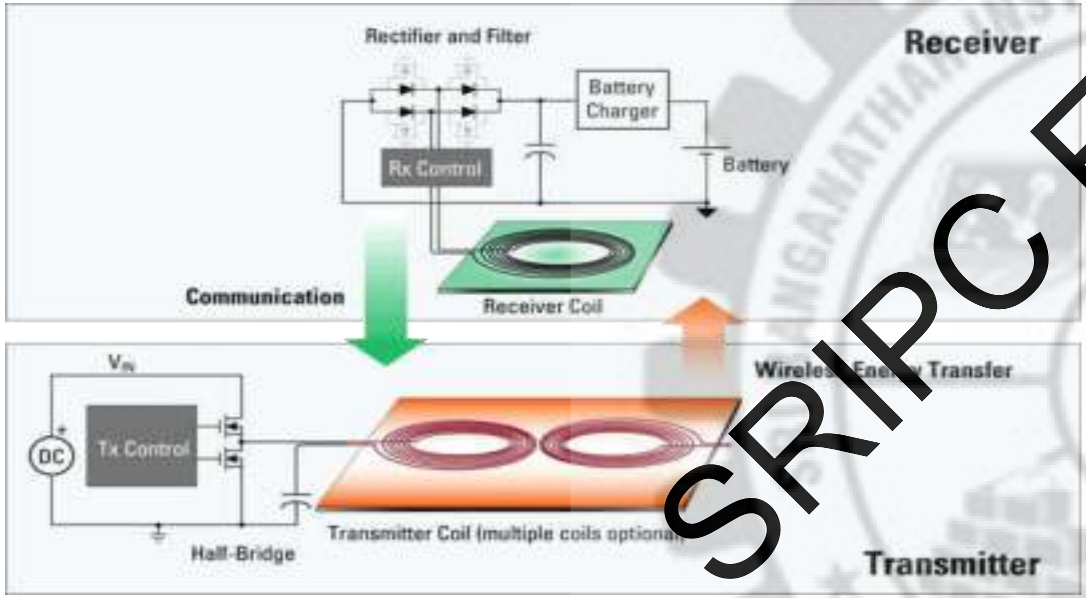


Liquid Cooled DC Super Charger



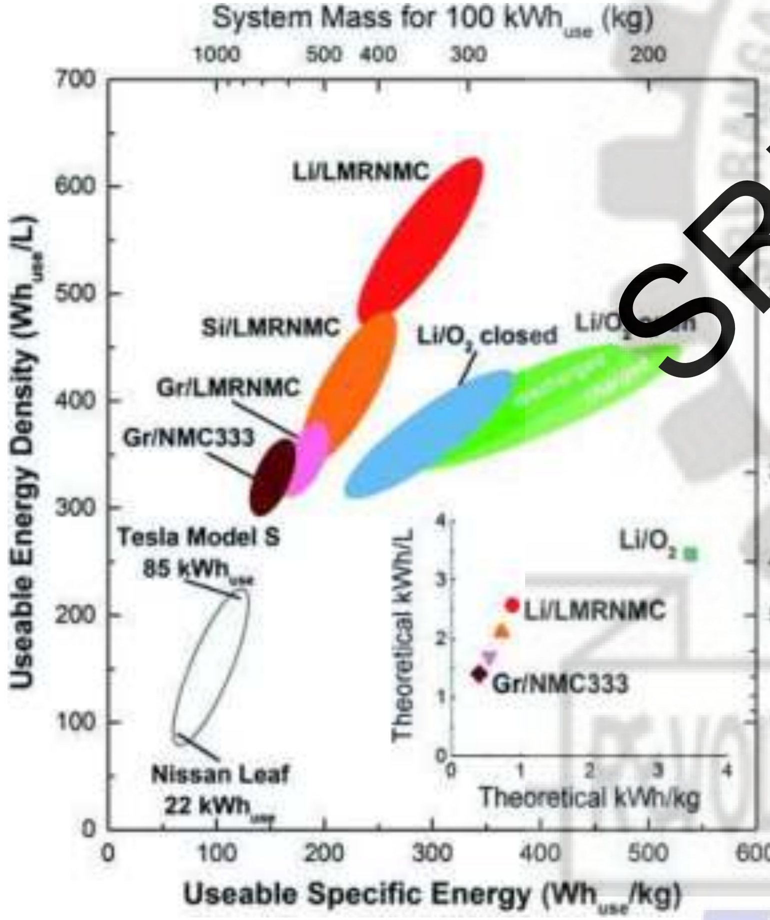


Wireless Charging

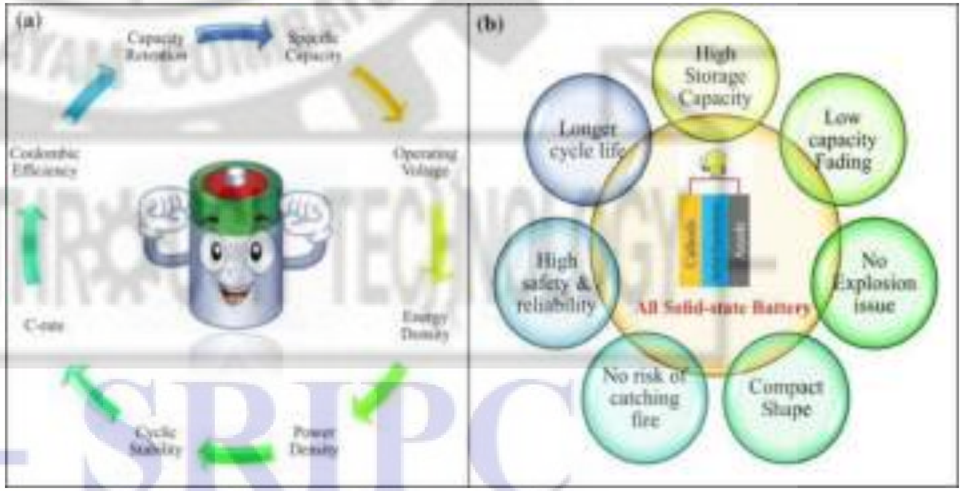


Maintenance of battery pack

Latest development in battery chaemistry



Parameter	SOTA Li-Ion	Solid Power
Energy (Wh/kg)	150-270	320-700
Energy (Wh/L)	400-700	700-1100
Power (W/kg)	100-2000	>1000, temp. dependent
Cycles	>1000	>1000
Safety	Acceptable w/ Features	Excellent
Shelf Life	2-3 years	10+ years
Temp. Operation	-20-60 °C	0-150 °C



Effects of EV

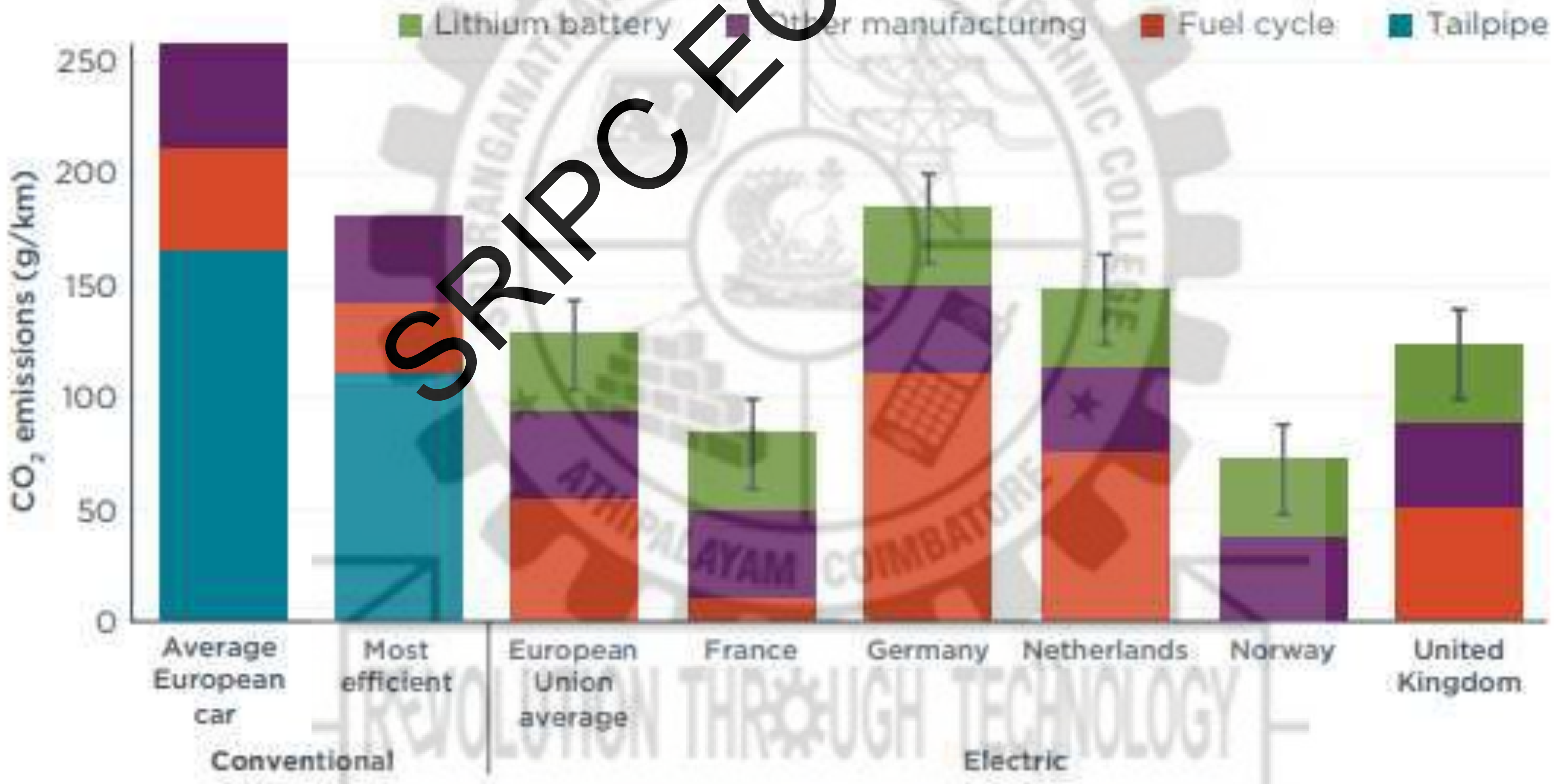


Figure 1. Life-cycle emissions (over 150,000 km) of electric and conventional vehicles in Europe

Effects of EV

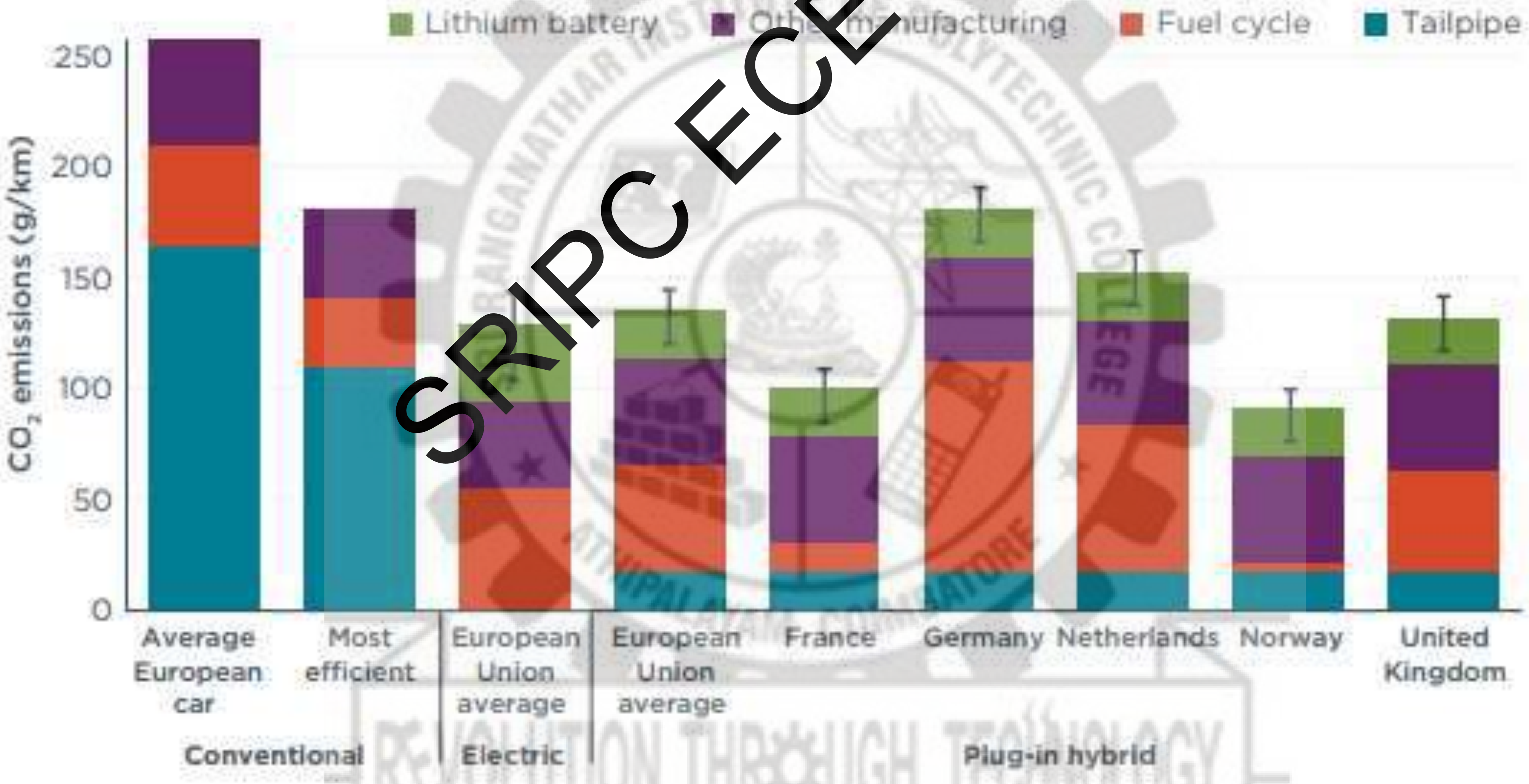


Figure 2. Comparison of life-cycle greenhouse gas emissions in conventional, electric, and plug-in hybrid vehicles in various European markets.

Battery Composition

Table 2. Materials in battery cells of a Chevrolet Bolt and their approximate cost per ton

Material	Percent of battery cell mass	Cost per ton
Aluminum	16%	$1,600
Graphite	14%	$10,000
Steel	13%	$600
Iron	9%	$74
Copper	8%	$6,348
Cobalt	6%	$27,000
Nickel	6%	$10,000
Manganese	5%	$1,700
Polyester	3%	N/A
Lithium	2%	$15,000
Other	18%	N/A

Battery Technology Trend

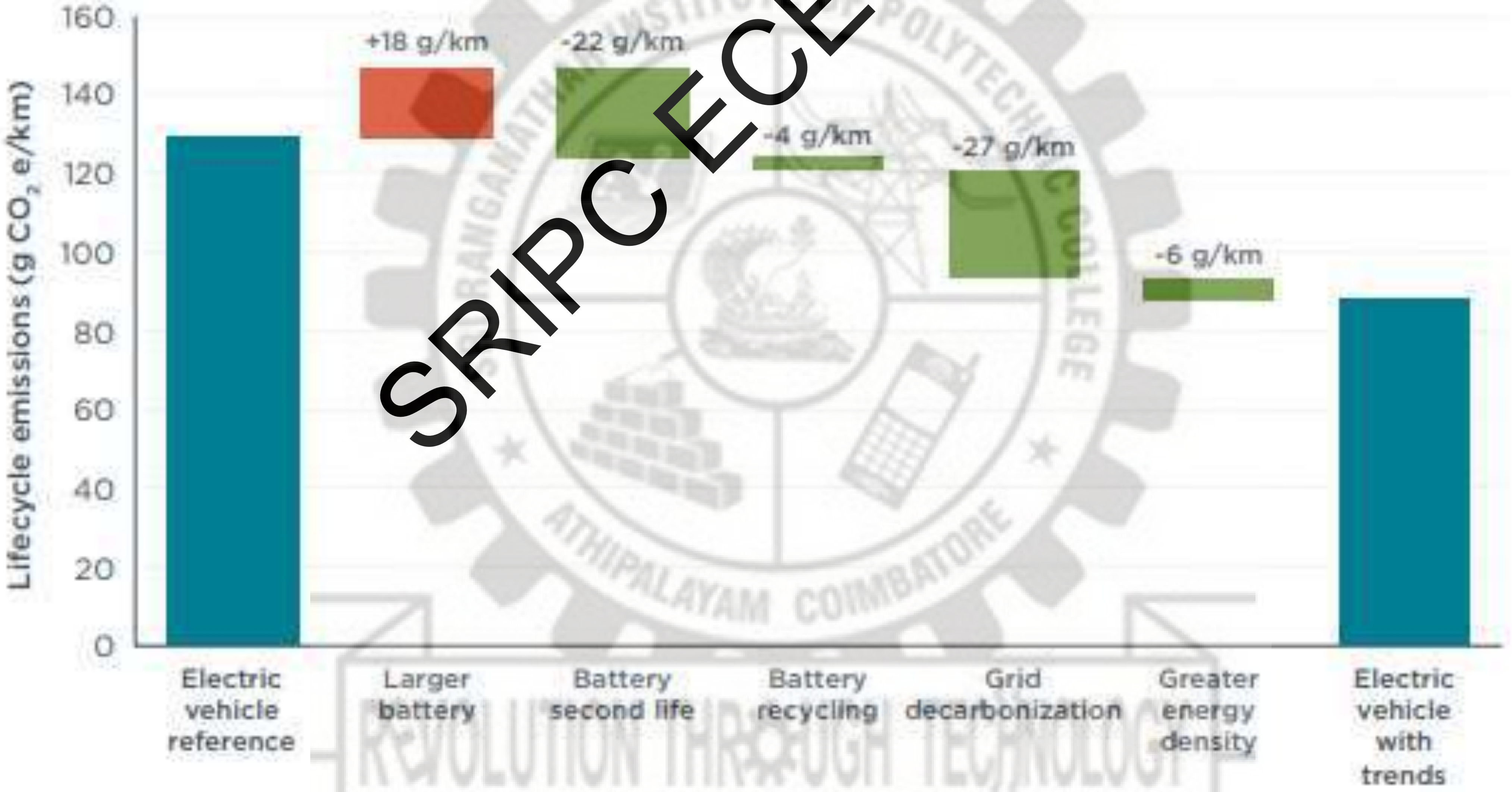
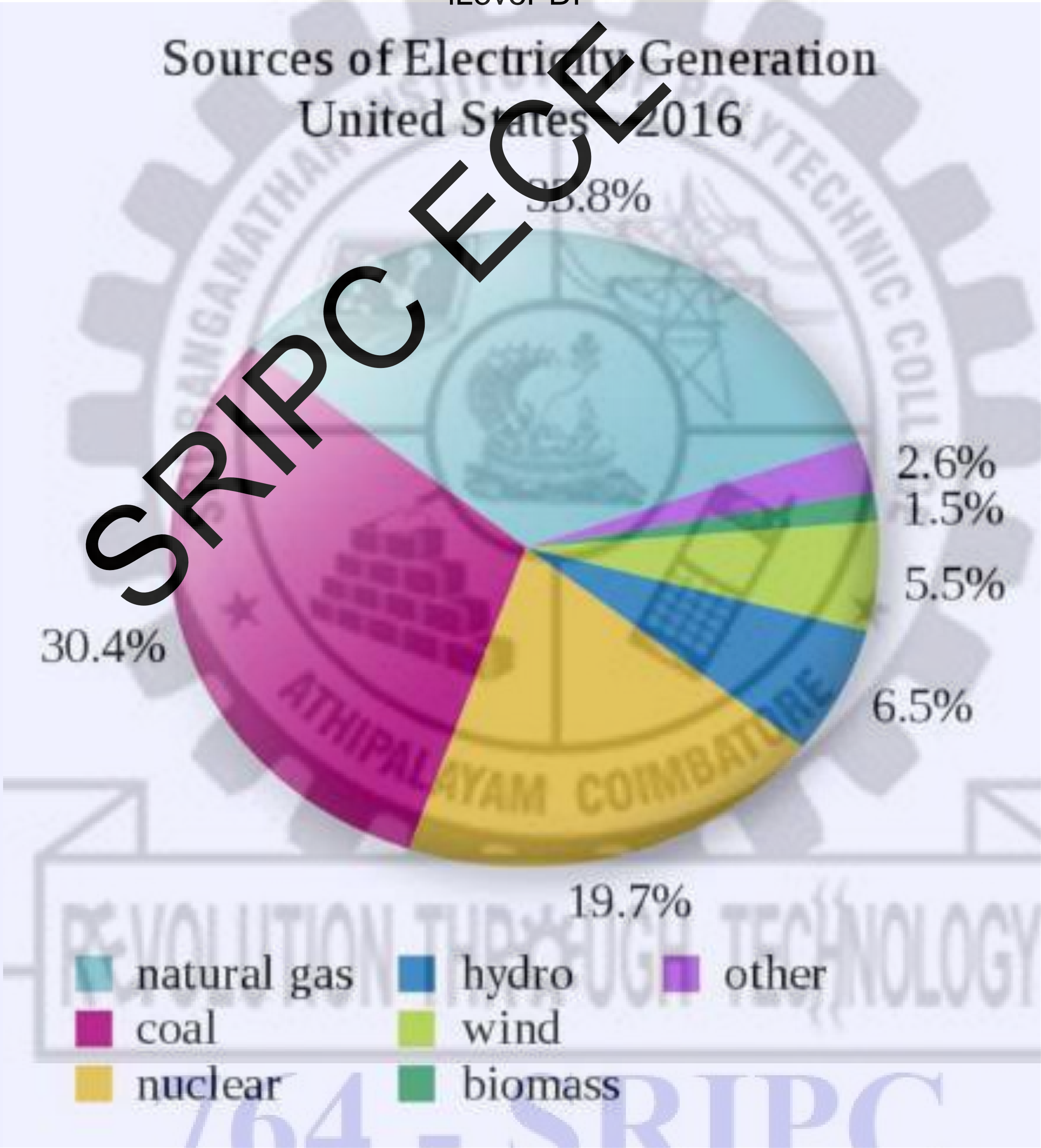


Figure 3. Potential changes in battery manufacturing greenhouse gas emissions (compared to reference 2017 electric vehicle) resulting from increased pack size and improvements in battery manufacturing and use.

Solar Cell Charging


Sources of Electricity Generation
United States - 2016
33.8%
2.6%
1.5%
5.5%
6.5%
30.4%
19.7%
natural gas
coal
nuclear
hydro
wind
biomass
other

Rare Earth Magnet demand and recycling rate

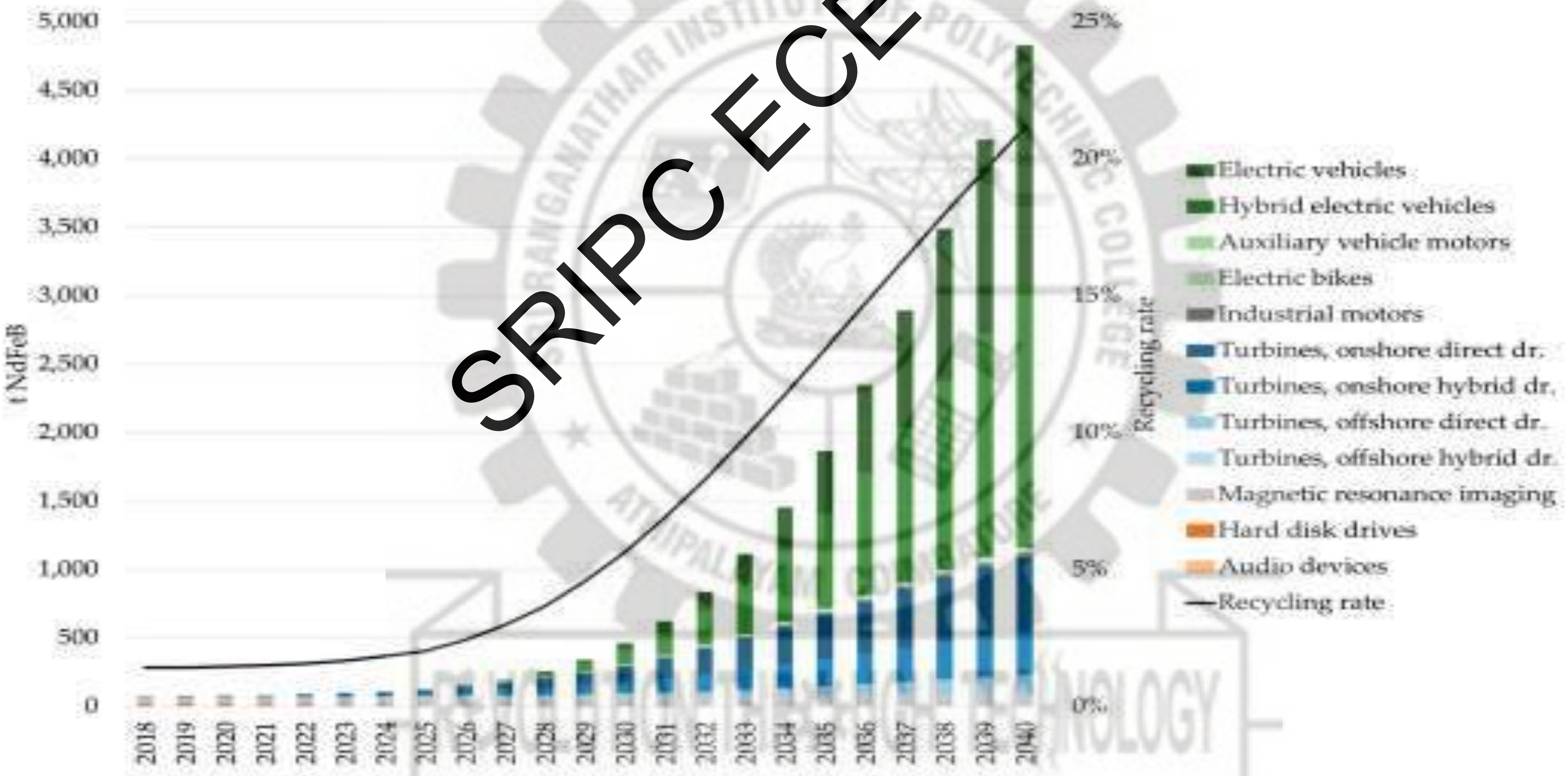
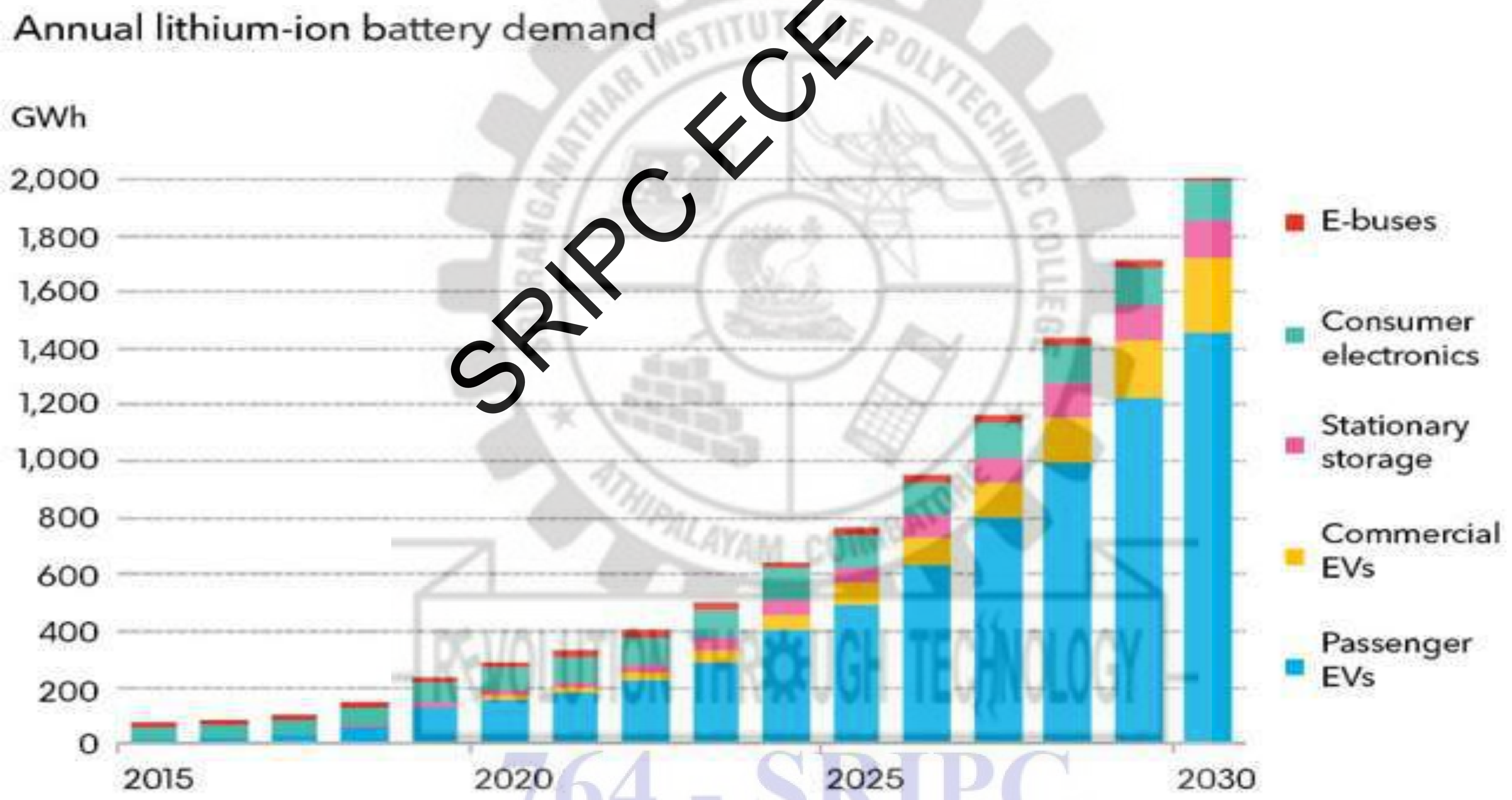


Figure 7. Estimation of the realistic return flows by application in tons of NdFeB and overall recycling rate.


Annual lithium-ion battery demand
GWh
2,000
1,800
1,600
1,400
1,200
1,000
800
600
400
200
0
2015
2020
2025
2030
E-buses
Consumer electronics
Stationary storage
Commercial EVs
Passenger EVs

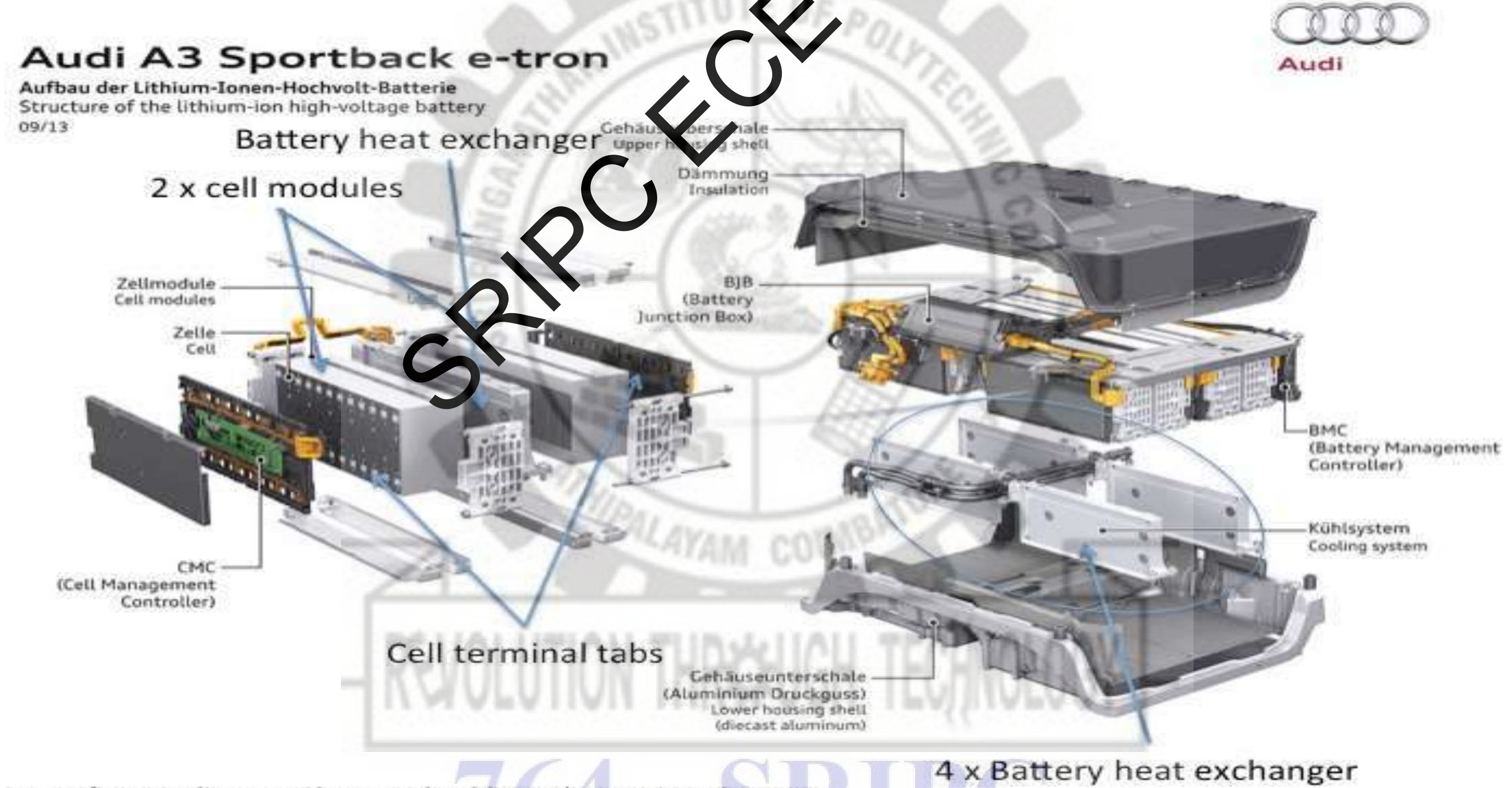
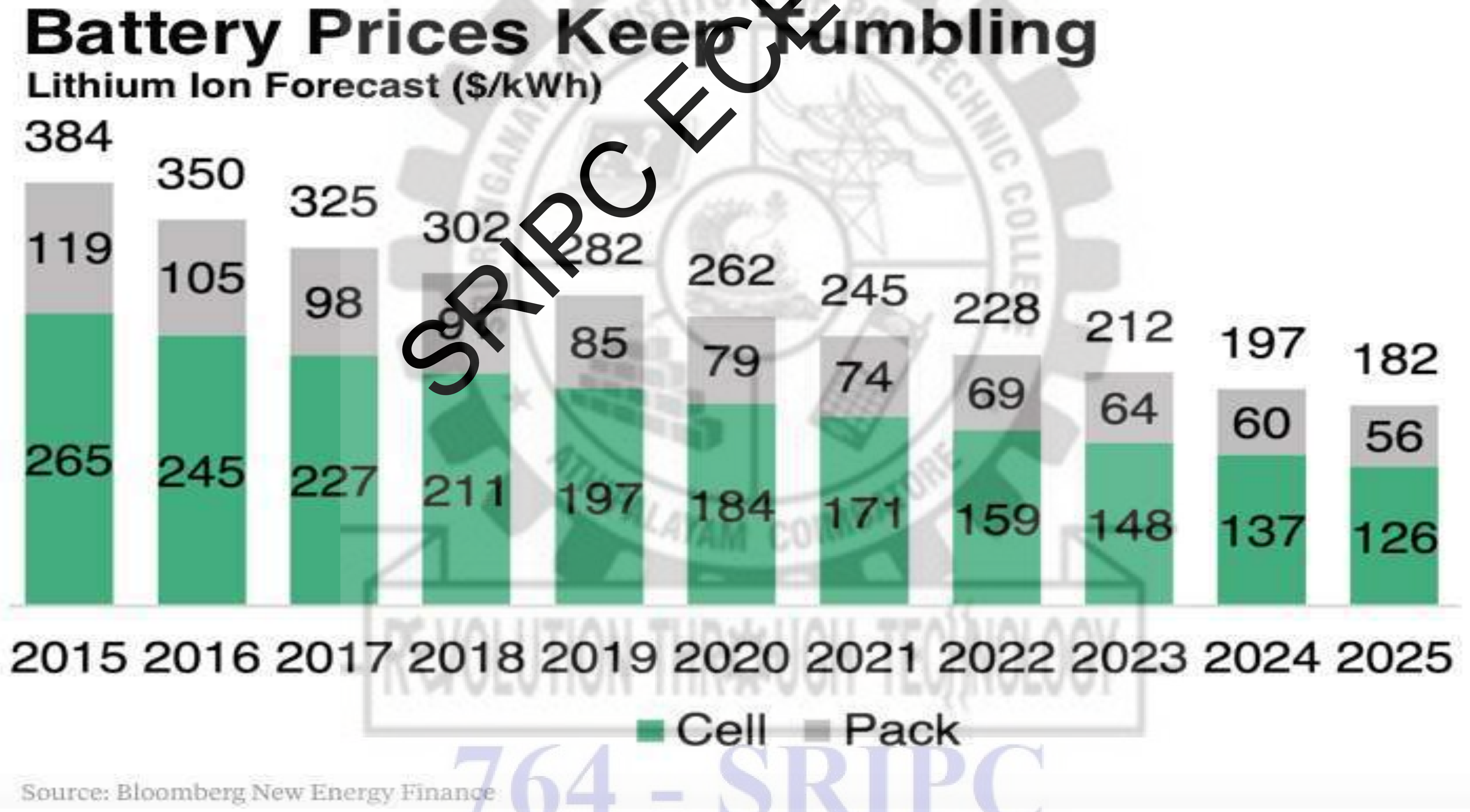
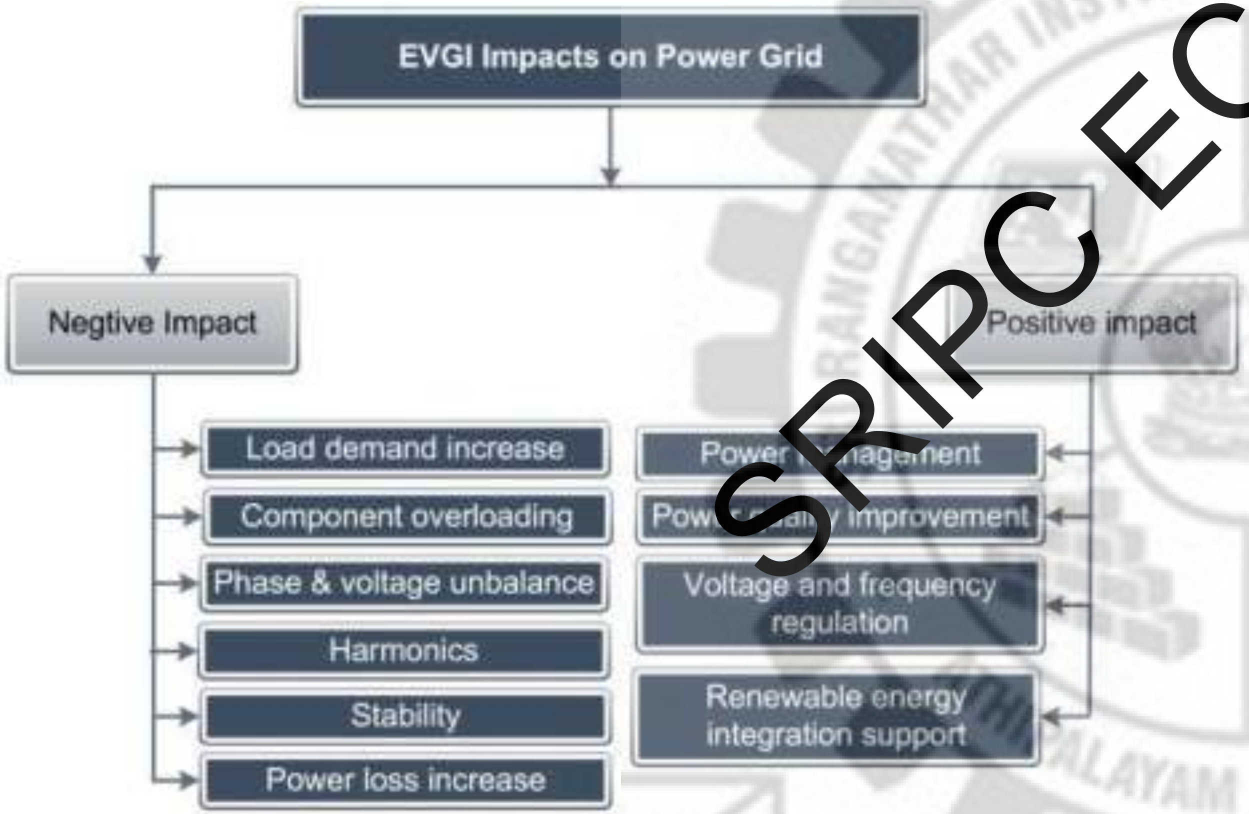


Image from Audi press release with additional annotation by AVID


Battery Prices Keep Tumbling
Lithium Ion Forecast ($/kWh)
384
350
325
302
282
262
245
228
212
197
182
119
105
98
91
85
79
74
69
64
60
56
265
245
227
211
197
184
171
159
148
137
126
2015 2016 2017 2018 2019 2020 2021 2022 2023 2024 2025
Cell
Pack
Source: Bloomberg New Energy Finance


Lithium-ion
Battery
Market (2019-2027)
~9%
Value CAGR
2019-2027
Market Share by Region, 2019
North America
Europe
Asia Pacific
Middle East
& Africa
South America
7 Billion
Units
Global Sales, 2019
Rise in sales
of electric vehicles
increasing demand for
lithium-ion batteries
Market by Product, 2019
Cells/Modules
Battery Packs
Energy Storage
Systems (ESS)
Key Strategies
- Capitalize on Growing EVs in Asia Pacific
- Leverage Recycle Process to Control
Overhead Costs
www.transparencymarketresearch.com
Transparency
Market Research

Impact on Power Grid



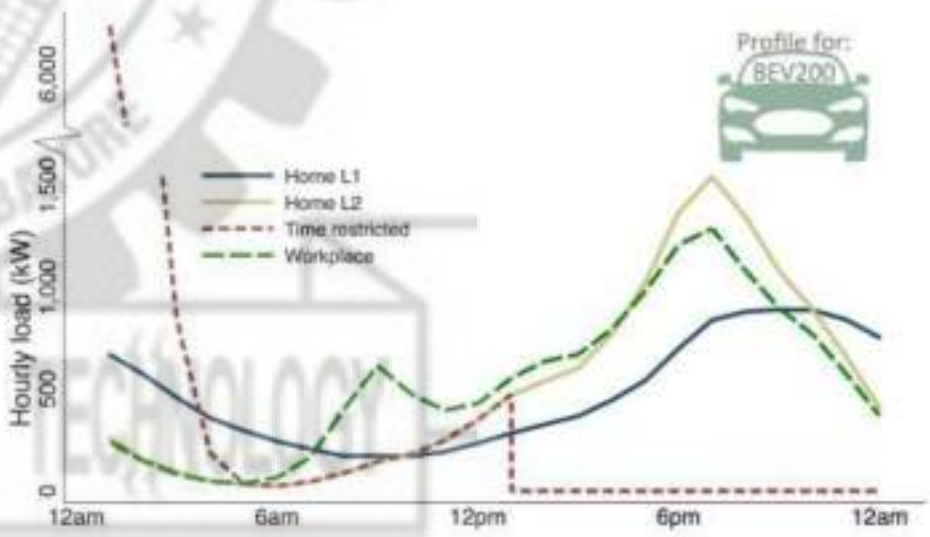
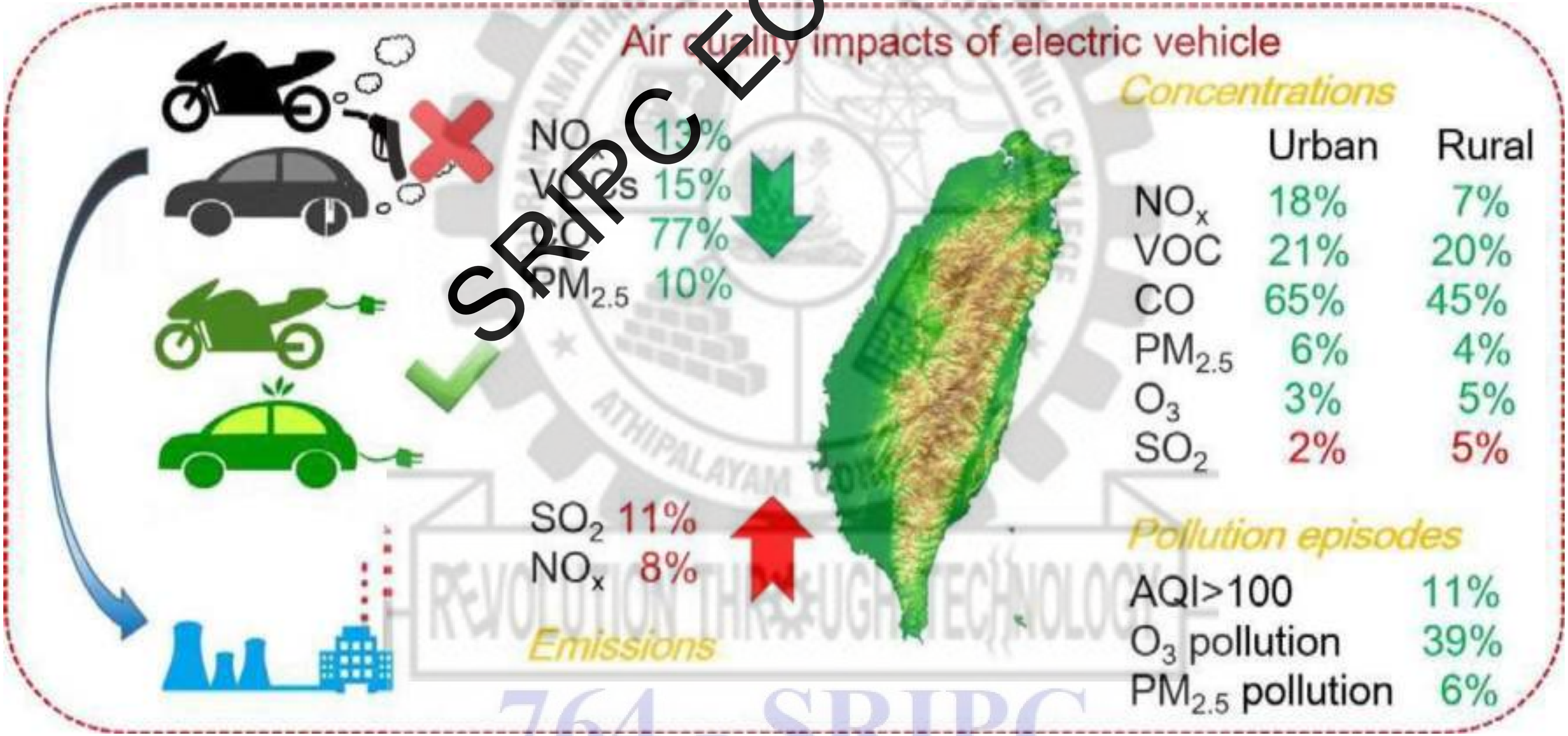


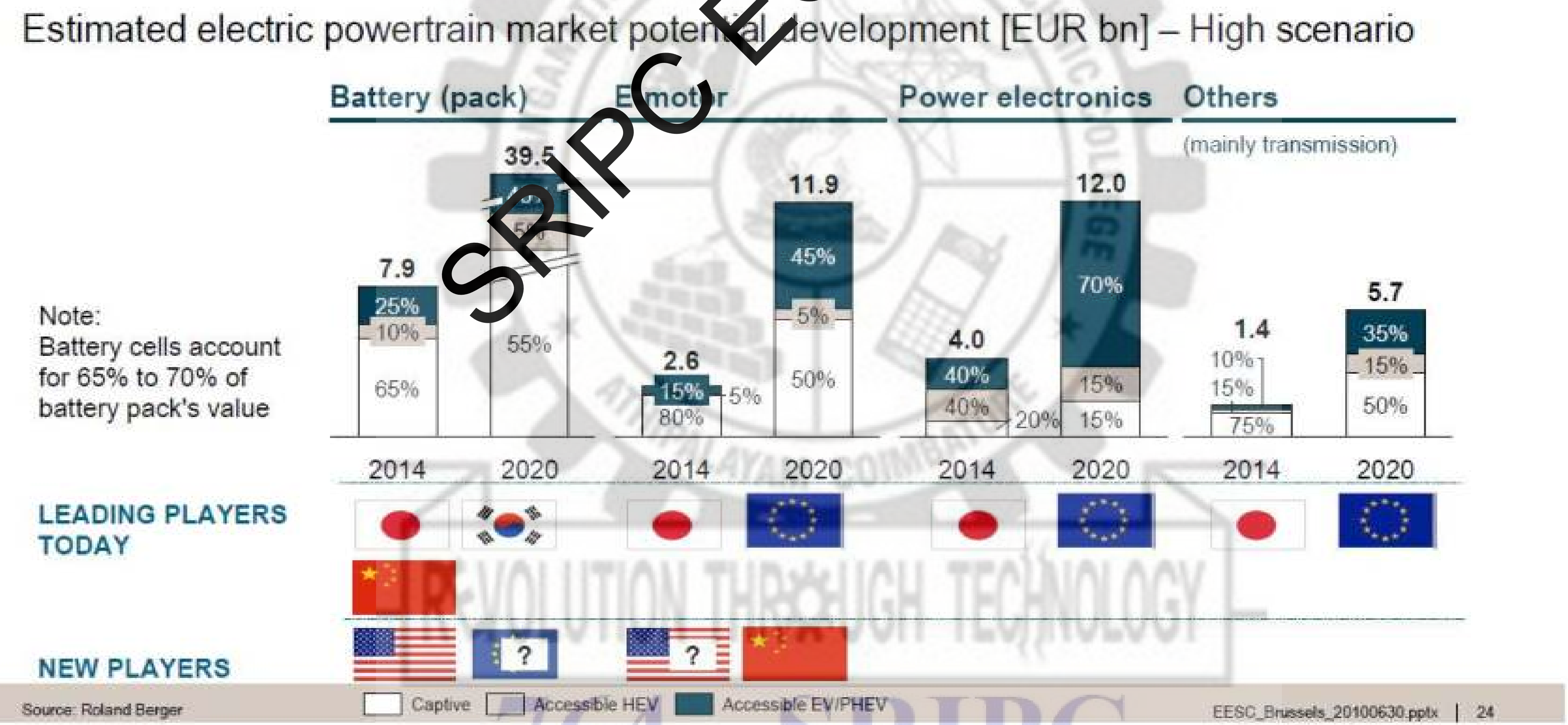
Figure 7. BEV load profile by scenario

Note: The scale in the figure is capped at 1,500 kW for presentation purposes (the time restricted scenario peaks at 6,200 kW at 12 a.m.).

Impact on Environment

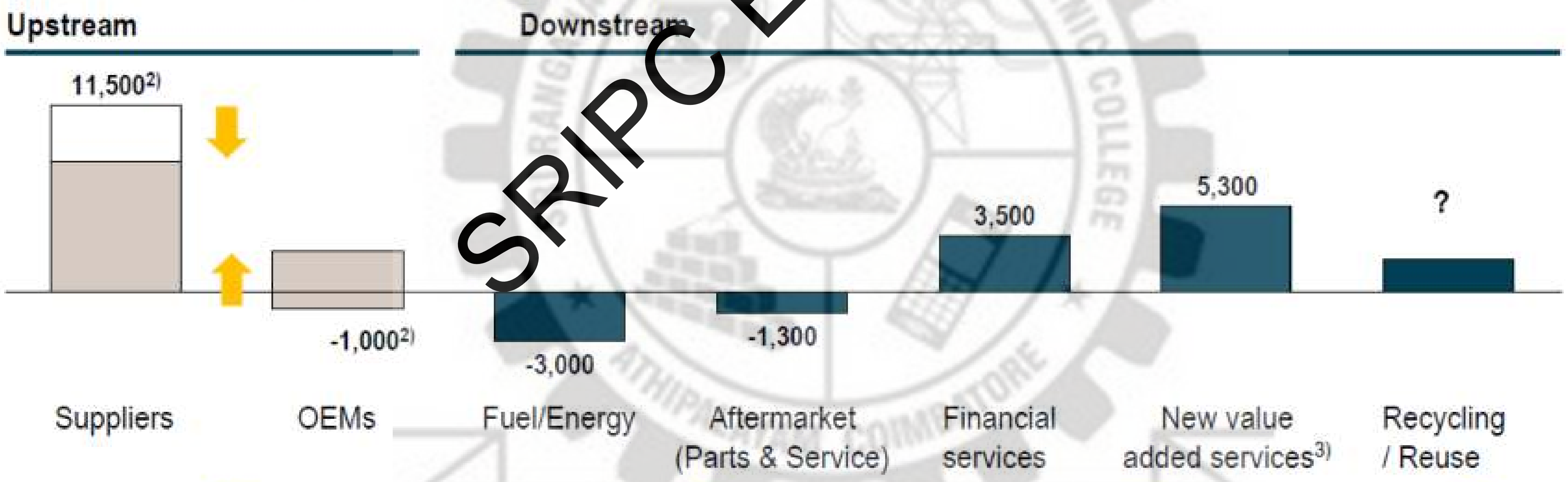


Impact on Economy



Impact on Economy

Changes in lifecycle revenue pools per vehicle EV vs. ICE [EUR], 2015[1)]



- OEMs eager to produce components
- Car sharing models etc. to leverage lower operating costs
- Mobility services / new leasing models to switch to TCO comparision
- High efficient recycling needed

1) Assumption: Â-class vehicle produced in 2015, life time 15 years, 12.500 km p.a., one battery change, all figures at 2015 costs (2nd battery: at 20220 cost level)
2) Assumption: all new powertrain components manufactured by suppliers 3) Telematik, fast Charging, ...

Session 5

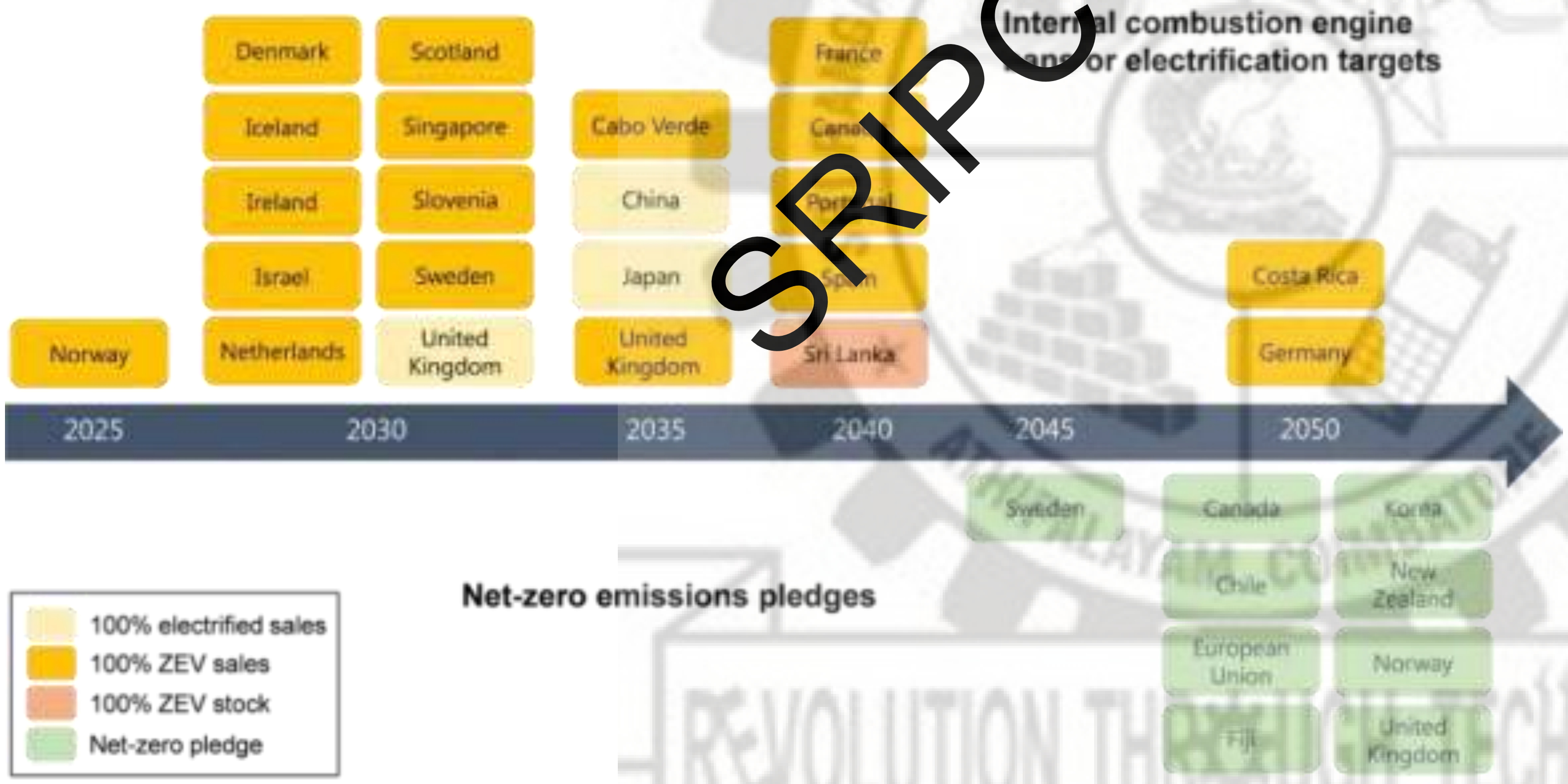
Electric Mobility Policy Frame Work

- Government of India Electric Mobility Policy Frame work
- Global Scenario of EV adoption
- Electric mobility in India
- National Electric Mobility Mission Plan 2020
- Action led by Original Equipment Manufacturers
- Need of EV Policy
- Advantage of EV Eco system
- Scope and Applicability of EV Policy
- ARAI Standards for Electric Vehicle – AIS 038, AIS 039 &AIS 123
- Key Performance Indicator - Global impact
- Trends and Future Developments

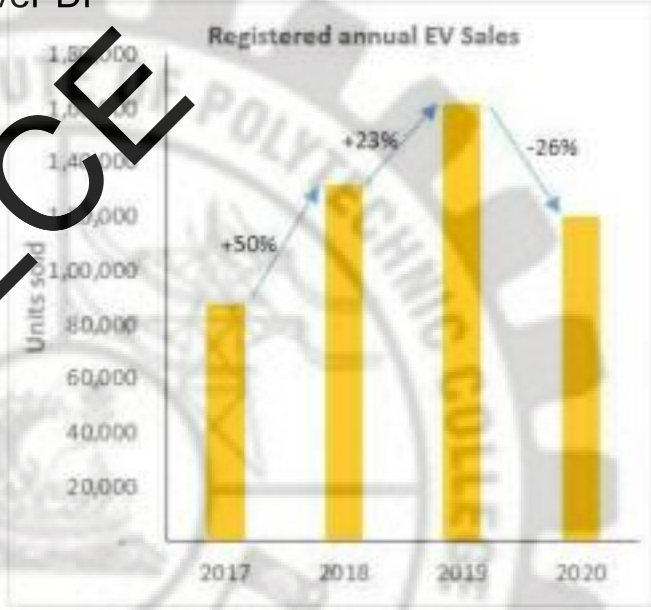
FAME-India
(National Mission on Electric Mobility)

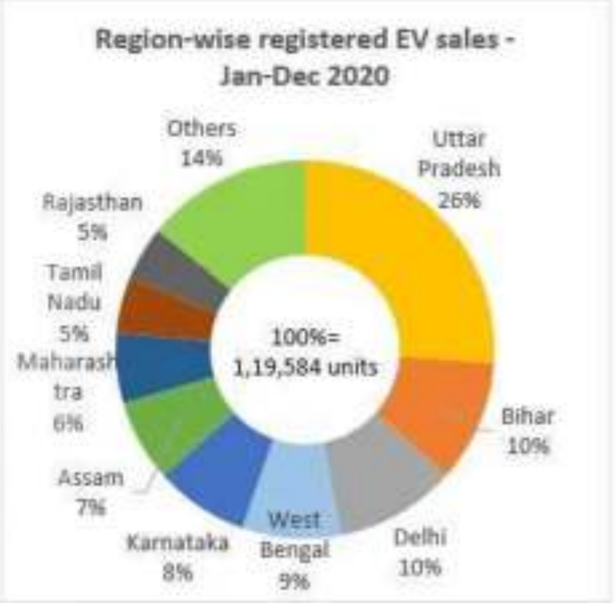
FAME
India Scheme

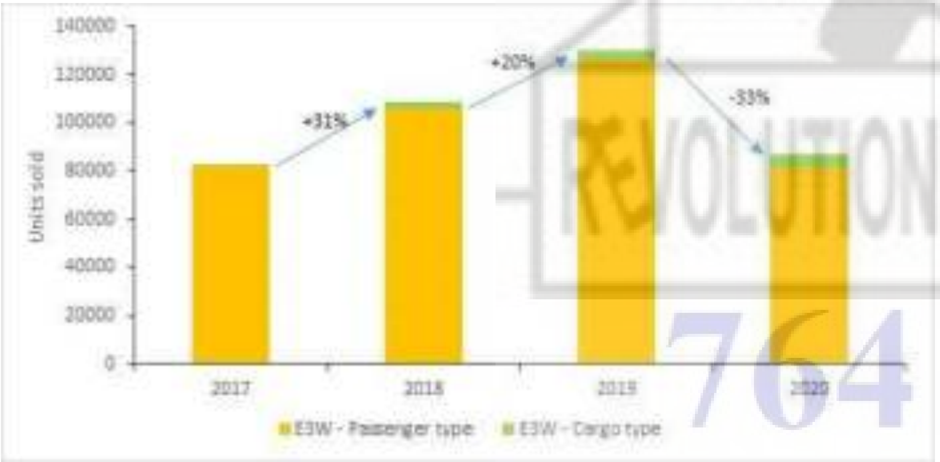
Global Scenario of EV adoption

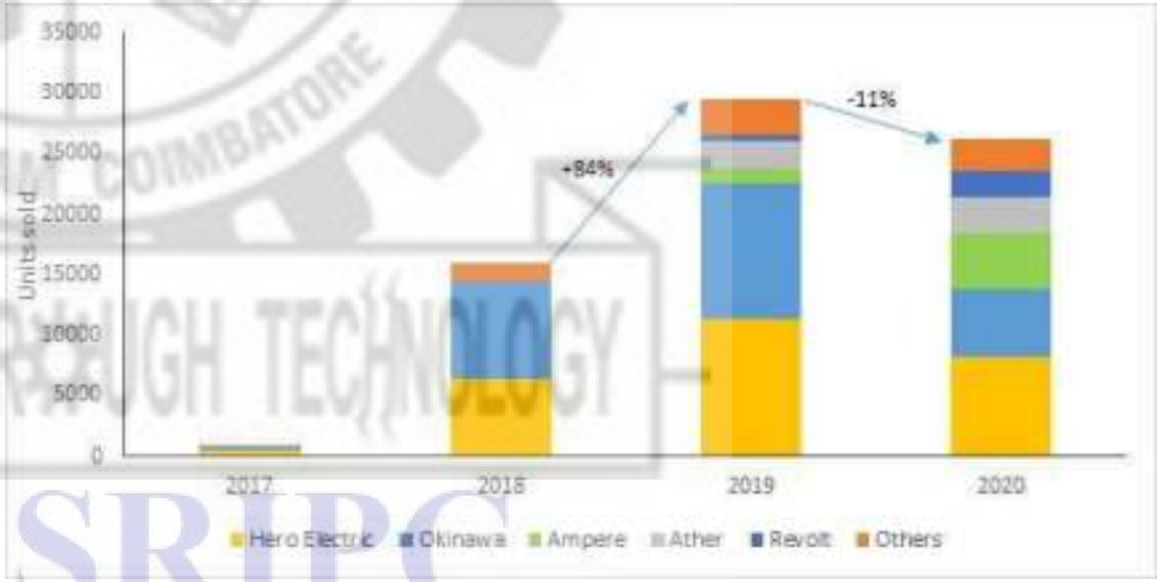


Electric mobility in India









National Electric Mobility Mission Plan 2020

•Demand side incentives to facilitate acquisition of hybrid/electric vehicles Promoting R&D in technology including battery technology, power electronics, motors, systems integration, battery management system, testing infrastructure, and ensuring industry participation in the same

•Promoting charging infrastructure Supply side incentives

•Encouraging retro-fitment of on-road vehicles with hybrid kit

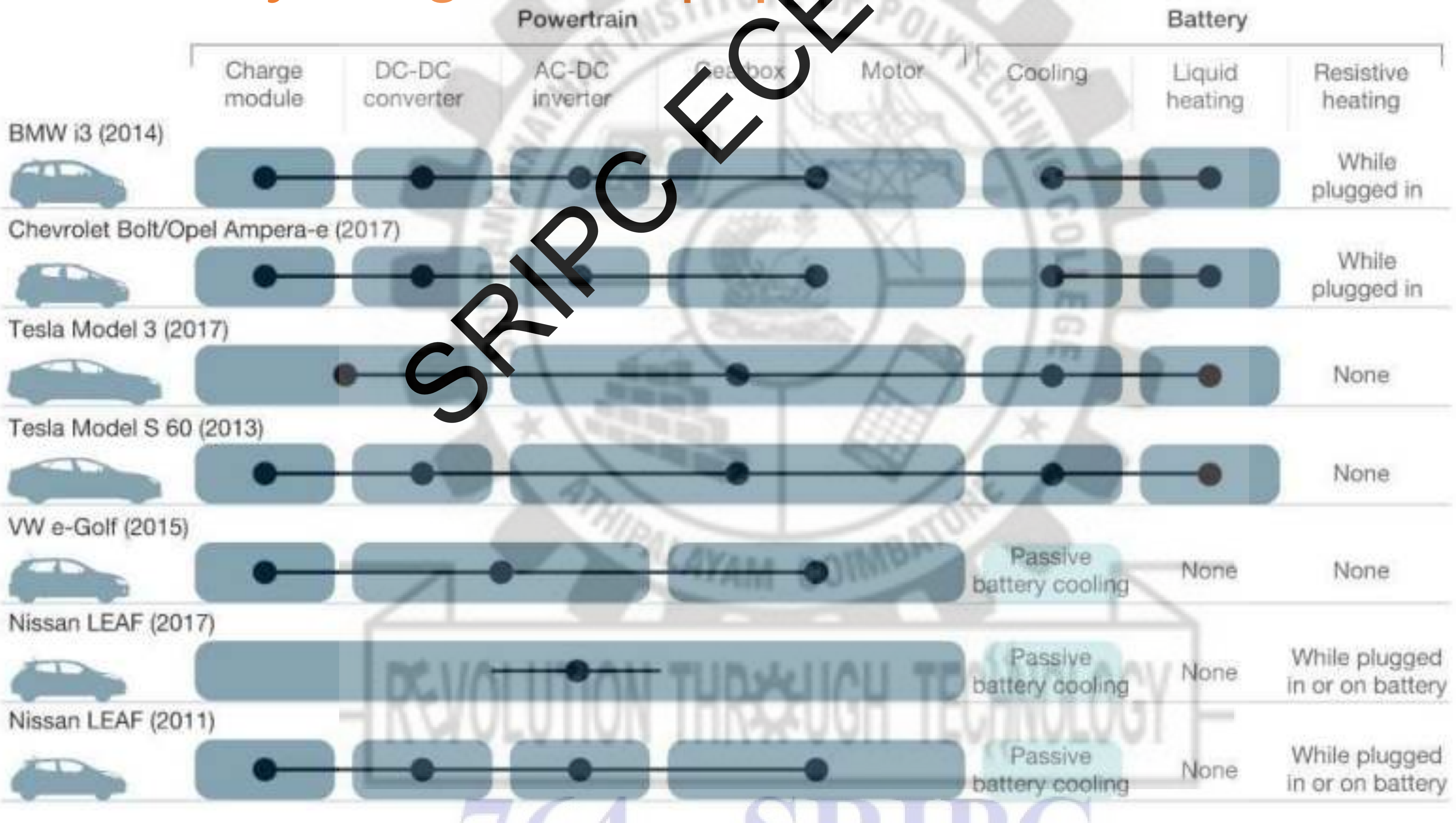
Action led by Original Equipment Manufacturers

Original equipment manufacturer	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
BMW Group			25		15-25%					10
BAIC Group	2				1.3					50%
Changan Automobile (Group)					33					
Daimler		10			25%					50%
Dongfeng Motor Co	1	30%	1		1				1	1
FAW					40%					60%
Ford		40				100%*				
GM Group			22		30	1				1
Honda										40%ᵀ
Hyundai-Kia					1					
					29					
Mazda		1								5%
Renault-Nissan		20								
		20%								
Maruti Suzuki	1									1.5
SAIC					30%					30
Stellantis					38%*					70%*
					31%**					35%**
Toyota Group	1				15					>1
Volkswagen					20%					70%*
			1		3				26	50%**
					75					
Volvo (Geely Group)	1	1	1	1	50%					100%*

- % of sales electric
- Annual sales (million)
- New EV models (number)
- Cumulative sales (million)

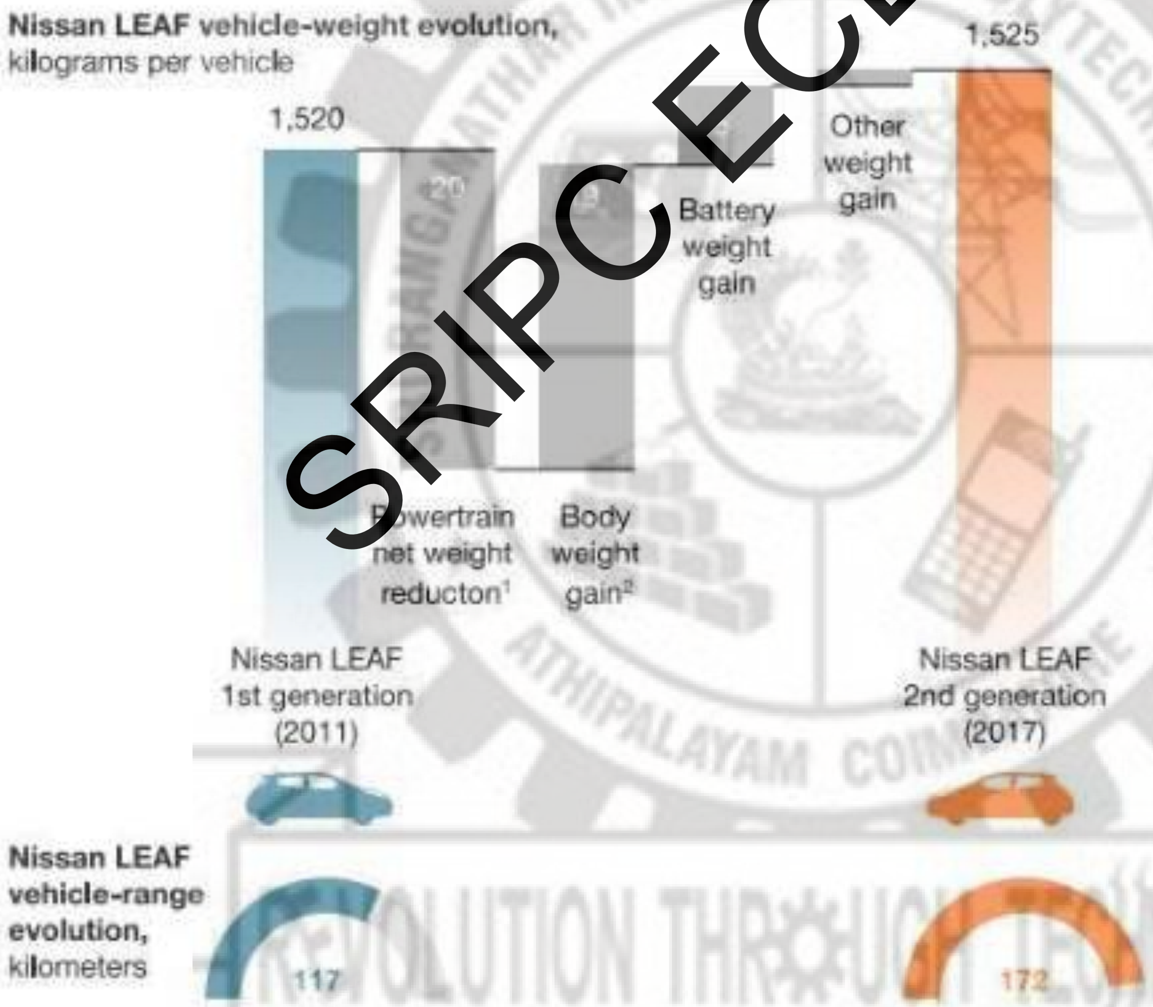
* European market only
** Chinese and US markets only
ᵀ Includes both EVs and FCEVs

Action led by Original Equipment Manufacturers



Note: Exhibit is a simplification of more detailed schematics

Design-to-cost efforts have focused on component integration and use of materials.



[1] Powertrain is motor, transmission system, and related electronics. Weight reduced through integration of powertrain components (inverter, converter, charger, and motor).
[2] Body weight gain from material change on doors from aluminum to steel.

Original equipment manufacturers fo[illegible]g powertrain and battery supply-chain strategies for electric [illegible]ehicles.

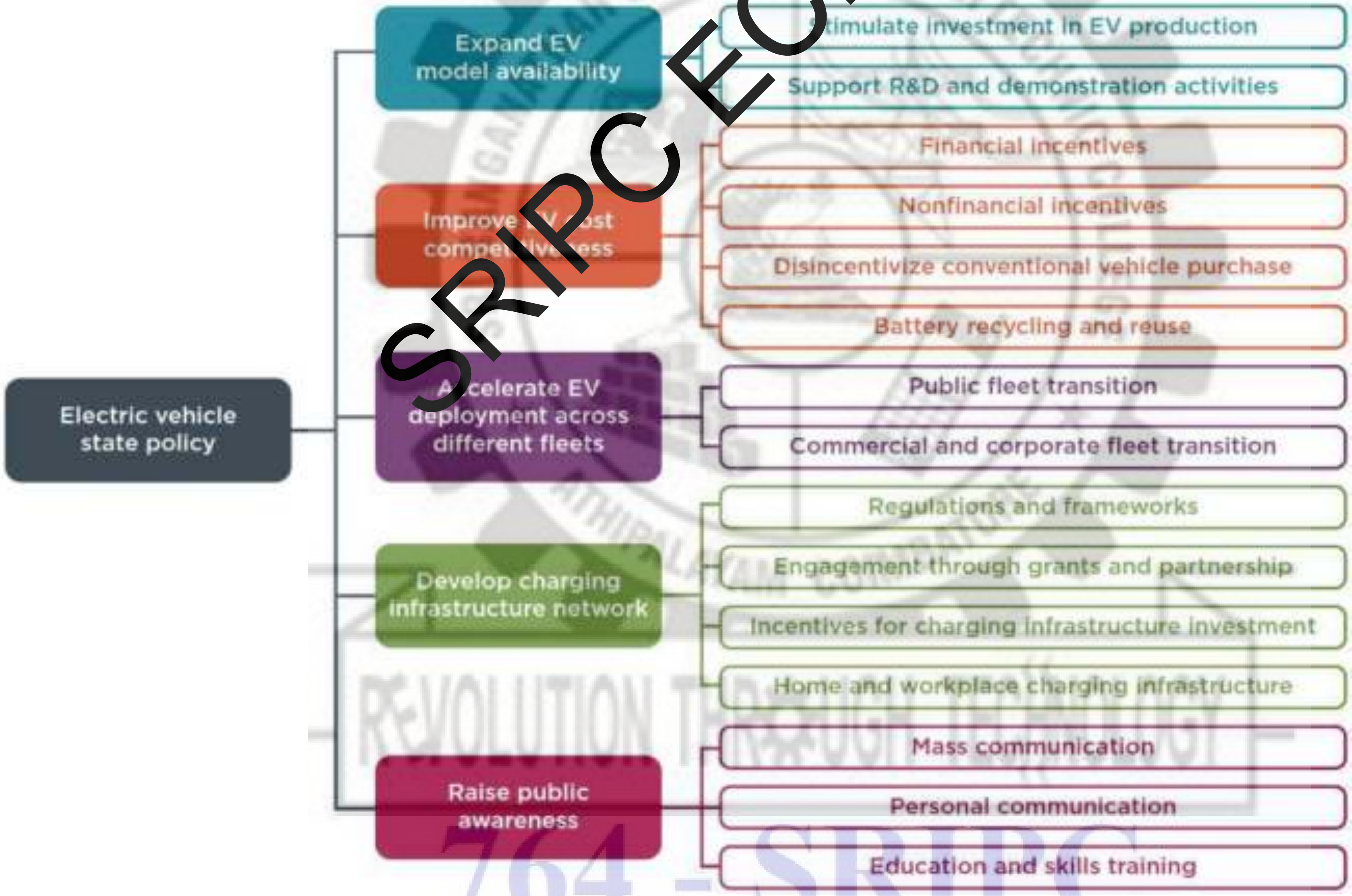
Electric-vehicle manufacturers' battery supply-chain strategies — [illegible] / Buy

	Battery cell	Battery pack	Battery management system	Power electronics[1]	Motor	Transmission[2]
BYD E6 (2015)						Not available
Tesla S 60 (2013)	Panasonic					Borg-Warner[4]
BMW i3 (2014)	Sa[illegible]		Preh			
VW e-Golf (2015)	[illegible]		Panasonic[3]	Bosch		
Chevrolet Spark (2[illegible]	A123		A123			Not available
VW e-up! (2013)	Panasonic		Panasonic[3]	Bosch		
Nissan LEAF (2011)	AESC	AESC	Calsonic Kansei	Calsonic Kansei/Denso		Aichi
Nissan LEAF (2017)	AESC	AESC	Calsonic Kansei	Calsonic Kansei/Denso		Aichi
Chevrolet Bolt/Opel Ampera-e (2017)	LG	LG	LG	LG	LG	LG

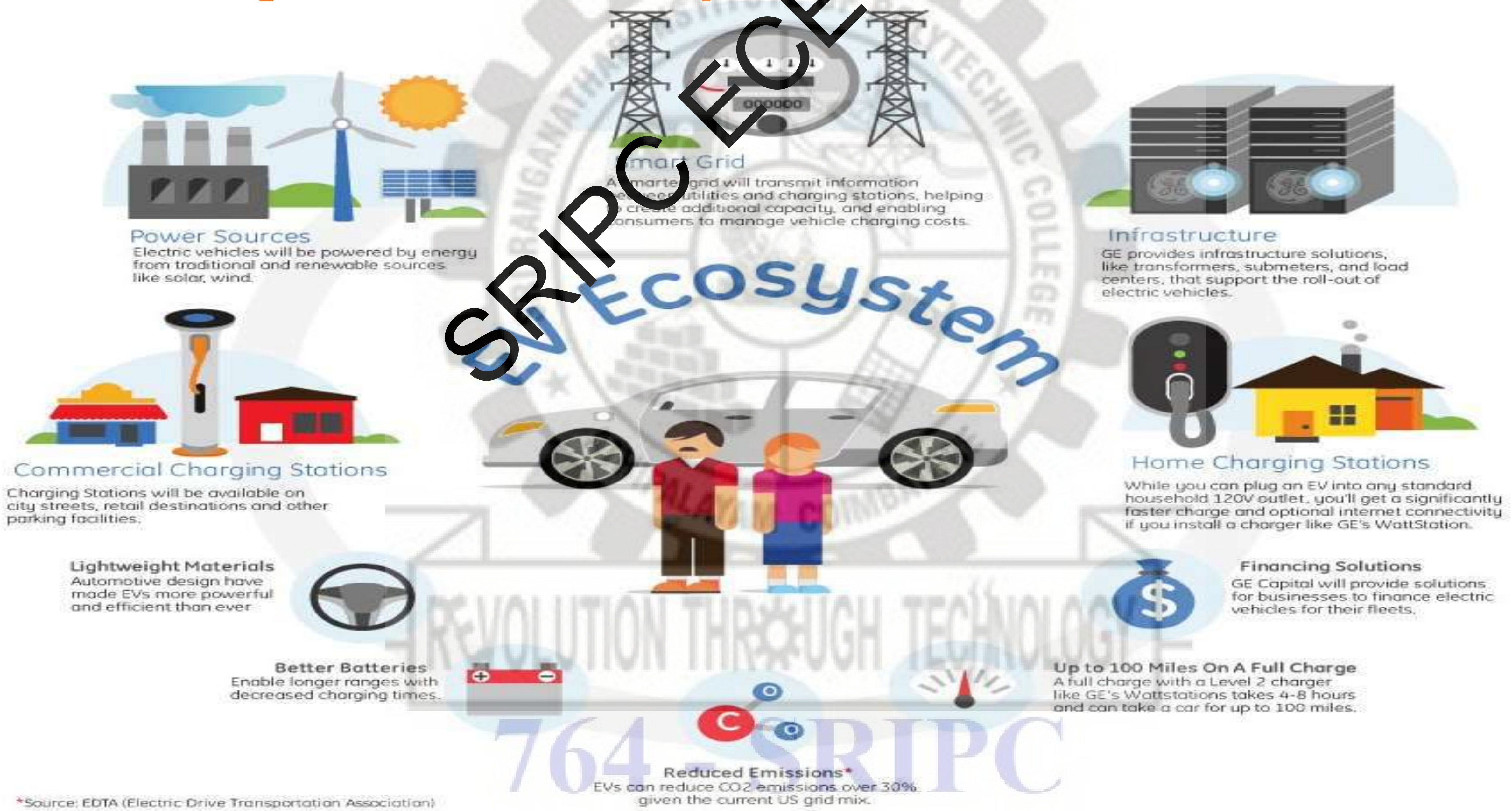
[1] DC-DC converter and AC-DC inverter.
[2] Only single-speed transmission.
[3] Formerly Ficosa, now owned by Panasonic.
[4] Formerly Eaton, now owned by BorgWarner.

McKinsey&Company | Source: A2Mac1; McKinsey Center for Future Mobility

Need of EV Policy



Advantage of EV Eco system



Faster Adoption & Manufacturing of Hybrid & Electric Vehicle In India (FAME)

Published by : Ministry of Heavy Industry & Public Enterprise

Background:

	FAME Phase - I	FAME Phase - II
Date of Release:	1st April 2015	8th March 2019
Duration :	4yr (2015-2019)	3 yr (2019-2022)

Objective:

To :-

Adopt and create market for both hybrid and electric technologies vehicles in the country.

Develop Market & its manufacturing eco-system in country in order to achieve self-sustenance in stipulated period.

Focused areas:

Public transport.

Registered for commercial purpose in 3w, 4w,Bus segment &

Privately owned 2W

Financial Implication:

- Total fund — **Rs. 10,000 crores**
- Time Duration — **3Yr**
- Scheme Activation — **2019-20 to 2021-22**

Scheme Categorization:

Sl.No	Component	2019-2020	2020-2021	2021-2022	Total Fund Requirement In Crore
1	Demand Incentives	822	4581	3187	**8596**
2	Charging Infrastructure	300	400	300	**1000**
3	Administrative Expenditure Including Publicity ,ICE activity	12	13	13	**38**
Total For Fame II Scheme		1134	5000	3500	**9634**
	Committee Expenditure for Phase -I	366	0	0	**0**
Total		**1500**	**5000**	**3500**	**10000**

Special Wavier for vehicle register under FAME-II

- ❑ Road tax
- ❑ Exemption in permit
- ❑ Toll tax
- ❑ Parking fee
- ❑ Registration charges etc.

Wavier may vary State to State as its Sate Government dependent

Demand Incentives

SL.No.	Vehicle Segment	Maximum number of vehicle to be supported	Approximately size of battery in KWH	Total approximately incentive@1000KWH For all electric vehicle and 2000/Kwh for buses& Truck	Maximum Ex-factory price to avail incentive (Lakhs)	Total support fund for DHI(Crore)
1	Registered e-2 Wheelers	1000000	2	Rs. 20000/-	Rs. 1.5	2000
2	Registered e-3 Wheelers(including Registered E-Rickshaws/E- Carts)	500000	5	Rs. 50000/-	Rs. 5 Lakhs	2500
3	e-4 Wheelers	35000	15	Rs. 150000/-	Rs. 15 Lakhs	525
4	4W Strong hybrid electric vehicle	20000	1.3	Rs. 13000/-	Rs. 15 Lakhs	26
5	e- bus	7090	250	Rs. 5000000/-	Rs. 2 Crores	3545
Total Demand Incentive						8596

Initial demand incentive

% of total cost of vehicle ↓ Max. Value Restriction

- ❑ 20% for all vehicle excluding bus
- ❑ 40% for Busses

- ❑ Rs. 10,000 /-Per Kw- Hr for all vehicle(including PHEV& SHEV)
- ❑ Rs. 20,000 /-Per Kw- Hr for Buses .

General Information

- Each OEM need to register under DHI/NAB..
- Demand Incentive would be based on battery capacity(Kw-Hr)
- For individual beneficiaries, not more than one vehicle of particular categories will be incentivized.
- No restriction for number of vehicle other than individual categories of buyer
- **3 year Vehicle Warranty including Battery**
- FAME-II certificate will be valid for one year(April to March).
- List of at least 25 vehicle dealers and service centers along with their searchable addresses/ locations and contact number to be situated at least in two states
- OEM has to ensure that eligible demand incentive should be deducted at last after all taxes.

Disbursement of demand incentives

- Disbursement Through E- Enabled frame work & Mechanism set up under DHI except bus
- OEM need to submit the reimbursement claim once in a month but not later from 120 days of the sale at dealer
- Dealer need to submit the reimbursement claim Within a period of 90days from date of sale of vehicle to their OEMs

conformity of production (COP) For 3w

SL. No.	Government Agencies	Annual Production		Renewal Time Duration
		Exceeding	Upto	
1	3W	250 per 6 months	10,000 per year	Once every year
2	3W	10,000 per year	75,000 per 6 months	Once every 6 months
3	3W	75,000 per 6 months	-	Once every 3 months

COP not applicable for E-Rickshaw

Performance & Efficiency Eligibility Criteria for Electric 2W, 3W and 4W categories

Sr. No.	Vehicle Segment	Vehicle Category*1	Vehicle Model Eligibility Criteria) (to be measured as per the standards/procedures specified in Annexure)			
			Minimum Range *2 (km)	Maximum Electric Energy Consumption*2 (kWh/100 km)	Minimum Max Speed*3 (km / hr)	Minimum Acceleration*3 (m/s2)
1.	e-2W	L1 & L2	80	Not Exceeding 7	40	0.65
2.	e-3W	E-Rickshaw**4, 5** & E-Cart ***4, 5**	80	Not Exceeding 8	NA	NA
3.	e-3W	L5	80	Not Exceeding 10	40	0.65
4.	e-4W (Passenger Carrier)	M1(Length less than 4 m)	140	Not Exceeding 15	70	1.04
		M1(Length 4m [illegible]	140	Not Exceeding 20	70	1.04
5.	e-4W(LCV/ State Carriage / Maxi Cabs etc)	N1	100	Not Exceeding 30	50	1.04

Note:

*** Eligibility criteria for e-Buses will be notified separately.**

*1 As defined in the Central Motor Vehicles Rules (CMVR), 1989.

*2 As per applicable test standard / Procedure mentioned in CMVR, 1989.

*3 Measurement shall be carried out at Gross Vehicle weight (GVW)

*4 Shall need to comply with the type approval requirements as per L5 category under CMVR, 1989.

*5 Except for E-Rickshaw/

*6 All vehicle models will have to undergo conformity of production COP test for all the eligibility parameters by recognized testing agencies at l least once a year

*7 Testing/Homologation Certificate complying with FAME-II eligibility criteria issued by designated testing agency under rule 126 of CMVR,1989

*8 Minimum technical eligibility criteria with regards to Performance and efficiency to be notified later(standard test procedure as per CMVR rule 126)

Reference → **REGD. NO. D. L.-33004/99**
CLAUSE 28 of S.O. 1300(E)
PART II—Section 3—Sub-section (ii)

PMP to promote indigenous manufacturing of electric vehicle

SL.No	Item Description		Current BCD wef 30/01/2019	Phase Manufacturing Proposal 2021-2022	
				Proposed BCD	Proposed Date of PMP
1.	SKD	Pv(HS8703) & 3W (HS8703/8704)	15%	30%	April 2020 onwards
		2W(HS8711)		25%	
2.	CKD	Pv(HS8703) 2W(HS8711) 3W (HS8703/8704) &Truck (HS8704)	10%	10%	
3.	Battery packs(HS8507) for use in the manufacture of EVs		5%	15%	April 2021 onwards
4.	Parts for use in the manufacture of EVs like • AC or DC Charger • AC or DC Motor • AC or DC Motor Controller • Power Control Unit (Inverter, AC/DC Converter, Condenser) • Energy Monitor • Contactor • Brake System for recovering • Electric Compressor		0%	15%	April 2021 onwards

Reference → F.No. 12 (31) 2017 -AEI
Release Date- 6th March 2019

Note
- **CKD** - Complete Knocked Down 2. **SKD** - Semi Knocked Down 3. **Pv** - Private Vehicle 4. **BCD**- Basic Custom Duty **5. PMP- Phase manufacturing Programme**

Note* Refer Annexure-1 for complete detail

PMP for xEV Parts for eligibility under FAME Scheme phase-II

Item Description/ Category	e-2W	e-3W	e-3W	e-4W	e-4W	e-Buses
	L1 &L2	E Rickshaw & E-Cart	L5	M1	N1	M2/M3
Power and Control Wiring harness along with connectors	A	A	A	B	B	B
MCB/Circuit breaker/electric safety device	A	A	A	C	C	C
DC-DC Convertor	B	B	B	C	C	C
Electronic Throttle	C	C	C	C	C	C
Vehicle Control Unit	C	B	C	C	C	C
Traction motor	C	B	C	E	E	E
Integrated rear axle including,motor,motor controller,transmission system & rear braking system	NA	B	C	NA	NA	NA
Traction motor Controller/inverter	C	B	C	E	E	E

Note *

1. Traction battery pack to be assembled domestically.
2. battery cells and associated thermal and battery management system may be imported.

- All other parts, components, assemblies or sub-assemblies should be domestically manufactured and assembled. CMVR notified safety components should be tested by the testing agencies notified under rule 126 of CMVR,1989
- Imported source includes direct as well as indirect import.

...ssembled and tested

Note* Refer Annexure-2 for complete detail

Definations:

NA- Not Applicable

Code	Effective date of indigenization of parts
A	w.e.f 1st April 2019
A*	w.e.f 1st July 2019
B	w.e.f 1st October 2019
C	w.e.f 1st April 2020
D	w.e.f 1st October 2020

xEV Technology Definitions

(AS PER CLAUSE 19 of S.O. 1300(E) dated 8th March 2019)

XEV Technology	Technology Definition
Advanced Batteries	Advance Battery' represents the new generation batteries such as Lithium polymer, Lithium Iron phosphate, Lithium Cobalt Oxide, Lithium Titanate, Lithium Nickel Manganese Cobalt, Lithium Manganese Oxide, Metal Hydride,Zinc Air, Sodium Air, Nickel Zinc, Lithium Air and other similar chemistry under development or under use.In addition this battery should have specific density of at least 70 Wh/kg and cycle life of at least 1000 cycle.
Electric Regenerative Braking System	An integrated vehicle braking system which provides for the conversion of vehicle kinetic energy into electrical energy during braking.
Engine 'Stop-Start' arrangement	A system by which the engine is started or stopped in a hybrid electric vehicle by vehicle control unit at operating conditions depending upon traction power required for the propulsion of the vehicle.
Off Vehicle Charging (OVC)	Rechargeable Energy Storage System **(ReESS)** in the vehicle has a provision for external charging.
Hybrid Electric Vehicle (HEV)1	A vehicle that for the purpose of mechanical propulsion draws energy from both of the following on-vehicle sources of energy/power: • A consumable fuel • Rechargeable Energy Storage System **(ReESS)**
Strong Hybrid Electric Vehicle (SHEV)	A 'Hybrid Electric Vehicle **(HEV)**' which has an engine 'Stop-Start' arrangement, 'Electric Regenerative Braking System' and a 'Motor Drive' (motor alone is capable to propel/drive the vehicle from a stationary condition).
Plug-in HEV (PHEV)/ Range Extended Electric Vehicle (REEV)	A 'Strong Hybrid Electric Vehicle **(SHEV)**' which has a provision for 'Off Vehicle Charging' **(OVC)** of 'Rechargeable Energy Storage System **(ReESS)**'.
Battery Electric Vehicle (BEV)	A vehicle which is powered exclusively by an electric motor; whose traction energy is supplied exclusively by traction battery installed in the vehicle; and has an 'Electric Regenerative Braking System'.

Annexure 1

PMP to promote indigenous manufacturing of electric vehicle

SL.No	Item Description		Current BCD wef 30/01/2019	Phase Manufacturing Proposal 2021-2022	
				Proposed BCD	Proposed Date of PMP
1	CBU	Bus (HS8702) Trucks(HS8704)	25%	50%	April 2020 onwards
2.	SKD	**Pv(HS8703) & 3W (HS8703/8704)**	**15%**	**30%**	
		2W(HS8711)		25%	
		Bus (HS8702)		25%	
		Truck (HS8704)		25%	
3.	CKD	Bus (HS8702)	**10%**	15%	
		Pv(HS8703) 2W(HS8711) **3W (HS8703/8704)**& Truck (HS8704)		**10%**	
4.	Lithium ion cells(HS85076000) for use in the manufacture of lithium ion accumulator for Evs		5%	10%	April 2021 onwards
5.	Battery packs(HS8507) for use in the manufacture of EVs		5%	15%	
6.	**Parts for use in the manufacture of EVs like** • **AC or DC Charger** • **AC or DC Motor** • **AC or DC Motor Controller** • **Power Control Unit (Inverter, AC/DC Converter, Condenser)** • **Energy Monitor** • **Contactor** • **Brake System for recovering**		**0%**	**15%**	April 2021 onwards

Note*
1. **CBU** – Complete Build-Up Unit **CKD**- Complete Knocked Down **SKD**- Semi Knocked Down **Pv** - Private Vehicle **BCD:** Basic Custom Duty
2. **PMP-** Phase manufacturing Programme

Annexure 2

Phase manufacturing Program for xEV Parts for eligibility under FAME Scheme phase-II

Item Description/ Category	e-2W	e-3W	e-3W	e-4W	e-4W	e-Buses
	L1 &L2	E-Rickshaw & E-Cart	L5	M1	N1	M2/M3
HVAC	NA	NA	NA	B	B	C
Electric Compressor	NA	NA	NA	D	D	D
Wheel Rim	A	A	A	A	A	A
Power and Control Wiring harness along with connectors	A	A	A	B	B	B
MCB/Circuit breaker/electric safety device	A	A	A	C	C	C
Ac charging inlet type2	NA	NA	NA	C	C	C
Dc charging inlet CCS2/CHAdeMO	NA	NA	NA	D	D	D
Dc charging inlet BEVC DC 001	NA	NA	NA	D	D	NA
Traction battery pack	A*	A*	A*	A*	A*	A*
Wheel rim integrated with hub motor	B	B	B	B	B	B
DC-DC Convertor	B	B	B	C	C	C
Electronic Throttle	C	C	C	C	C	C
Vehicle Control Unit	C	B	C	C	C	C
On board Charger	C	B	C	C	C	C
Traction motor	C	B	C	E	E	E
Integrated rear axle including,motor,motor controller,transmission system &rear braking system	NA	B	C	NA	NA	NA
Traction motor Controller/inverter	C	B	C	E	E	E
Instrument Panel	A*	A*	A*	A*	A*	
Windscreen Wiping System	NA	A*	A*	A	A	A
Chassis(for e2W &e3W-allowable Imported content @20%	A*	A*	A*	A	A	A

Note * Traction battery pack to be assembled domestically, for which battery cells and associated thermal and battery management system may be imported.

All other parts, components, assemblies or sub-assemblies should be domestically manufactured and assembled. CMVR notified safety components should be tested by the testing agencies notified under rule 126 of CMVR,1989

Imported source includes direct as well as indirect import.

Indigenous source implies domestically manufactured/assembled and tested

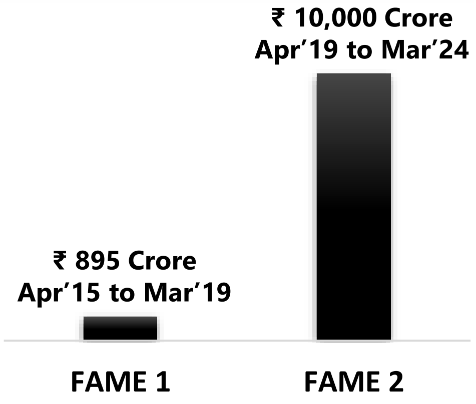
Definations:

NA- Not Applicable

Code	Effective date of indigenization of parts
A	w.e.f 1st April 2019
A*	w.e.f 1st July 2019
B	w.e.f 1st October 2019
C	w.e.f 1st April 2020
D	w.e.f 1st October 2020
E	w.e.f 1st April 2019

FAME II – Overview

FAME – Total Fund Outlay



FAME II – Total Fund Outlay Split

Component	FY'20	FY'21	FY'22	Total
Demand Incentives	822	4,587	3,187	**8,596**
Charging Infrastructure	300	400	300	**1,000**
Admin. Expenditure (publicity & IEC activities)	12	13	13	**38**
Committed expenditure of Phase I	366	-	-	**366**
Total (in INR Crore)	**1,500**	**5,000**	**3,500**	**10,000**

Vehicle Segment	Vehicle Incentive Classification	Max. no. of vehicles to be supported	Approx. size of battery	Total Approx. Incentive	Max. Ex-factory price to avail incentive	Total Fund
2 Wheeler	Registered e-2W	1,000,000	2 kWh	₹ 40,000	₹ 1.5 Lakhs	**₹ 2,000 Crores**
3 Wheeler	Registered e-3W (including e-rickshaws)	500,000	5 kWh	₹ 50,000	₹ 5 Lakhs	**₹ 2,500 Crores**
4 Wheeler	e-4W (Full electric)	35,000	15 kWh	₹ 150,000	₹ 15 Lakhs	**₹ 525 Crores**
	4W Hybrid Vehicle (PHEV, Full HEV)	20,000	1.3 kWh	₹ 13,000	₹ 15 Lakhs	**₹ 26 Crores**
Bus	e-Bus (Full electric)	7,090	250 kWh	₹ 5,000,000	₹ 2 Crores	**₹ 3,545 Crores**
	Total Demand Incentive (in INR Crore)					**₹ 8,596 Crores**

FAME II – Eligibility Criteria

Vehicle Segment	Transport Classification	Vehicle Segment	Vehicle Category (as defined by CMVR)	Vehicle Model Eligibility Criteria			
				Min. Range (km)	Max. Power Consumption (kWh/100 km)	Minimum Top-Speed (km/hr)	Min. Acceleration (m/s^2)
2 Wheeler	Private usage	e-2W	L1 & L2	80	Max. 7 kWh	40	0.65
3 Wheeler	Public Transport	e-3W	e-rickshaw & e-cart	80	Max. 8 kWh	NA	NA
	Public Transport	e-3W	L5	80	Max. 10 kWh	40	0.65
4 Wheeler	Public Transport	e-4W (Passenger Carrier)	M1 (Length < 4m)	140	Max. 15 kWh	70	1.04
	Public Transport		M1 (Length > 4m)	140	Max. 20 kWh	70	1.04
	Public Transport	e-4W (LCV/ State Carriage/ Maxi Cabs etc)	N1	100	Max. 30 kWh	50	1.04

Indian Auto Homologation	
Category L1	Means a motorcycle with maximum speed not exceeding 45 km/h and engine capacity not exceeding 50cc if fitted with thermic engine or motor power not exceeding 0.5 kilo watt if fitted with electric motor.
Category L2	Means a motorcycle other than Category L1.
Category L5	A vehicle with three wheels symmetrically arranged in relation to the longitudinal median plane with an engine cylinder capacity in the case of a thermic engine exceeding 50 cm3 or whatever the means of propulsion a maximum design speed exceeding 50 km/h.
Category M1	Means a motor vehicle used for the carriage of passengers, comprising not more than eight seats in addition to the driver's seat.
Category N1	Means a motor vehicles used for carriage of goods and having a Gross vehicle Weight not exceeding 3.5 tons.

Incentives & Subsidies on EV by State Governments

Delhi
- E2W: Rs 5,000/kWh + scrappage benefits upto Rs 5,000
- E3W: Benefits upto Rs 30,000
- In addition, No registration fees and road tax on all EVs

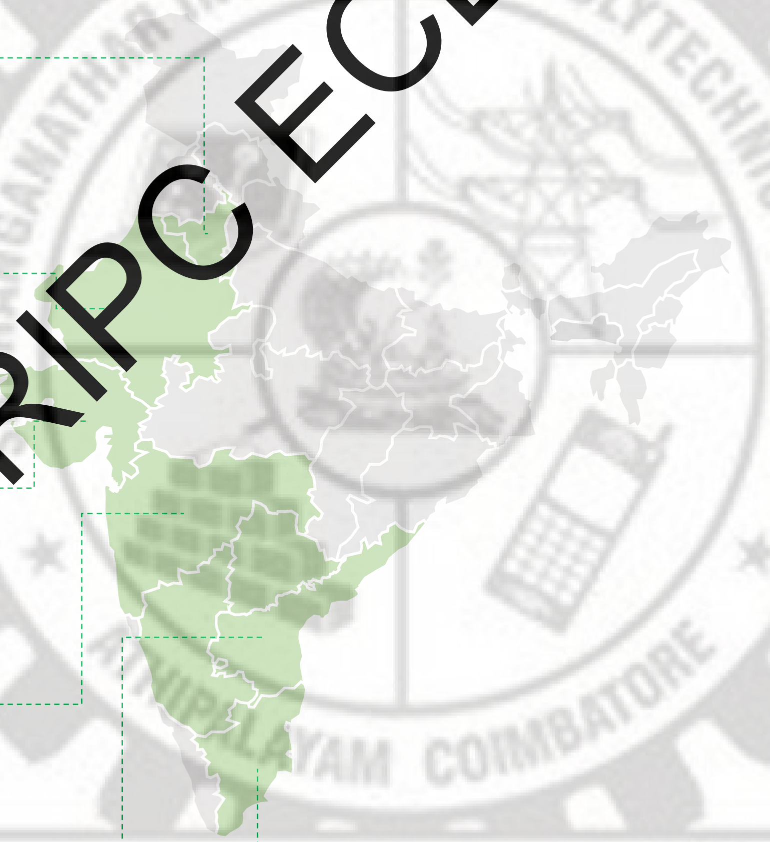
Rajasthan
- E2W: Rs 5,000 for battery capacity upto 2 kWh and upto Rs 10,000 for battery capacity more than 5 KWh
- E3W: Rs 10,000 for battery capacity less than 3 kWh and upto Rs 20,000 with more than 5 kWh battery capacity.

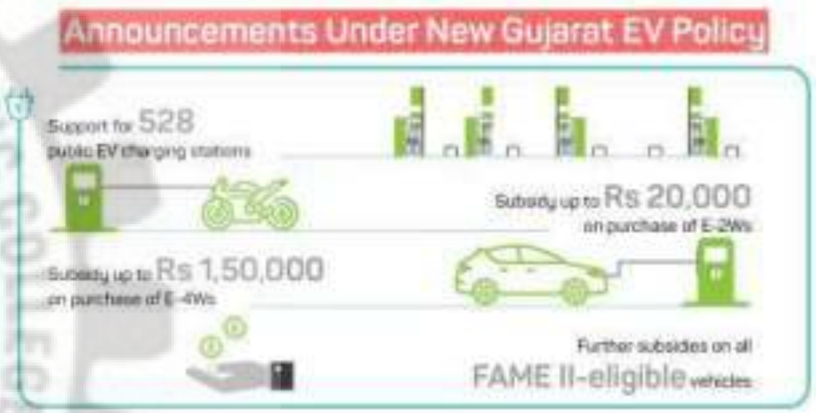
Gujarat
- E2W: Rs 20,000/kWh
- E3W: Benefits upto Rs 50,000
- In addition, No registration fees and road tax on all EVs

Maharashtra
- E2W: Rs 10,000/kWh + Rs 15,000 early bird incentive + Rs 7,000 scrappage + Rs 12,000 other incentives
- E3W: Benefits upto Rs 30,000
- In addition, No registration fees and road tax on all EVs

Karnataka, Andhra Pradesh & Telangana
- No direct subsidy to EV owners but is offering full exemption from road tax and registration fees for electric vehicles

Tamil Nadu
- 100% motor vehicle tax exemption for BEVs





ARAI AIS 038 – Electric Power Train Vehicles Construction and Functional Safety

No.	Test items	CHINA(GB 38031-2020)	EU(R100 Rev 2)	INDIA(AIS 038)
1	Mechanical integrity	Crush plate (Type 1, Type 2)	Crush plate (Type 1, Type 2)	Crush plate (Type 2)
2	Thermal shock and cycling test	Storage in the lowest and highest temperature for at least 8 hours	Storage in the lowest and highest temperature for at least 6 hours	Storage in the lowest and highest temperature for at least 6 hours
3	Warning in the event of operational failure	NA	NA	Document
4	Low-temperature protection	NA	NA	Document
5	Vibration test	X/Y/Z 3 axes, total for 39h	X/Y 2 axes, total for 3h	X/Y 2 axes, total for 3h

- *Protection against electric shock*
- *Protection against direct contact*
- *Service disconnect*
- *Marking of High Voltage Equipment*
- *Protection against indirect contact*
- *Isolation resistance requirement for the coupling system for charging*
- *Protection against excessive current*
- *Functional Safety*
- *Creepage Distance Measurements*
- *Protection against Water Effects*
- *Washing*
- *Flooding*
- *Heavy Rainstorm*

ARAI AIS 039 Electric Power Train Vehicles– Measurement of Electrical Energy

- ***Initial charge of the Rechargeable Energy Storage System (REESS)***
- ***Discharge of the Rechargeable Energy Storage System (REESS)***
- ***Application of a normal overnight charge***
- ***End of charge criteria***
- ***Application of the Cycle and Measurement of the Distance***
- ***Charge of the Rechargeable Energy Storage System (REESS):***
- ***Electric Energy Consumption Calculation***

Parameters, Units and Accuracy of Measurements

Parameter	Unit	Accuracy	Resolution
Time	s	±0.1 s	0.1 s
Distance	m	±0.1 percent	1 m
Temperature	°C	± 1 °C	1 °C
Speed	km/h	±1 percent	0.2 km/h
Mass	kg	±0.5 percent	1 kg
Energy	Wh	±0.2 percent	Class 0.2 s according to IEC 687

IEC: International Electrotechnical Commission.

Where accuracy is specified in %, it is the % of the measured value.

ARAI AIS 039 Type Approval of Vehicles Retrofitted with Hybrid Electric System

- *VEHICLE WEIGHTMENT*
- *COAST DOWN TEST*
- *VISUAL INDICATION – diagnostics tell-tale*
- *GRADEABILITY TEST*
- *MASS EMISSION TEST PROCEDURE*
- *BRAKE PERFORMANCE*
- *MEASUREMENT OF PASS BY NOISE LEVEL*
- *TRACTION MOTOR TEST*
- *EMI TEST*
- *EMC TEST*
- *VERTICAL ORIENTATION OF DIPPED BEAM – HEAD LAMP*
- *REQUIREMENTS FOR CONSTRUCTIONAL AND FUNCTIONAL SAFETY*
- *REQUIREMENTS FOR RECHARGEABLE ENERGY STORAGE SYSTEM (REESS)*
- *WIRING HARNESS / CABLES / CONNECTORS*

Key Performance Indicator - Global impact

Table 1 Stakeholder concerns regarding public charging infrastructure

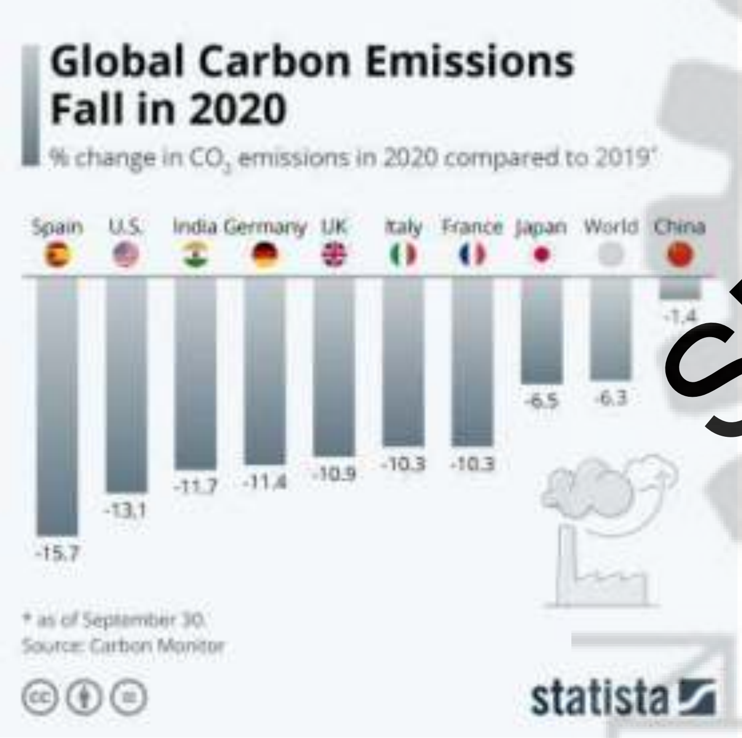
Stakeholder	Concern / Objective	Result indicators
Municipality	Achieve sustainability goals in a cost-effective way	Air quality improvements due to CI Climate change improvements due to CI Achieved cost effectiveness of CI
EV users / candidates	Stimulate electric mobility by enabling charging	Accessibility of CI Growth in amount of users of CI
Residents (non EV-users)	Optimize utilization of CI and manage parking pressure	Increased level of utilization of CI
CPOs/commercial parties in the EV chain	Facilitate a positive business case	CI-costs reduced CI-benefits increased Business case CI improved
Grid operators	Safeguard grid quality	Risks of power outage / grid-congestion reduced. Smart charging options facilitated.

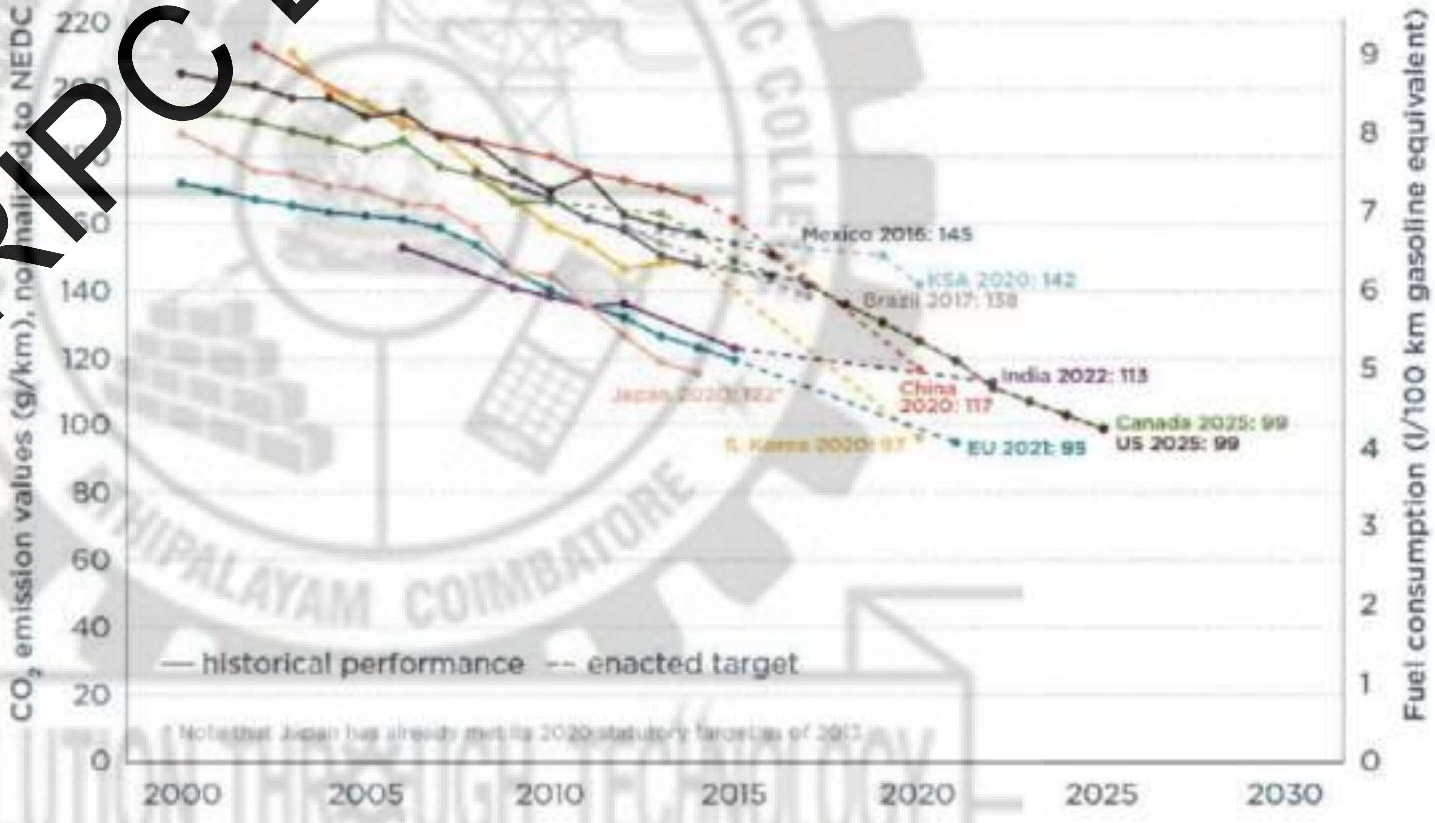
Key Performance Indicator - Global impact

Table 2 Overview of results indicators, performance indicators and intervention opportunities

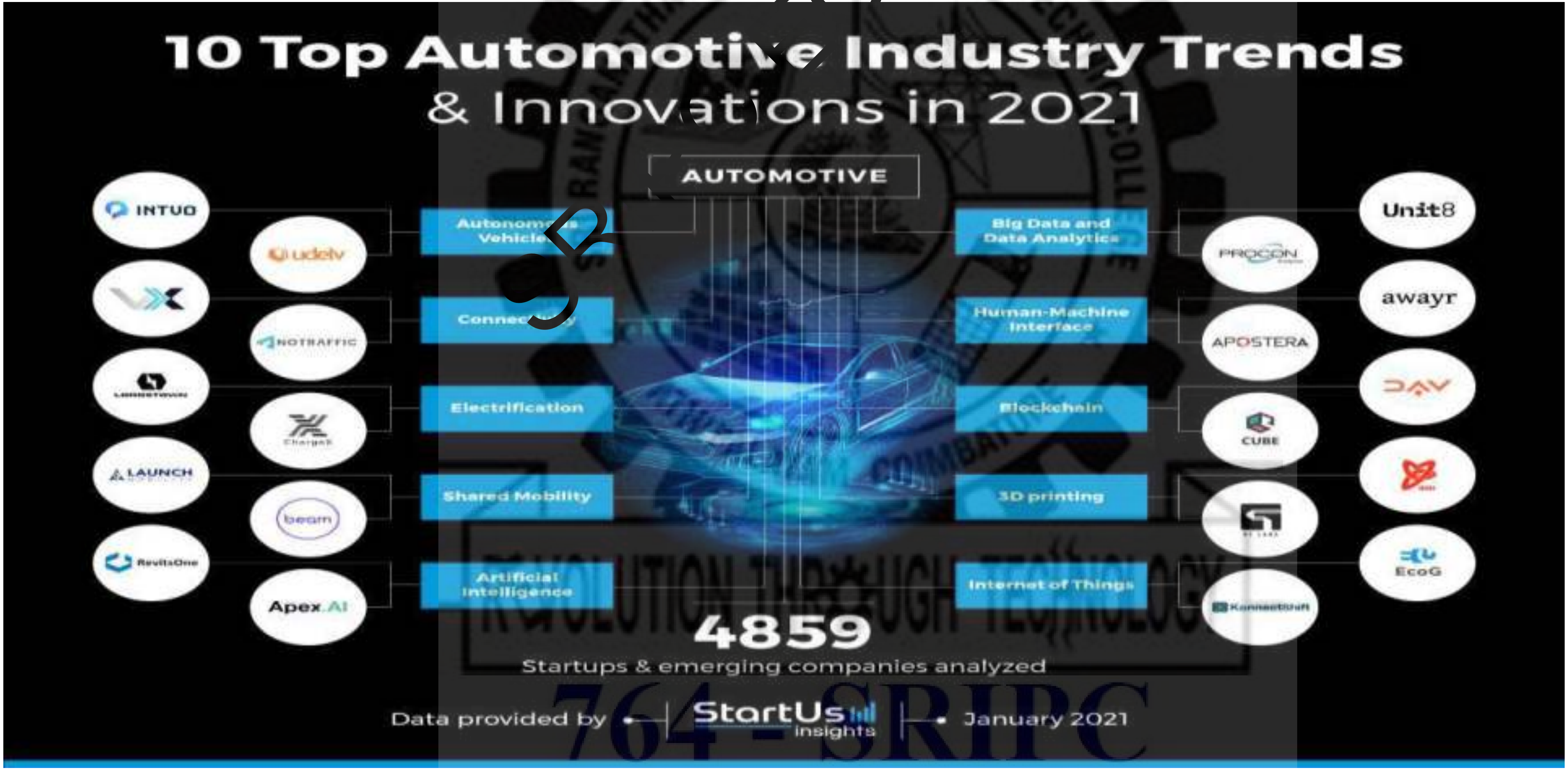
Goals	Result indicators	Performance indicators	Possible interventions
Achieve sustainability goals in a cost-effective way	• Air quality improved • CO_2 emission reduction • Costs for mitigated emission	• ∑kWh charged	• Add(/remove) charging stations • Incentives for re-parking • Purchase subsidy for EV candidates • Incentivize larger charge sessions
Stimulate electric mobility	• [illegible]ibility of CI • Growth in #users of CI	• Growth in capacity utilization • #frequent users/charging station • % long chargers • Charge time ratio (charge time/connection time)	• Add charging stations • Incentives to reduce long charging
Optimize utilization of CI and manage parking pressure	• Under-utilization CI. •	• % of low utilized stations (incl. peak times)	• Remove charging stations. • Allow regular parking during low-peak times (non-EV windows).
Enable market takeover of CI / Facilitate a positive business case	• Costs decreased • Benefits increased • Over-capacity reduced	• Costs/benefits-ratio • % of charging points with positive BC (incl. trendline) • Shelf life of CI • ∑kWh charged/∑potential kWh charged	• Lower grid costs (e.g. change in capacity, hub-satellite systems). • Reduce energy costs (e.g. taxes). • Lowering parking tariffs. • Stimulate more users, sessions and electricity charged (see above) • Enabling income streams (e.g. hourly/starting tariffs).
Safeguard grid quality	• Reduced risk of power outage.	• Peak power level • Peak shaving potential • % charging points with smart charging capability	• Enable delayed charging. • Enable different flexible power capacities. • Create incentives for smart charging.

Key Performance Indicator – Global impact

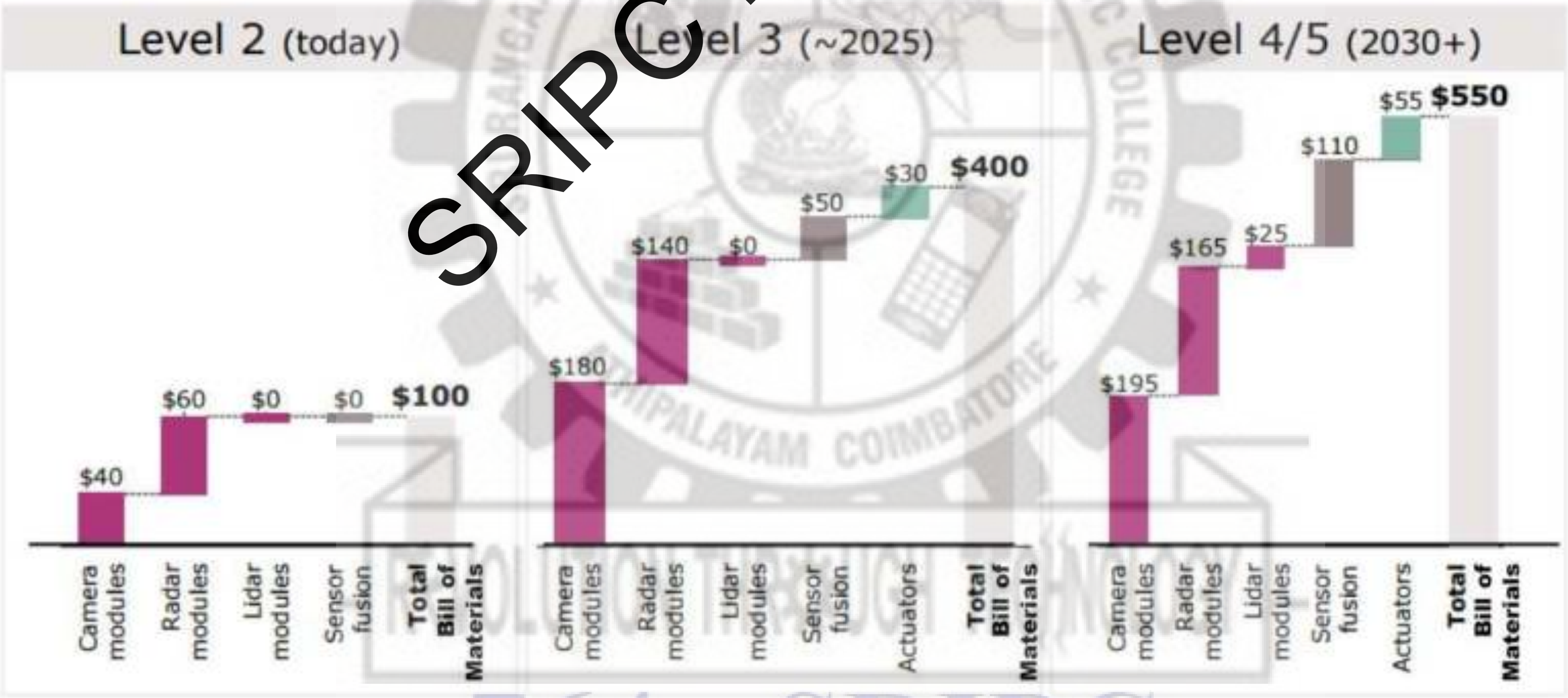




Trends and Future Developments



Semiconductor Chip content



Automotive Mega Trends

Connected Vehicle

Autonomous Vehicle

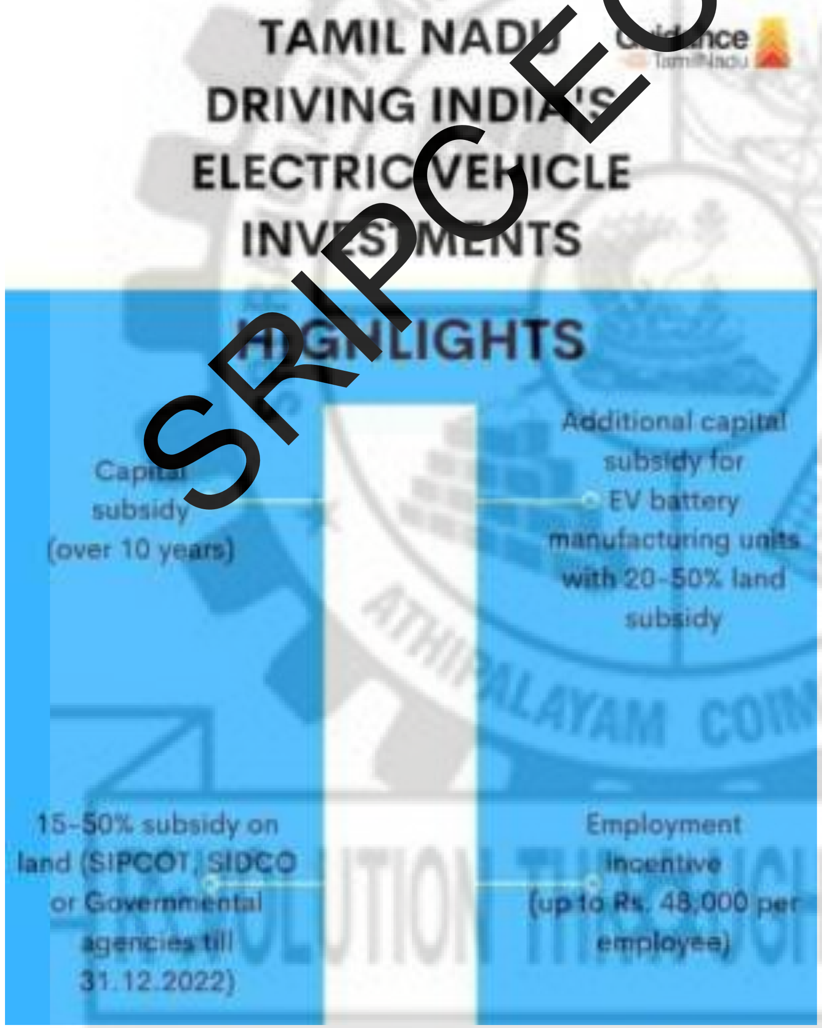
Shared Mobility

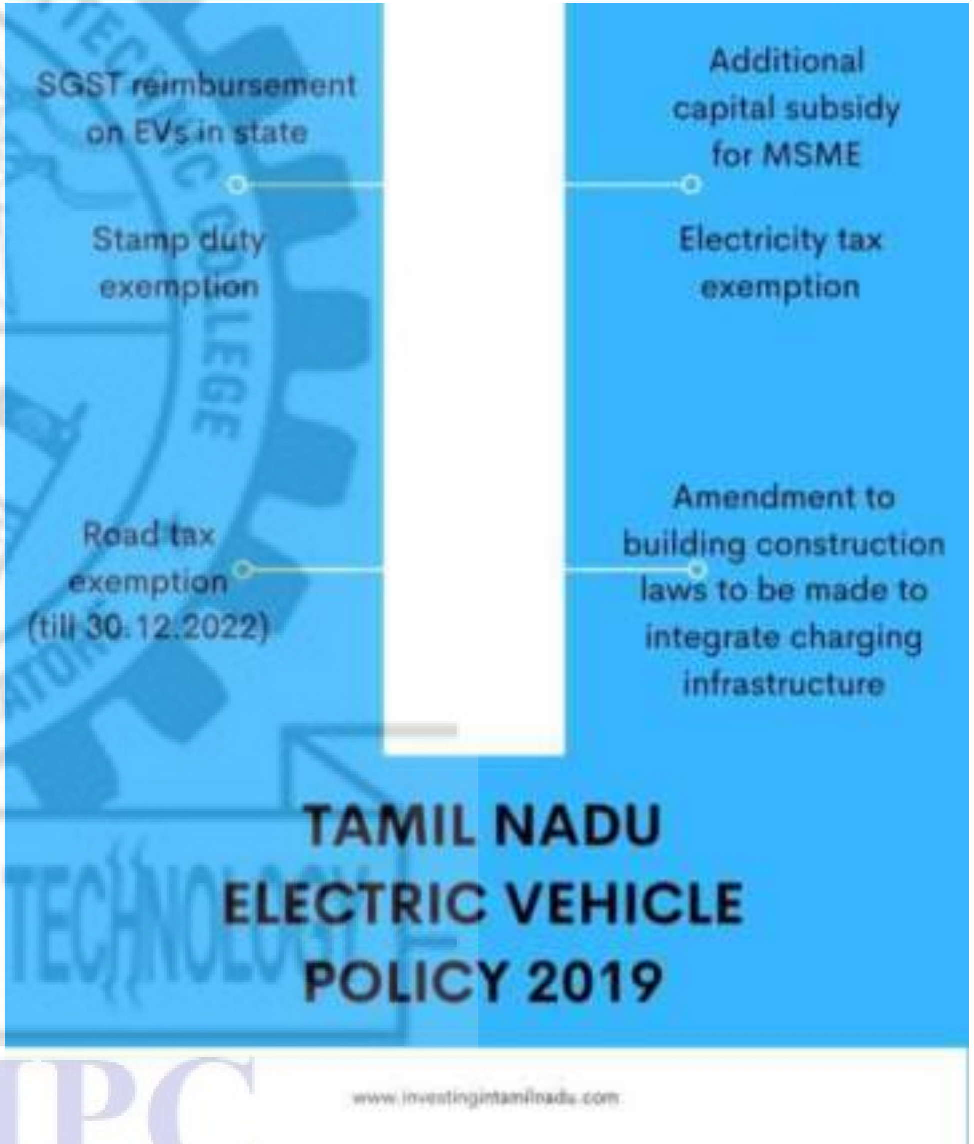
Session 6

Tamil Nadu E-Vehicle Policy 2019

- Tamil Nadu E-vehicle Policy 2019
- Vehicle Population in Tamil Nadu
- Objectives of EV Policy
- Policy Measures
- Demand side incentives
- Supply side incentives to promote EV manufacturing
- Revision of Transport Regulation of EV
- City building codes
- Capacity Building and Skilling
- Charging structure - implementing agencies
- Research & Development and Business Incubation
- Recycling Ecosystem – Battery and EVs

Tamil Nadu E-vehicle Policy 2019





Tamil Nadu E-vehicle Policy 2019

Reimbursement of SGST	100% Reimbursement to manufacturing companies till calendar year 2030 on sales but upto 100% of eligible investment
Capital Subsidy	In absence of SGST, capital subsidy of 15% will be given on eligible investments in the state over 10 years till calendar year 2025. The cost of land shall not exceed 20% of the total eligible investments.
Electricity Tax Exemption	100% till calendar year 2025 for EV manufacturing or setting up of charging infra
Stamp Duty Exemption	100% till calendar year 2022 for land (sale or lease) for EV manufacturing or setting up of charging infra
Subsidy on cost of Land	15% subsidy on the cost of land & 50% subsidy if the investment is in Southern districts. Subsidy will be available on allotments made till calendar year 2022.
Employment Incentive	Reimbursement of employer's contribution to the EPF for all new jobs created till Calendar year 2025. This incentive shall be paid for a period of one year and shall not exceed ₹48000 per employee.
Special Incentive for MSME Sector	Additional Capital Subsidy of 20% over and above of existing capital subsidy. 6% interest subvention will be provided against 3% under the existing scheme for availing loans from Tamil Nadu Industrial Investment Corporation.
Transition Support	Existing automobile manufacturing companies will be provided a onetime re-skilling allowance for every existing employee in the production line.

Vehicle Population in Tamil Nadu

YET TO HIT TOP GEAR

E-scooters have sold the most. But buyers have kept away from other vehicles. A look at what's happening in the EV sector in TN

HIGHER SALES (in TN)

Vehicle	2019	2020
IC engine*	19,68,035	14,92,185
Battery-operated	3,444	5,696

*Internal combustion vehicles include those running on diesel, petrol, LPG and/or hybrid mode

WHAT WORRIES BUYERS

- High cost and delay in government subsidy as per Faster Adoption and Manufacturing of Electric Vehicles (Fame) – II scheme
- Reluctance from financiers to offer vehicle loan
- Short-term warranty for batteries compared to IC
- Myths and misconceptions

E-VEHICLES ISSUED SUBSIDY UNDER FAME I

States	Two-wheelers	Three wheelers	Four wheelers	Total
Karnataka	[illegible]	169	377	11,301
Tamil Nadu	[illegible]	3	2	6,354
Maharashtra	5,030	82	248	5,360
Kerala	286	657	3	947

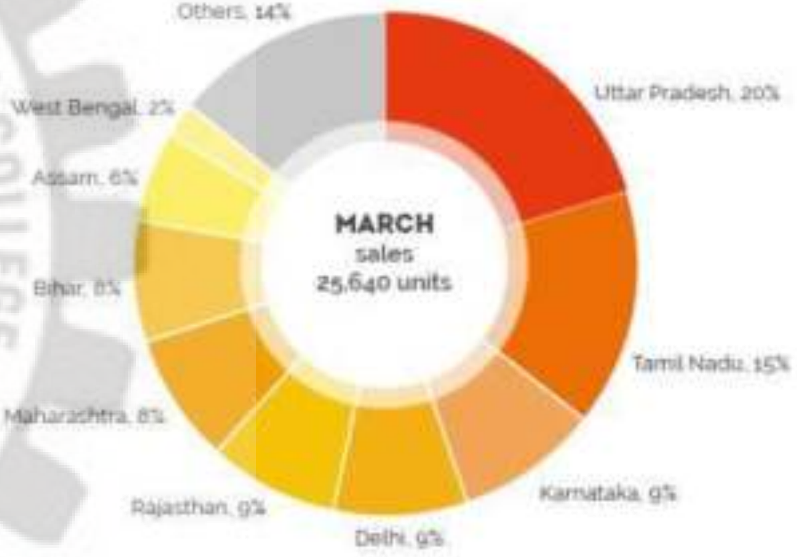
MYTH VS REALITY

Myth	Fact
E-vehicles are slow	Currently there are models which can travel up to 170kmph and can reach 80kmph in 3 to 5 seconds
Charging is cumbersome and costly	E-vehicles with in-built chargers and extension cables are sold now and all we need is a charging point. Travelling for 40-50km costs half the amount compared to IC bikes
No clarity about resale value	Some manufacturers offer buyback
Battery will drain out and commuters can get stranded	E-vehicle commute needs better planning, long-range vehicles (up to 300km) have hit the market and batteries with longer discharge time are being introduced

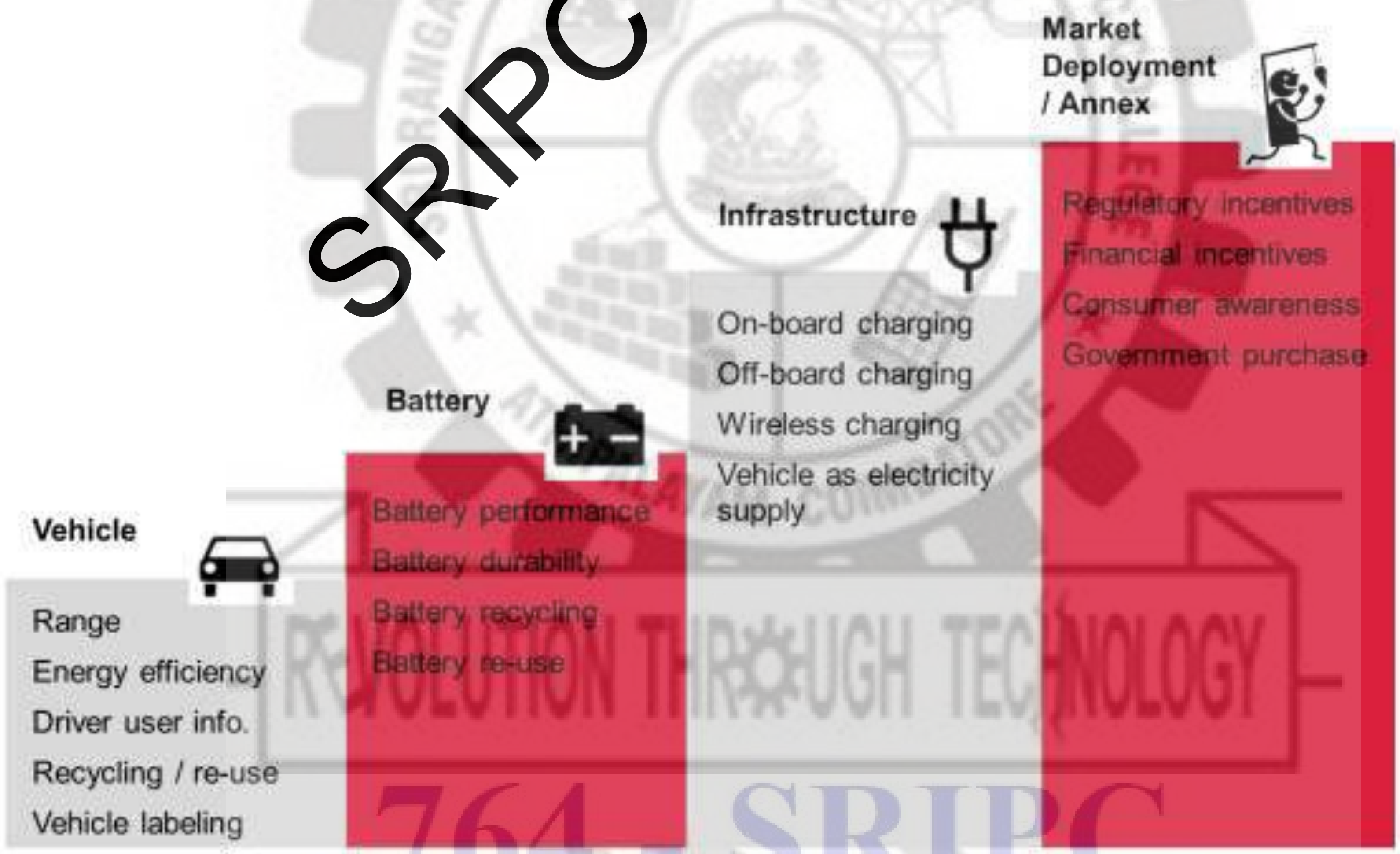
WHAT HAPPENED TO GOVT E-BUSES?

- Two buses operated on trial mode stopped
- 525 buses yet to be procured using Fame-II funds
- No progress in procuring more buses for Chennai

Fig 1.2: (State/ UT) Region wise registered EV sales March 2021



Revision of Transport Regulation of EV



Revision of Transport Regulation of EV

Revision of Transport Regulation of EV

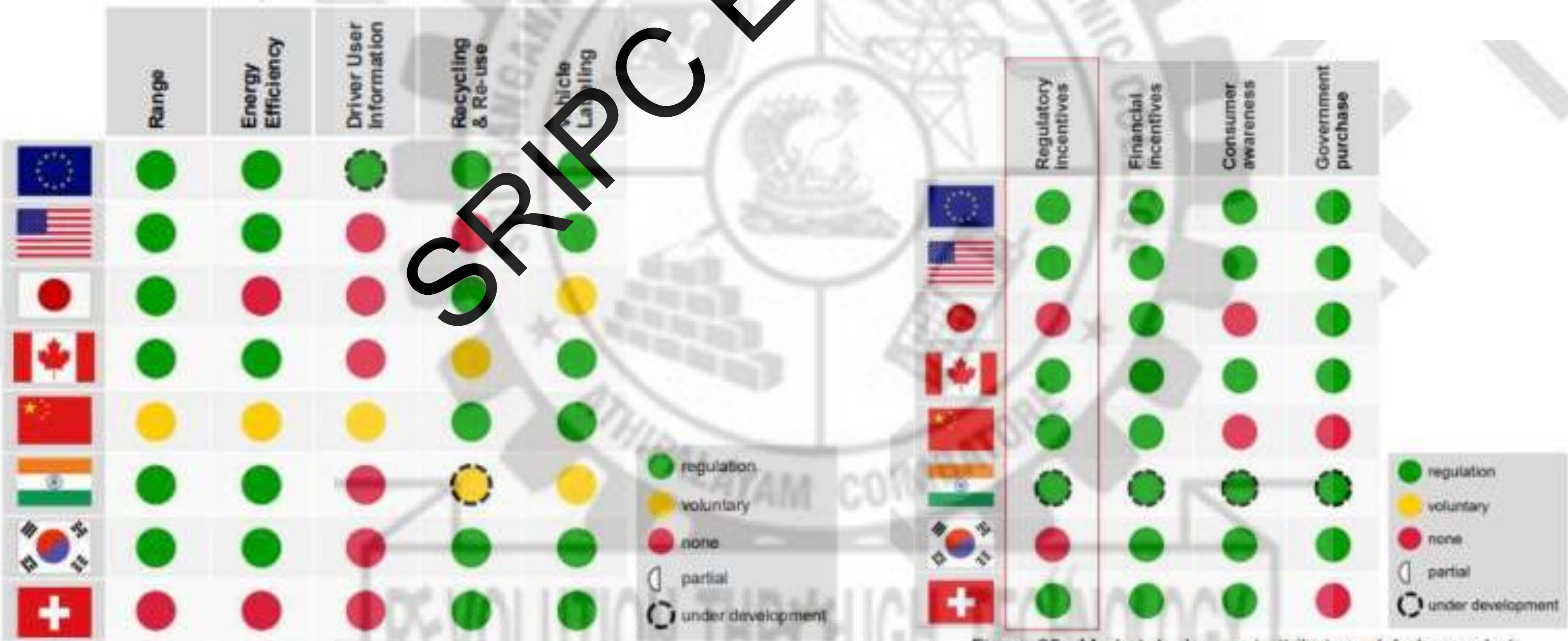


Figure 25 : Market deployment attributes, global snapshot

Revision of Transport Regulation of EV

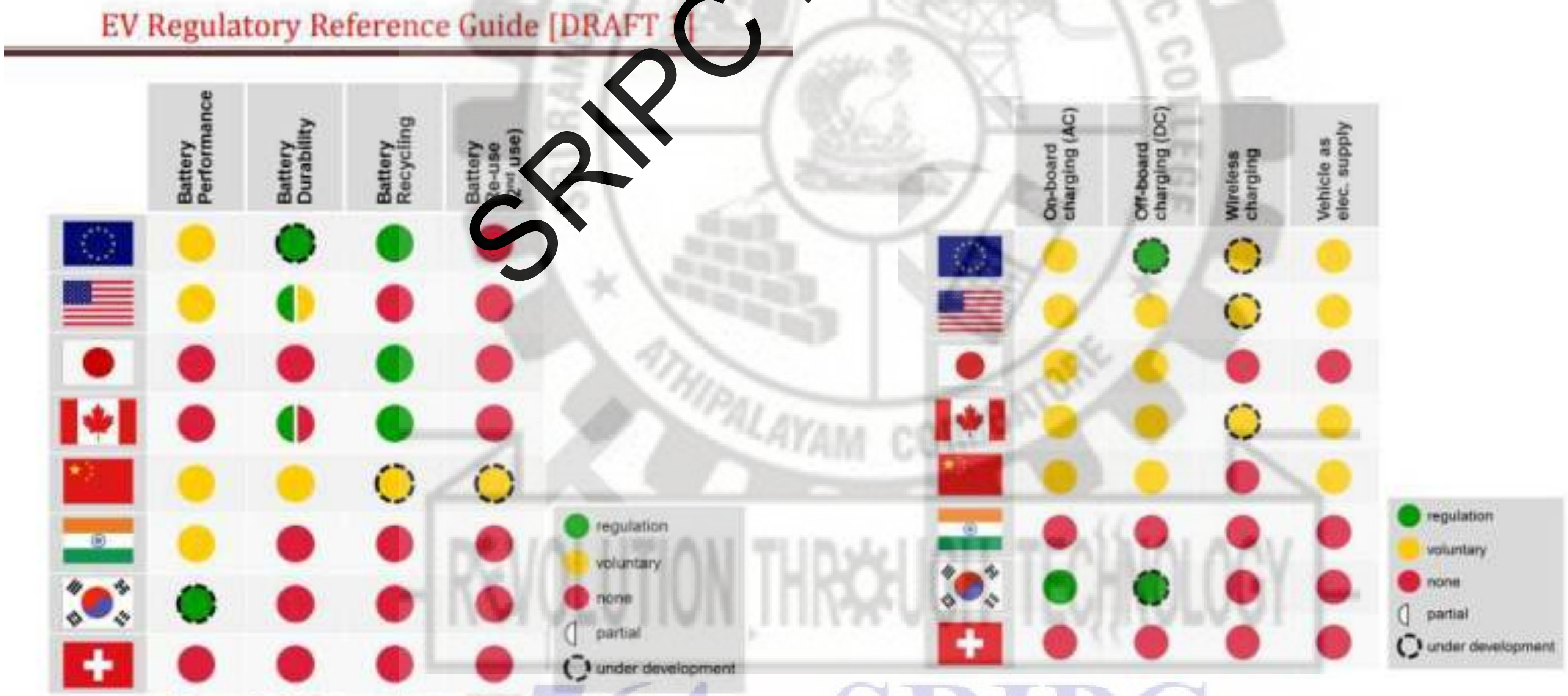
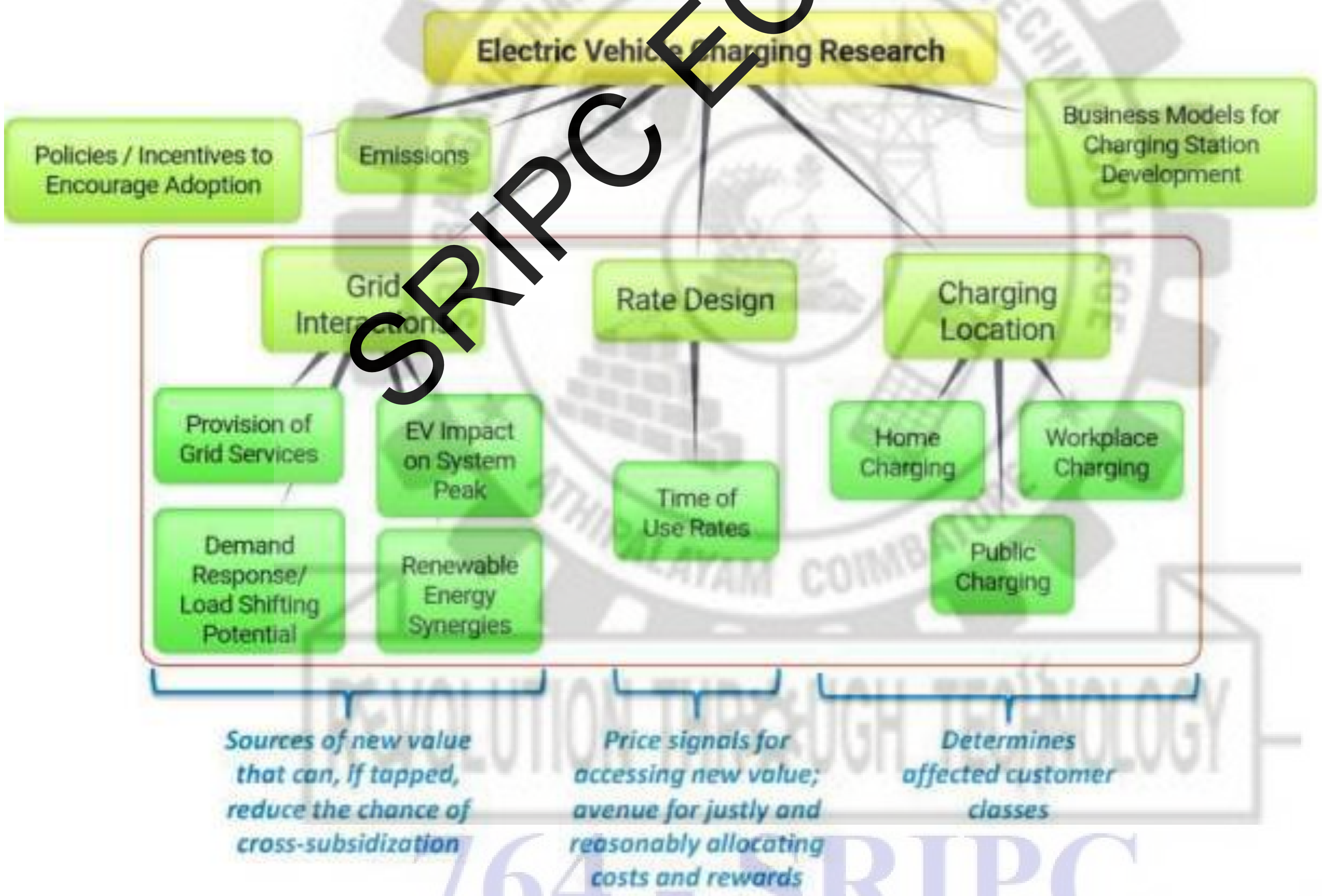


Figure 13 : Battery attributes, global snapshot

Capacity building & Skill development

Charging structure - implementing agencies



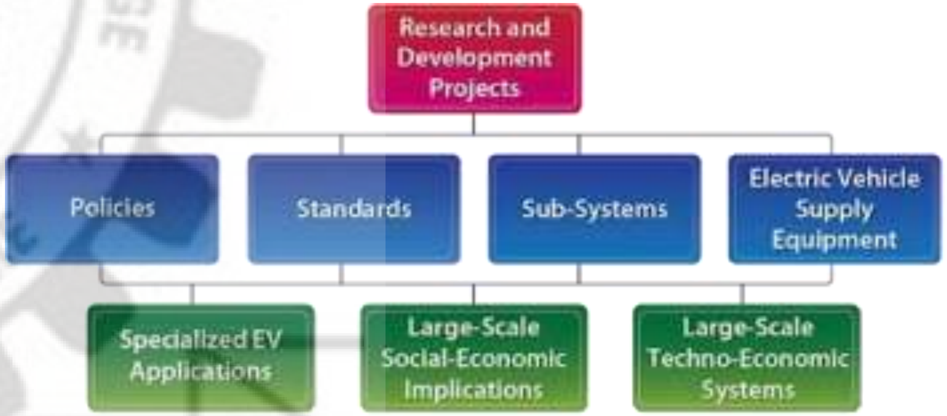
Electric vehicle Research & Development and Business Incubation

Figure 1

Ten states in India have policies on electric vehicles

Policy focus	Electric vehicle policy highlights	Andhra Pradesh	Bihar	Delhi	Karnataka	Kerala	Maharashtra	Uttarakhand	Uttar Pradesh	Tamil Nadu	Telangana
Demand	Conditional demand incentives based on segments, vehicles, and time periods		✓	✓		✓	✓	✓	✓	✓	
Supply	Lower tariff on production, subsidies, and tax benefits	✓			✓	✓	✓	✓	✓	✓	
R&D	Grants and venture funds to research organizations, incubators, and startups	✓	✓		✓	✓	✓	✓	✓	✓	✓
Charging ecosystem	Supporting public infrastructure by providing land, subsidy, and other support	✓	✓	✓	✓	✓		✓	✓	✓	✓
Technology	Financial support for growth of newer technologies in vehicle and charging space	✓		✓					✓		

Source: Kearney analysis

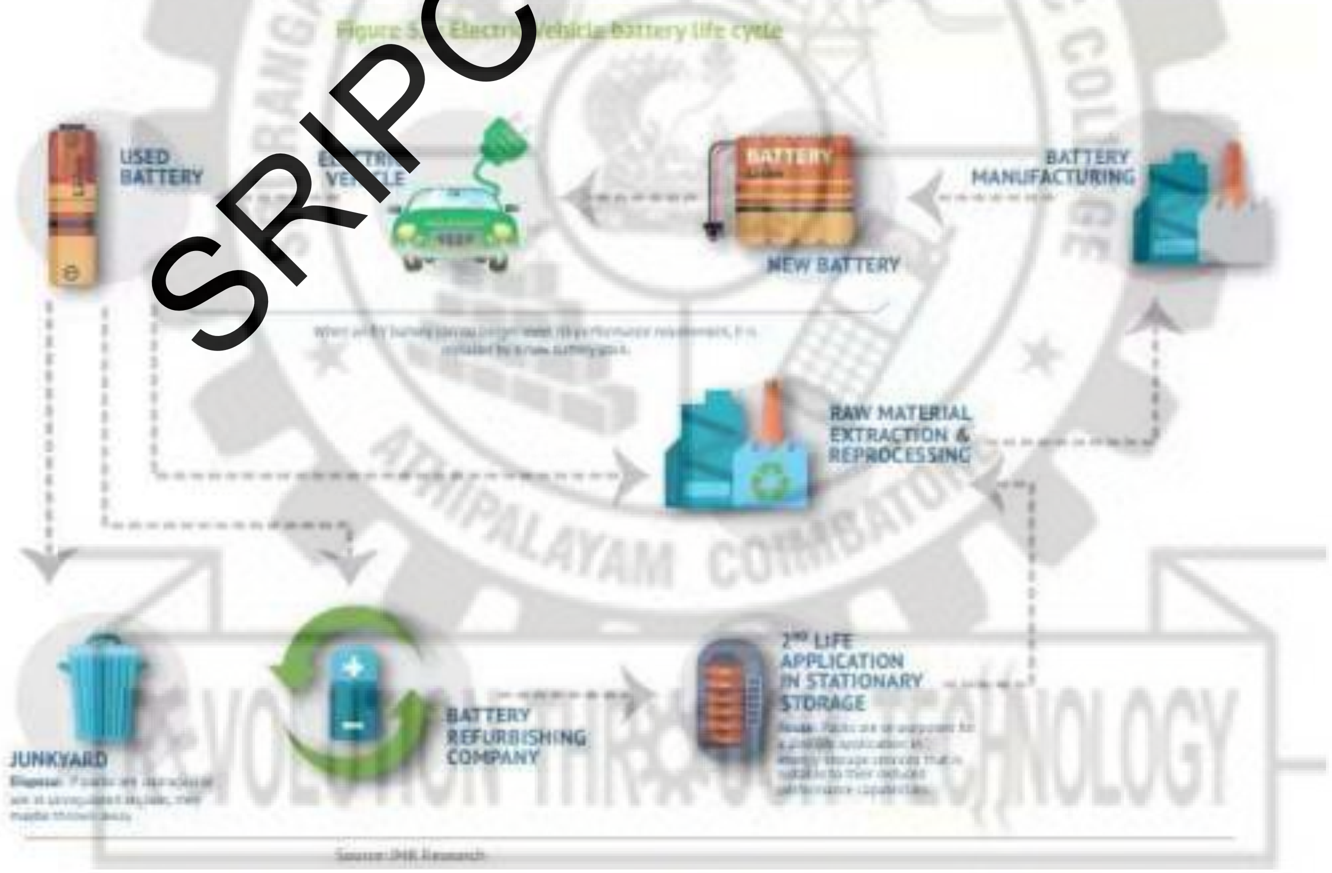


20 Companies to Recycle Li-Ion Cells in 2018

Japan – 3
South Korea - 2
Germany – 2
China – 4
Belgium – 1
America – 4
Switzerland – 1
France – 2
Australia - 1

- Estimation: 5-7% of li-ion cells produce worldwide are recycled.
- Recycling is concentrated in Far East and Europe but many companies are investing in R&D for entering the business.

Recycling Ecosystem – Battery and EVs



Battery Recycling Process

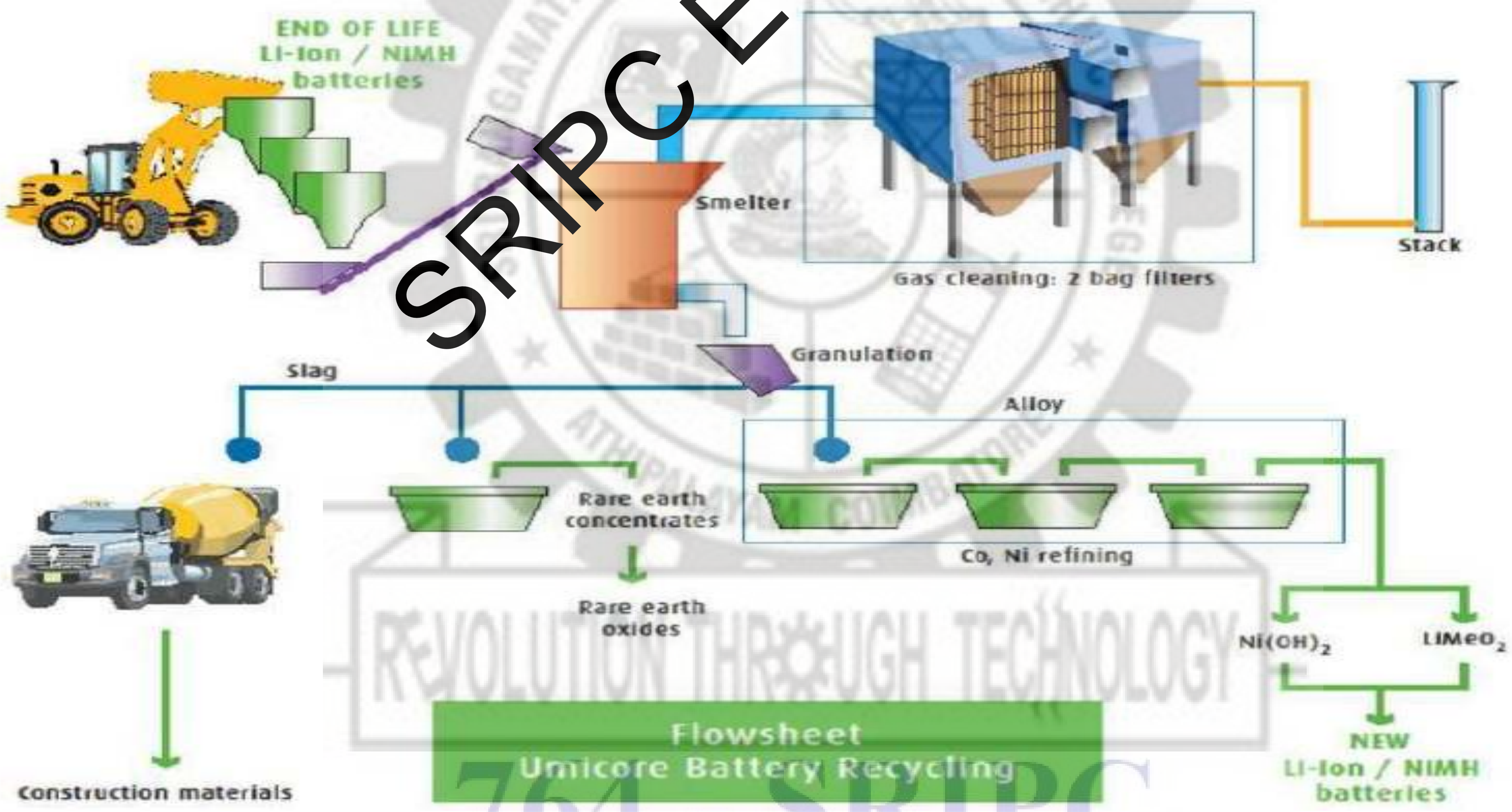
Available processes recover different products

	Pyrometallurgical	Hydrometallurgical	Physical
Temperature	High	Low	Low
Materials recovered	Co, Ni, Cu (Li and Al to slag)	Metals or salts, Li_2CO_3 or LiOH	Cathode, anode, electrolyte, metals
Feed requirements	None	Separation desirable	Single chemistry required
Comments	New chemistries yield reduced product value	New chemistries yield reduced product value	Recovers potentially high-value materials; Could implement on home scrap

Battery Recycling Process

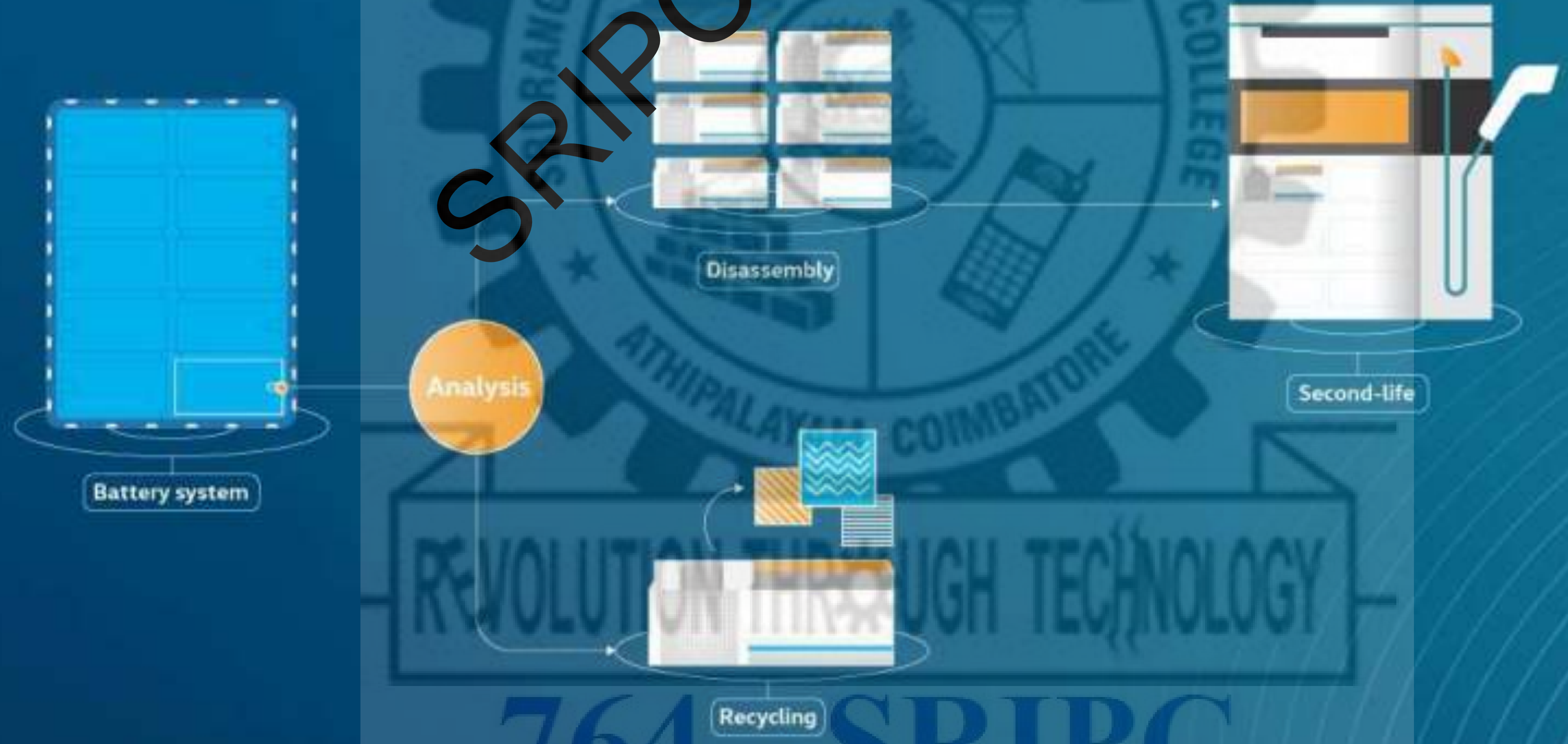
Battery Recycling process

Figure 3 : Umicore recycling process



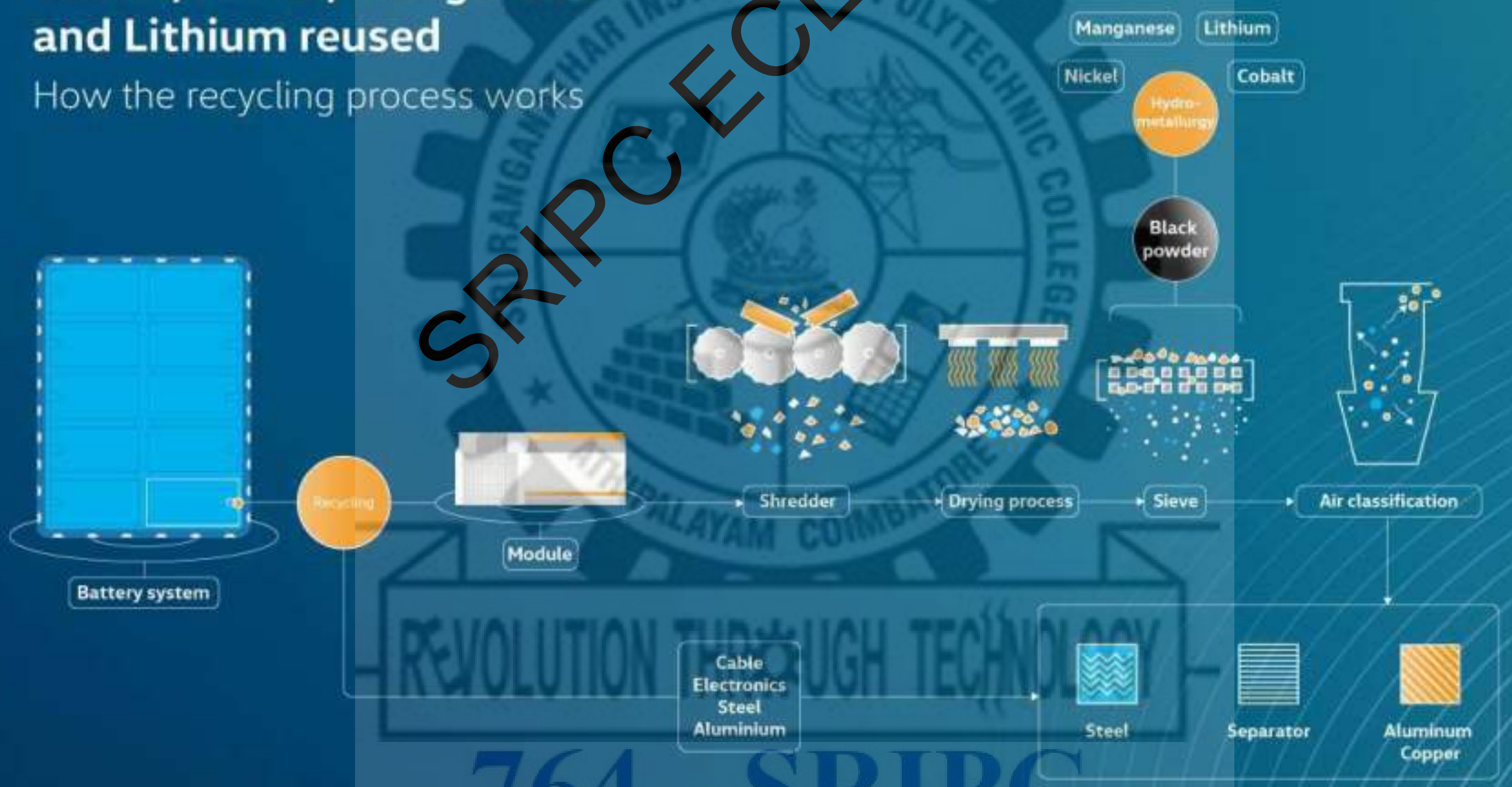
Each battery is used multiple times

They either receive a "second-life" or will be recycled



Cobalt, Nickel, Manganese and Lithium reused

How the recycling process works

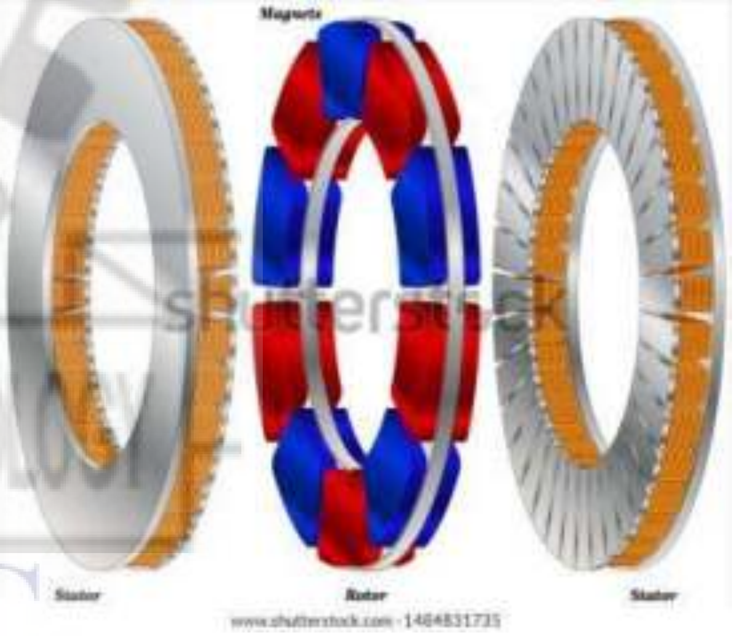


In-wheel Motor

PMSM Motor types

Radial Flux Motor

Axial Flux Motor

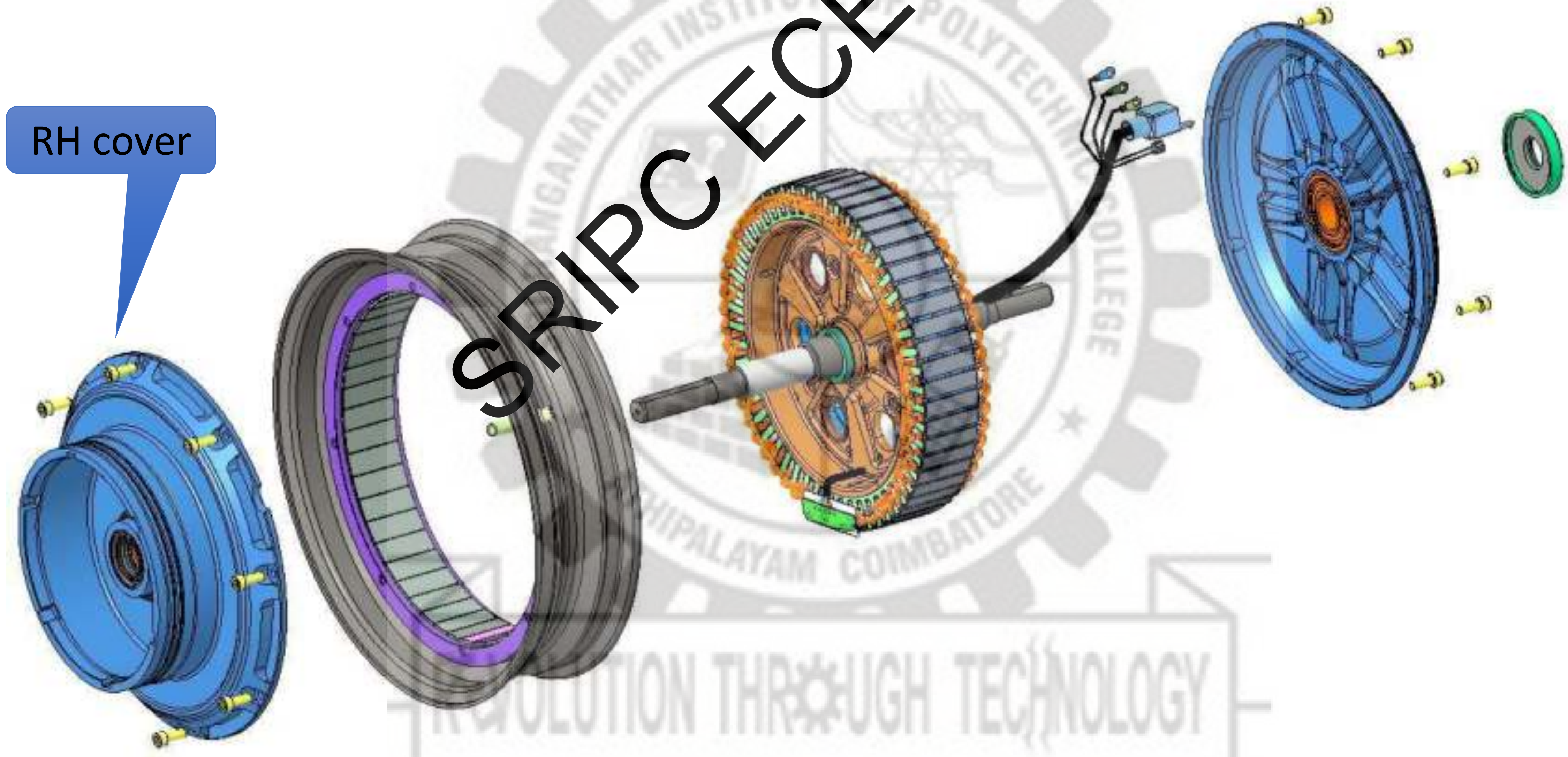


Electric scooter – mid mount motor


MOTOR SPECS
MOTOR TYPE | BLDC
CAN ENABLED | YES
MAX TORQUE | 14Nm
BASIC SPECS
WEIGHT | 90kg
POWER | 3 kW CONTINUOUS
5 kW PEAK
RANGE | 60 km
0-60 | 12.11 s
0-40 | 7.3 s
BATTERY TYPE | LITHIUM ION
COMMUNICATION | CAN ENABLED
VD SPECS
TYRE SIZE | 90/90 -12
SUSPENSION SET UP FRONT | TWIN TELESCOPIC
REAR | MONOSHOCK
FRONT WEIGHT BALANCE RATIO | 49:51
ON BOARD SENSORS
3 AXIS ACCELEROMETER
GYROSCOPE
GPS
MAGNETOMETER
AMBIENT LIGHT SENSOR
BATTERY SPECS
BATTERY VOLTAGE | 51.1V
BATTERY CAPACITY | 42.4 Ah
WATERPROOF LEVEL | IP 67
TRANSMISSION
STEPS | DOUBLE STEP REDUCTION
TYPE | BELT
BELT TYPE | CARBON BELT DRIVE
RATIO | 7.4
TORQUE AT WHEEL MAX Nm | 103.6
DISPLAY SPECS
TYPE | PROJECTIVE CAPACITIVE TOUCH
WATERPROOF LEVEL | IP 65

Electric scooter – Hub motor

Hub motor – Exploded view



Electric Bike – mid mount motor

Key specifications	Ola S1	Ola S1 Pro	Ather 450x	Bajaj Chetak	TVS iQube	Honda Activa 125
Max Speed (Kmph)	90	[illegible]	80	70	78	94
0 to 40 kmph (sec)	3.6	3.0	3.3	NA	4.2	4.1
0 to 60 kmph (sec)	7.0	5.0	-	-	-	8.7
Peak power (kw)	[illegible]	9	6	4	4	6.1
Continuos power (kw)	6	6	3	4	3	NA
Range in km (ARAI)	121	181	116	95	75	300
Fast charging (km in mins)	75 km in mins	75 km in mins	15km in mins	No	No	NA
Battery capacity (kwh)	3.0	4.0	2.9	3.0	2.3	NA
Range/kwh	**41**	**46**	**40**	**32**	**33**	**NA**
Weight (kg)	121	125	108	NA	118	111
Length (mm)	1,859	1,859	1,800	1,970	1,805	1850
Boot space (L)	36	36	22	NA	NA	18
Wheelbase (mm)	1,359	1,359	1,278	NA	1,301	1260
Tyres (front) width and rim diameter	110/12	110/12	90/12	90/12	90/12	90/12
Tyres (rear)	110/12	110/12	90/12	90/12	90/12	90/10
Ground clearance (mm)	165	165	160	NA	157	169

Electric 3 wheeler – mid mount motor

Electric Boat

Electric Airplane

Electric 2-Wheeler vs Conventional 2-Wheeler

HERO ELECTRIC

MODEL: Photon HX
OLD PRICE: ₹79,940
NEW PRICE: ₹71,440
CHANGE: 12%

MODEL: Optima HX
(single battery)
OLD PRICE: ₹61,640
NEW PRICE: ₹53,600
CHANGE: 15%

MODEL: NYX E5
(single battery)
OLD PRICE: ₹68,640
NEW PRICE: ₹61,000
CHANGE: 13%

MODEL: Optima ER
(double battery)
OLD PRICE: ₹78,640
NEW PRICE: ₹58,980
CHANGE: 33%

MODEL: NYX ER
(Double battery)
OLD PRICE: ₹83,940
NEW PRICE: ₹62,954
CHANGE: 33%

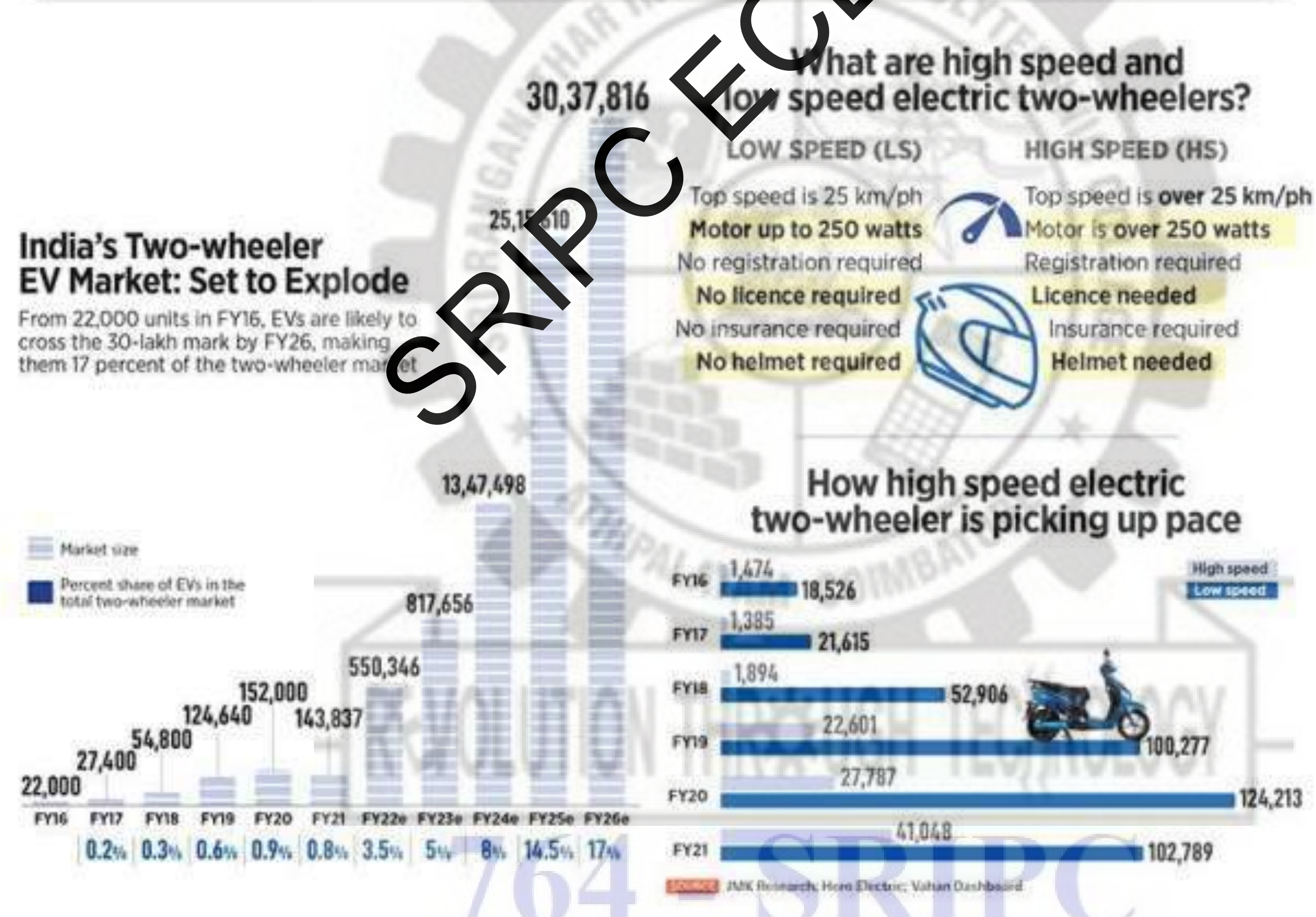
MODEL: NYX HX
(Triple battery)
OLD PRICE: ₹113,115
NEW PRICE: ₹85,136
CHANGE: 33%

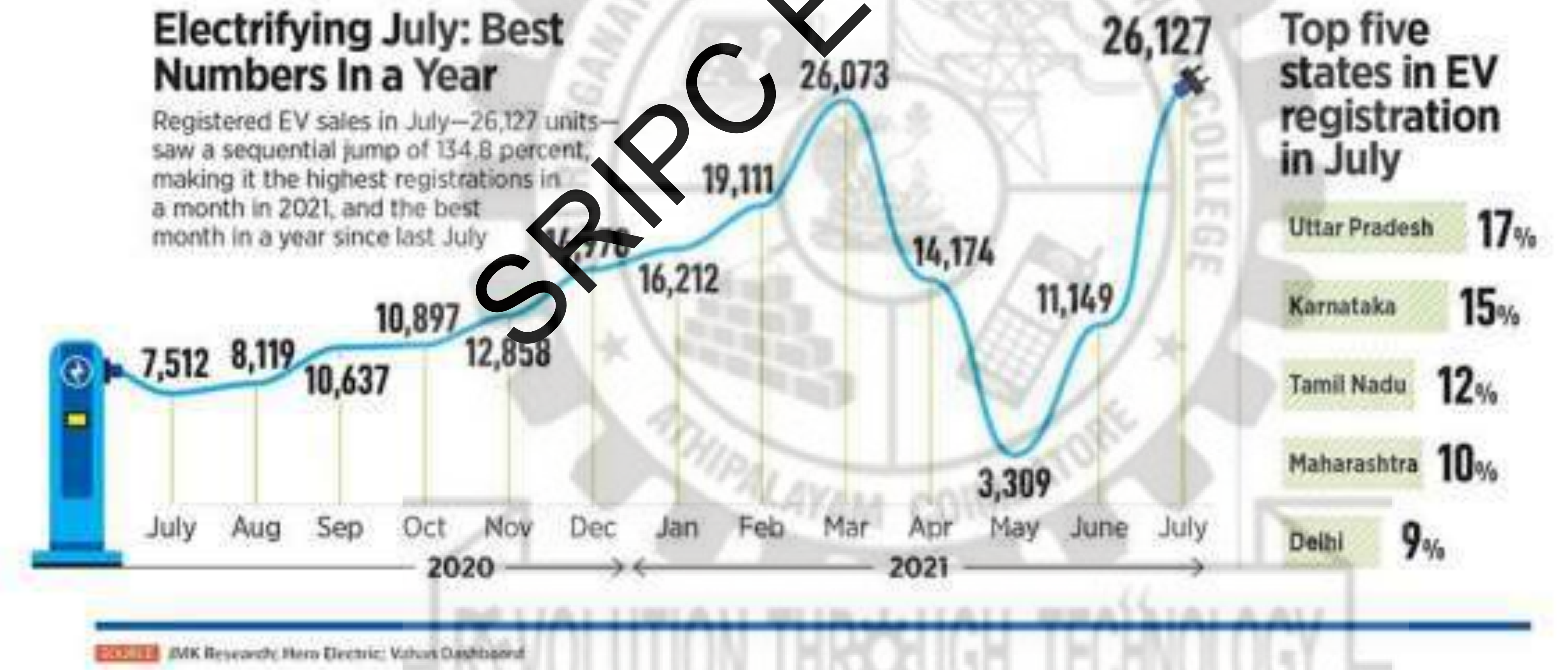
TVS

MODEL: iQube
OLD PRICE: ₹112,027
NEW PRICE: ₹100,777
CHANGE: 10%

SOURCE JMK Research; Hero Electric; Vahan Dashboard

India E-2Wheeler Market Outlook




Electrifying July: Best Numbers In a Year
Registered EV sales in July—26,127 units—saw a sequential jump of 134.8 percent, making it the highest registrations in a month in 2021, and the best month in a year since last July
7,512
8,119
10,637
10,897
12,858
16,212
19,111
26,073
14,174
3,309
11,149
26,127
July
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
June
July
2020
2021
Top five states in EV registration in July
Uttar Pradesh 17%
Karnataka 15%
Tamil Nadu 12%
Maharashtra 10%
Delhi 9%
JMK Research; Hero Electric; Vahan Dashboard

PLI Schemes for Automotive sector – Overview

Relevant PLI Schemes

- Automotive
- Technical Textiles (Mobile Textiles)
- ACC to cover battery cells
- Speciality steel

Automotive PLI

Objective

- Boost domestic manufacturing of Advanced Automotive Technology products
- Overcoming cost disabilities
- Creating economies of scale and building a robust supply chain

Target Segment

- **Existing automotive companies** meeting threshold criteria of Global Group Revenue and Global Investment in Fixed Assets
- Scheme is open for **new non-automotive investors** as well

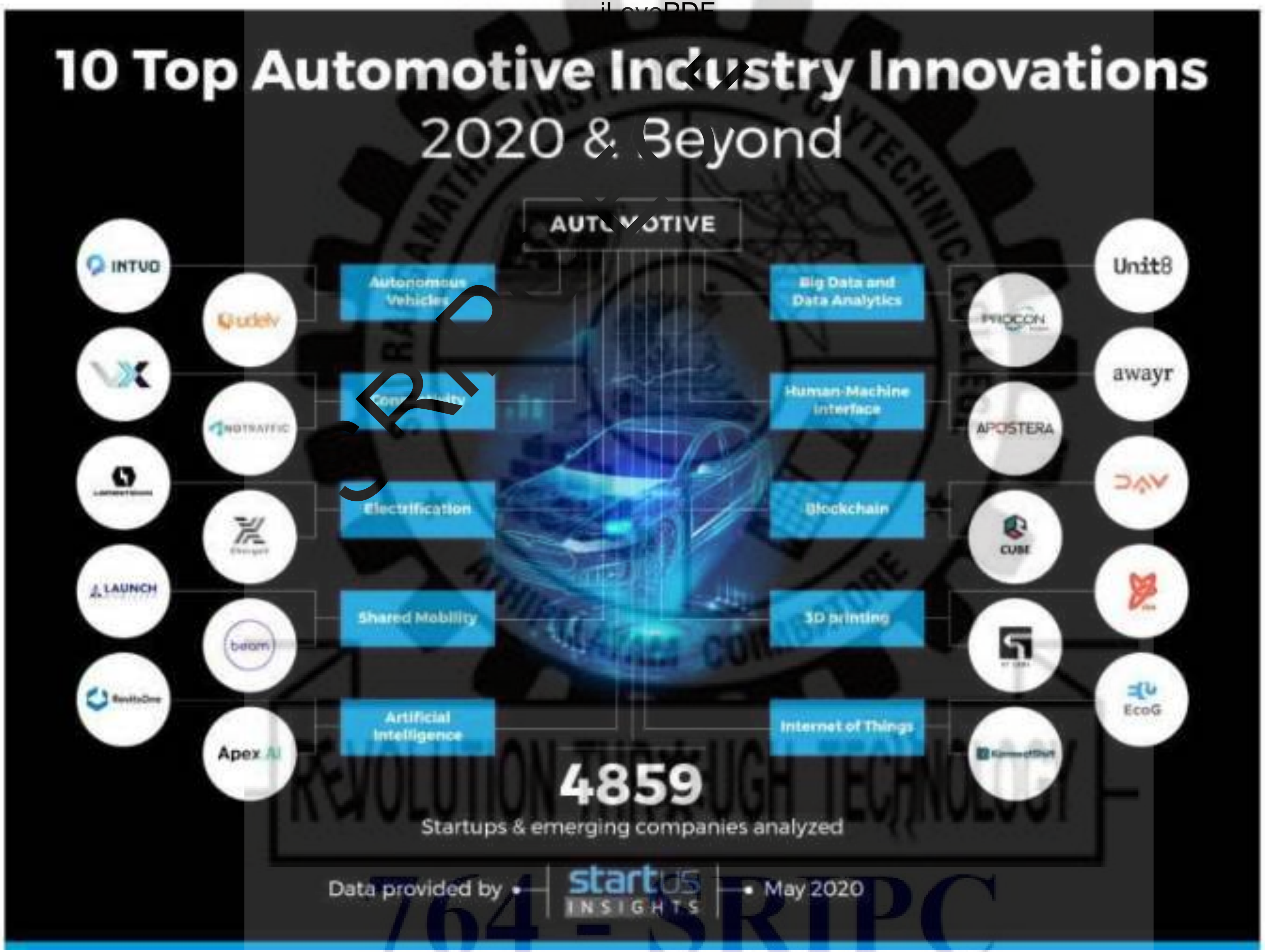
Scheme Components

- Incentivizing incremental sales of
  - Automobile
  - Auto Components

  related to Advanced Automotive Technology

Scheme Outlay

INR 25,938 crore for the scheme for Vehicle OEMs and Components Manufacturers


10 Top Automotive Industry Innovations
2020 & Beyond
Autonomous Vehicles
Electrification
Shared Mobility
Artificial Intelligence
Big Data and Data Analytics
Human-Machine Interface
Blockchain
3D printing
Internet of Things
INTUO
udelv
LAUNCH
beam
Apex AI
Unit8
PROCON
awayr
APOSTERA
CUBE
EcoG
4859
Startups & emerging companies analyzed
Data provided by
startus INSIGHTS
May 2020


Top 10 Automotive Industry Trends
2020 & Beyond
Autonomous Vehicles
21 %
Connectivity
18 %
Shared Mobility
14 %
Artificial Intelligence
7 %
Electrification
17 %
Big Data & Data Analytics
6 %
Human Machine Interface
5 %
Internet Of Things
4 %
3D Printing
4 %
Blockchain
4 %
This tree map illustrates the top 10 innovation trends & their impact on the automotive industry
startus INSIGHTS
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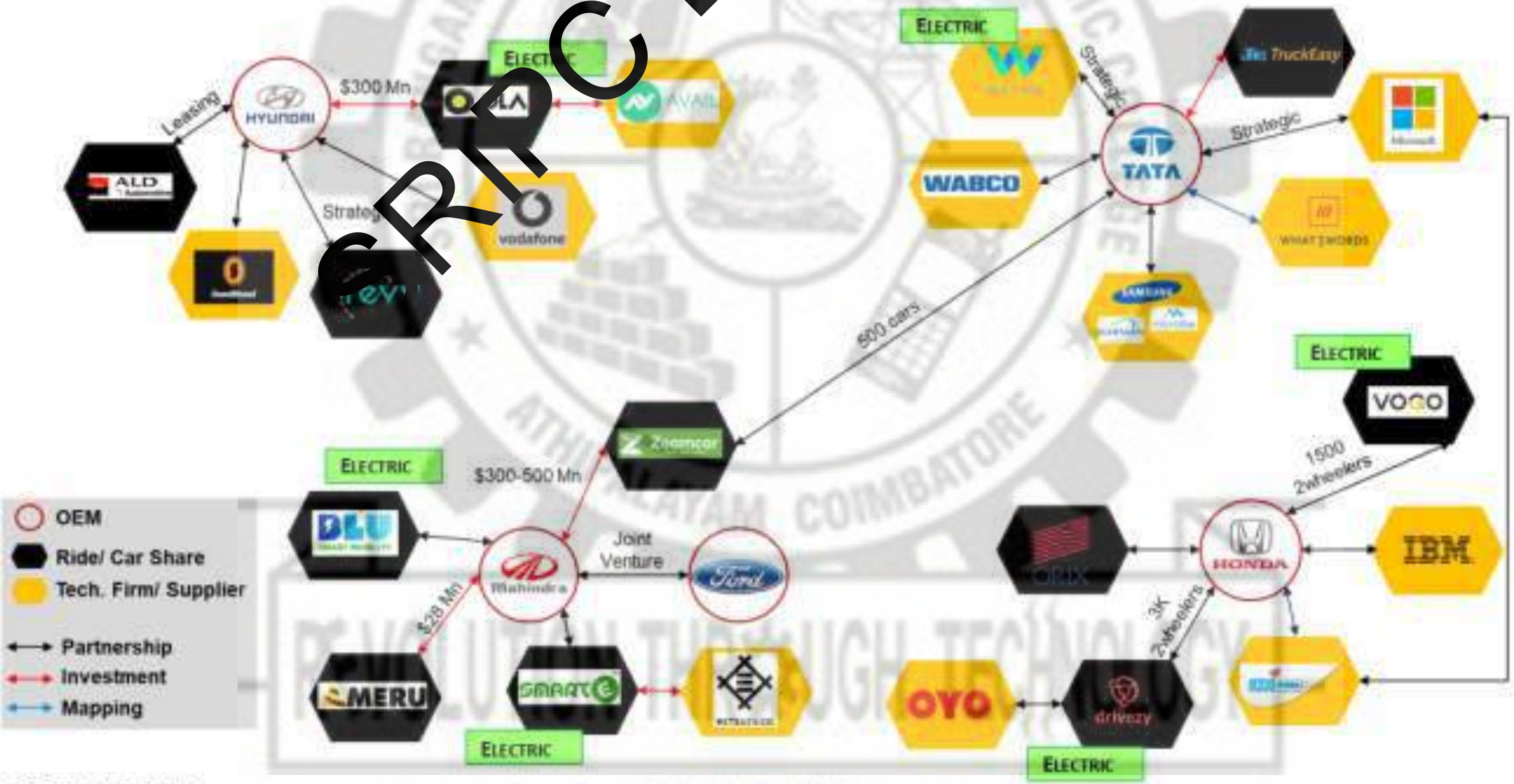
May 2020

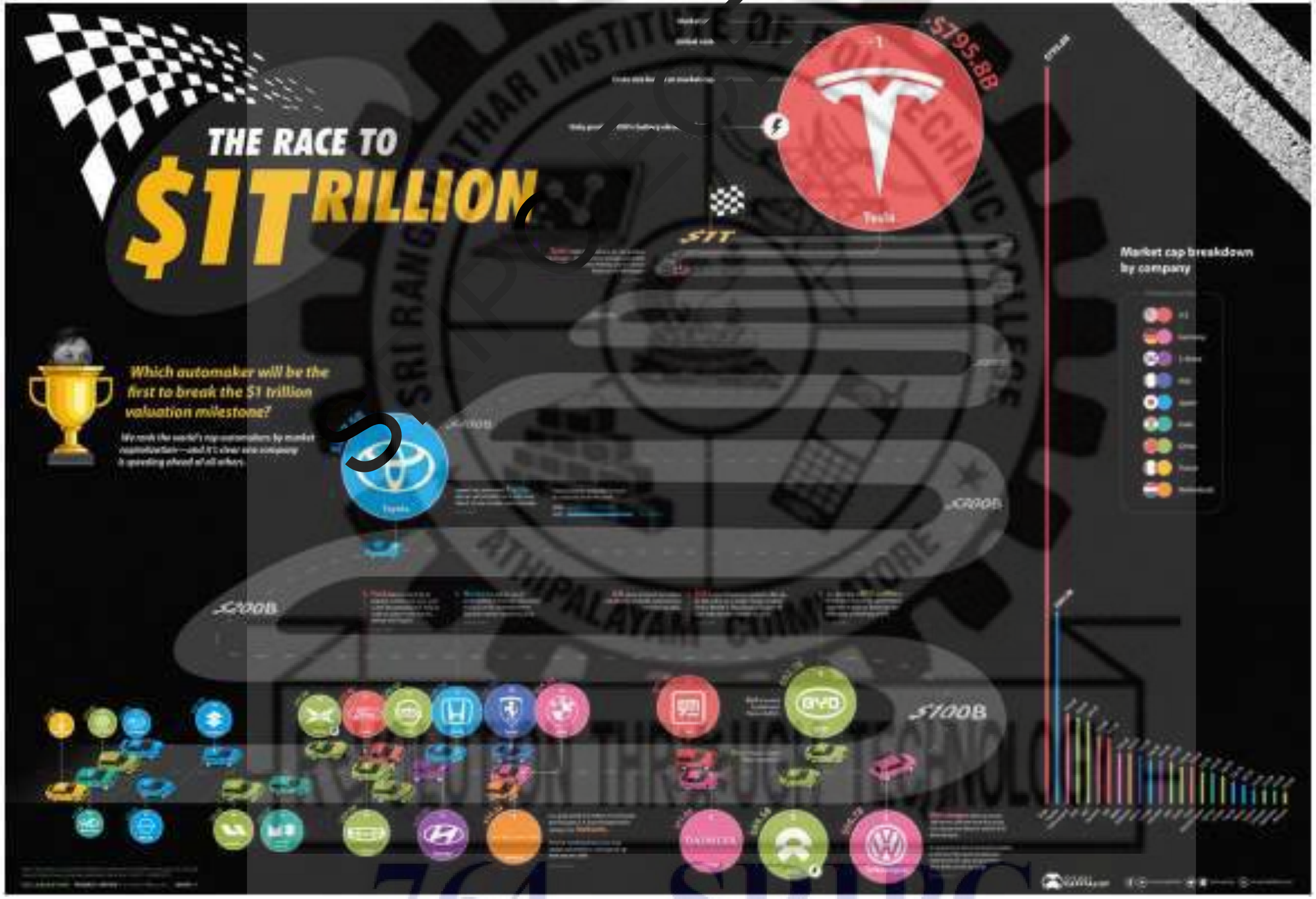
Indian shared mobility ecosystem is an *'interconnected'* network



PwC Source : PwC research & analysis

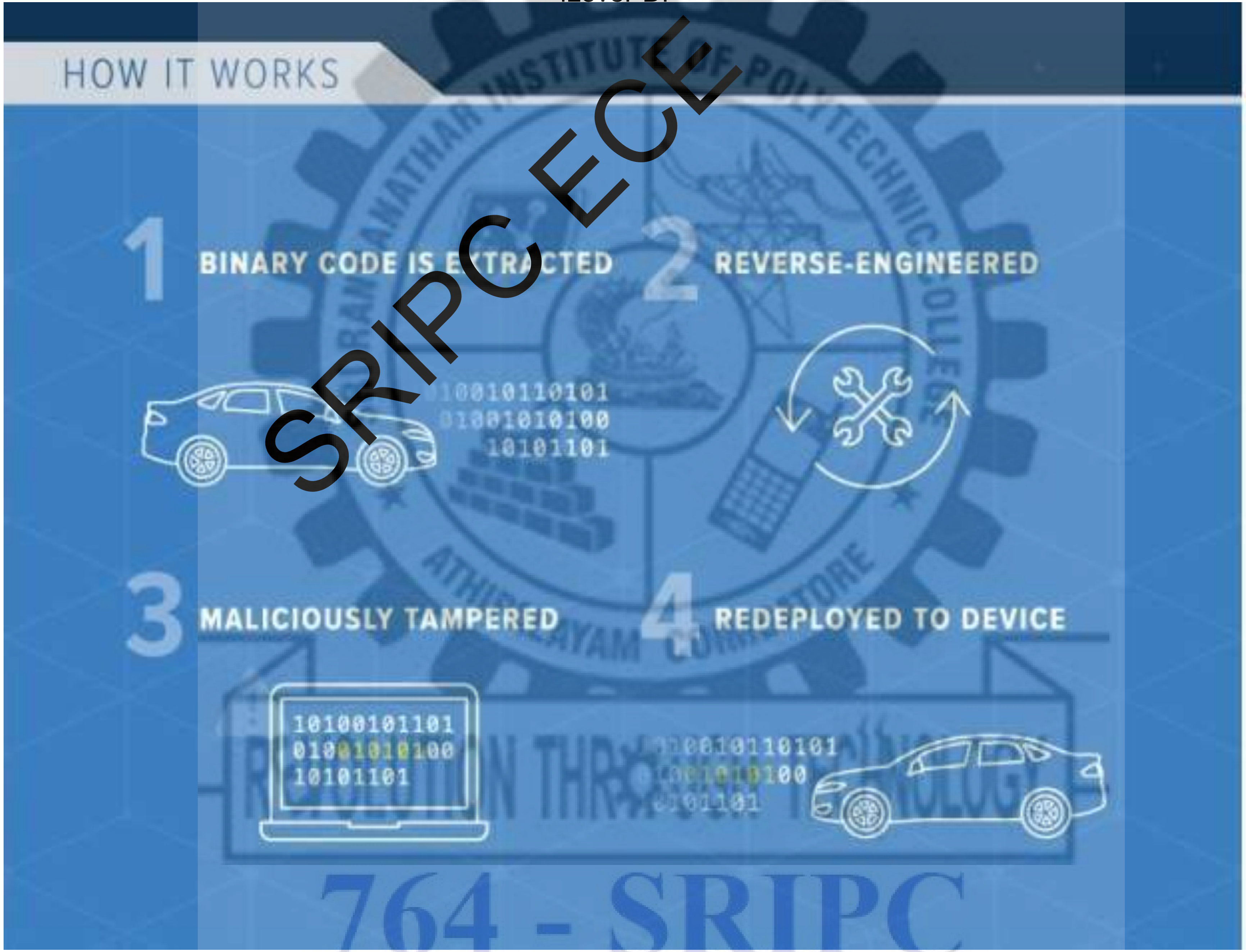
Power train technologies co-exist across xEV continuum

Note : Some studies define another intermediate segment: Range Extended Electric Vehicle (REEV) which use a generator to charge the battery, plug-in charging a& are powered by electric motor


THE RACE TO
$1TRILLION
$795.8B
Tesla
$1T
Which automaker will be the first to break the $1 trillion valuation milestone?
Toyota
$200B
$100B
Market cap breakdown by company
BYD

THE SCIENCE BEHIND THE WHEELS


VULNERABILITIES OF
THE CONNECTED CAR
75%
By 2020, three-quarters of cars shipped globally are expected to have internet connectivity.
x 10
Connected cars feature over 100M lines of code, that's ten times the amount found in a Boeing 787.


HOW IT WORKS
1 BINARY CODE IS EXTRACTED
2 REVERSE-ENGINEERED
3 MALICIOUSLY TAMPERED
4 REDEPLOYED TO DEVICE
10100101101
01001010100
10101101


ATTACK POINTS
MOBILE APPS
Hackers can intercept and control communication between your car and mobile apps acting as ignition keys.
OBD2
On-Board Diagnostic devices lacking firmware encryption enable hackers to command a vehicle's CAN bus.
Most insurance dongles lack security, making them vulnerable to reverse-engineering, data theft and modification.
INFOTAINMENT SYSTEM
One of the primary communication interfaces of a connected car, the infotainment system runs a well known standard operating system that may host high-value and sensitive applications that are easily hacked if not protected.
Researchers have shown open network ports to be an entry way for hackers to control critical car functions.
LTE coverage and Wifi inside the car expose you to the same vulnerabilities as a house on wheels.

Shared mobility trends 2021

Prices of E2W - Revised FAME II Scheme

Fig 5.2 : Electric 2-wheeler prices Vs ICE 2-wheeler prices (as of June 2021)

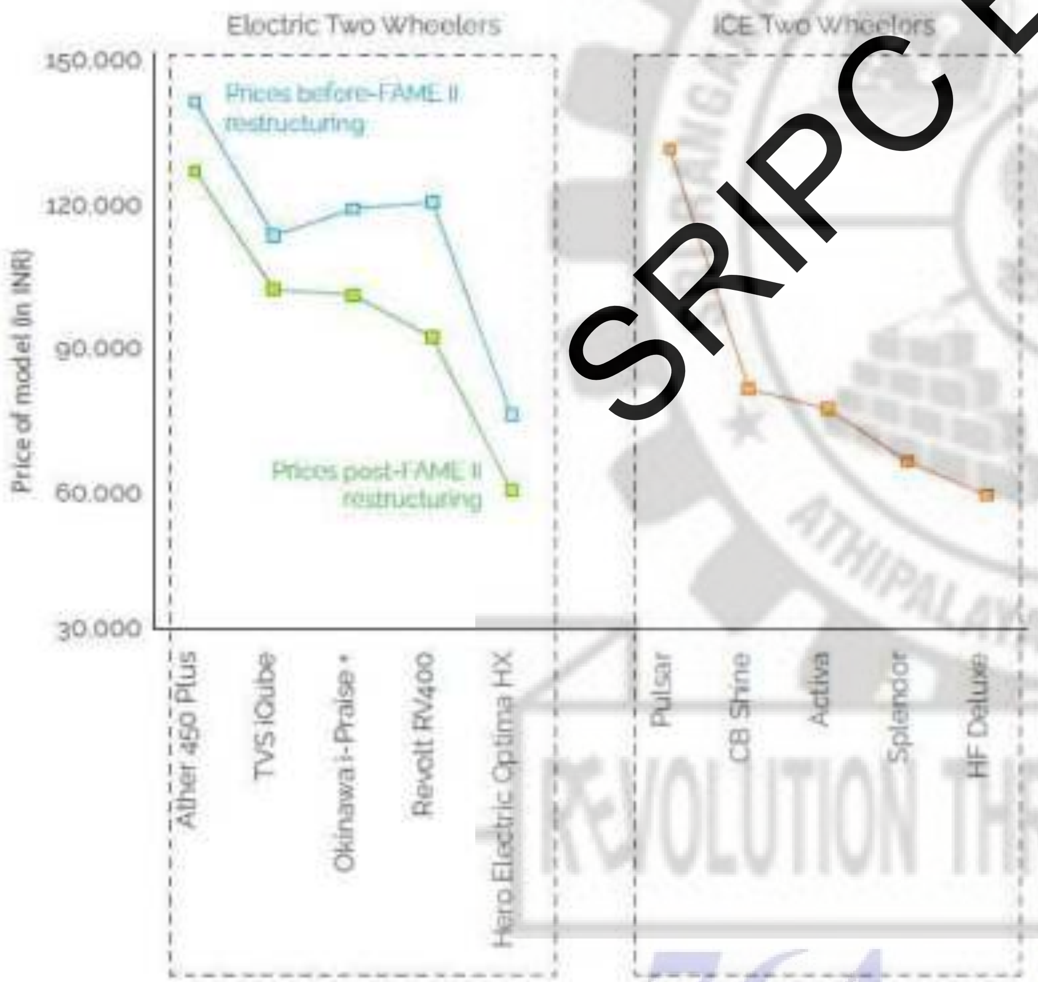
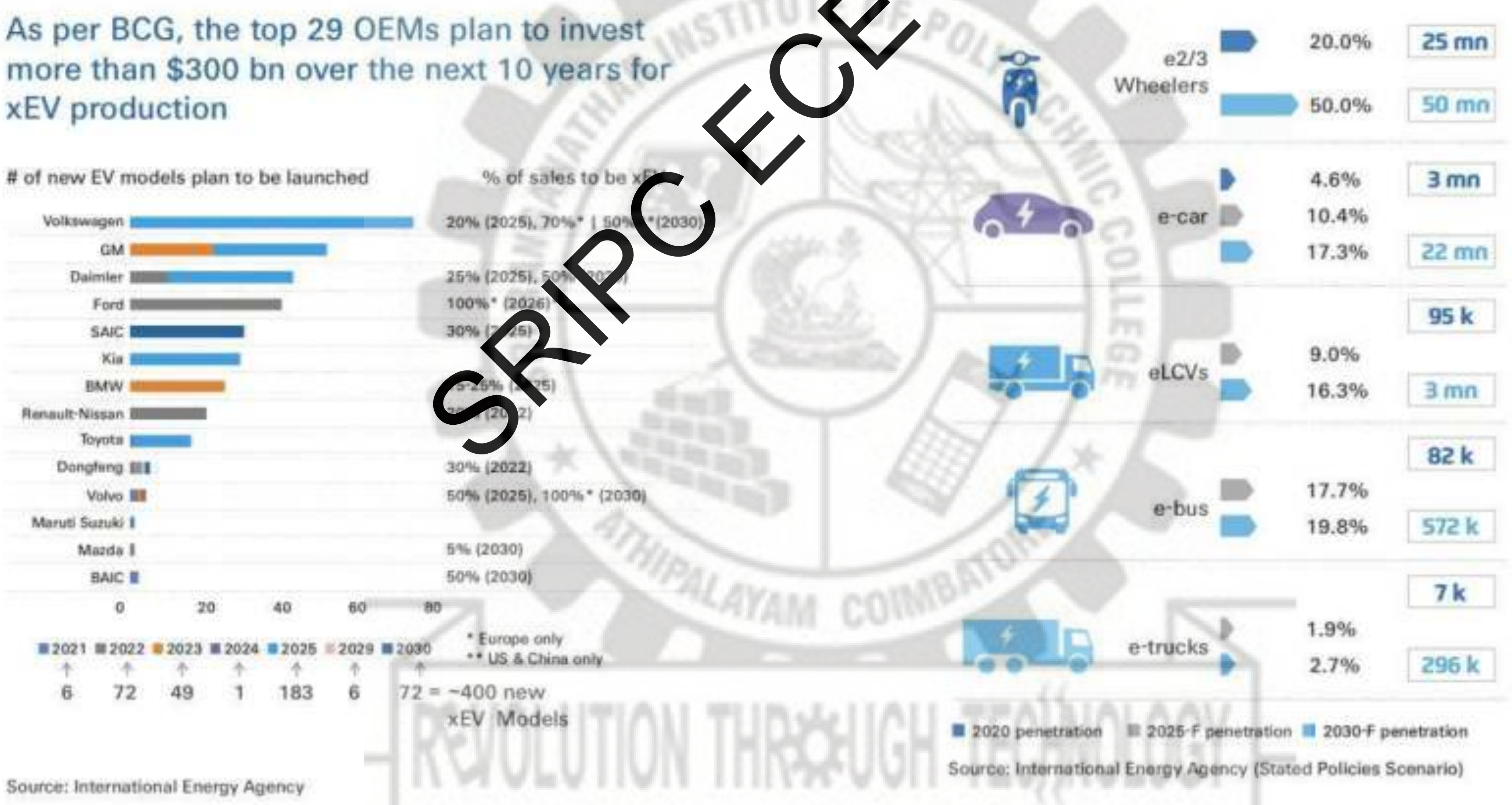


Table 5.1 : Prices of E2Ws after restructured FAME-II Scheme

Brand	Model	Price before FAME-II Restructuring (INR)	Price after FAME-II Restructuring (INR)	% Decrease
Ather	450 Plus	1,27,916	1,13,446	11.32%
	450X	1,46,926	1,32,498	9.82%
Ampere ✓	Zeal	68,990	59,990	13.04%
	Magnus Pro	74,990	65,990	12%
Revolt ✓	RV400	1,19,000	90,799	24%
Okinawa	iPraise+	1,17,600	99,708	15.2%
	Praise Pro	84,795	76,848	9.4%
	Ridge+	69,000	61,791	10.44%
Hero	Optima HX (Single Battery)	61,640	53,600	13%
	Optima HX (Dual Battery)	78,640	58,980	33%
	Photon HX	79,940	71,449	12%
	Nyx HX	1,13,115	85,136	33%
TVS	iQube	1,12,027	1,00,777	10%

Source: JMK Research

Strong OEM plans for Electrification



Takeaway	**Key Global OEM commitments to significant electrification by 2030**

Electrification across the vehicle segments

- Electrical power can be delivered from each of, or any combination of all of these:
  - On board vehicle battery (BEV / PHEV)
  - Dynamic energy transfer (ERS)
  - On vehicle generation (Series Hybrid)
  - On vehicle energy harvesting (Hybrid)

Takeaway	**3W, small/med PV segment can be addressed by 48V technologies, the rest need HV**

Source: Ricardo EDU Presentation 2021

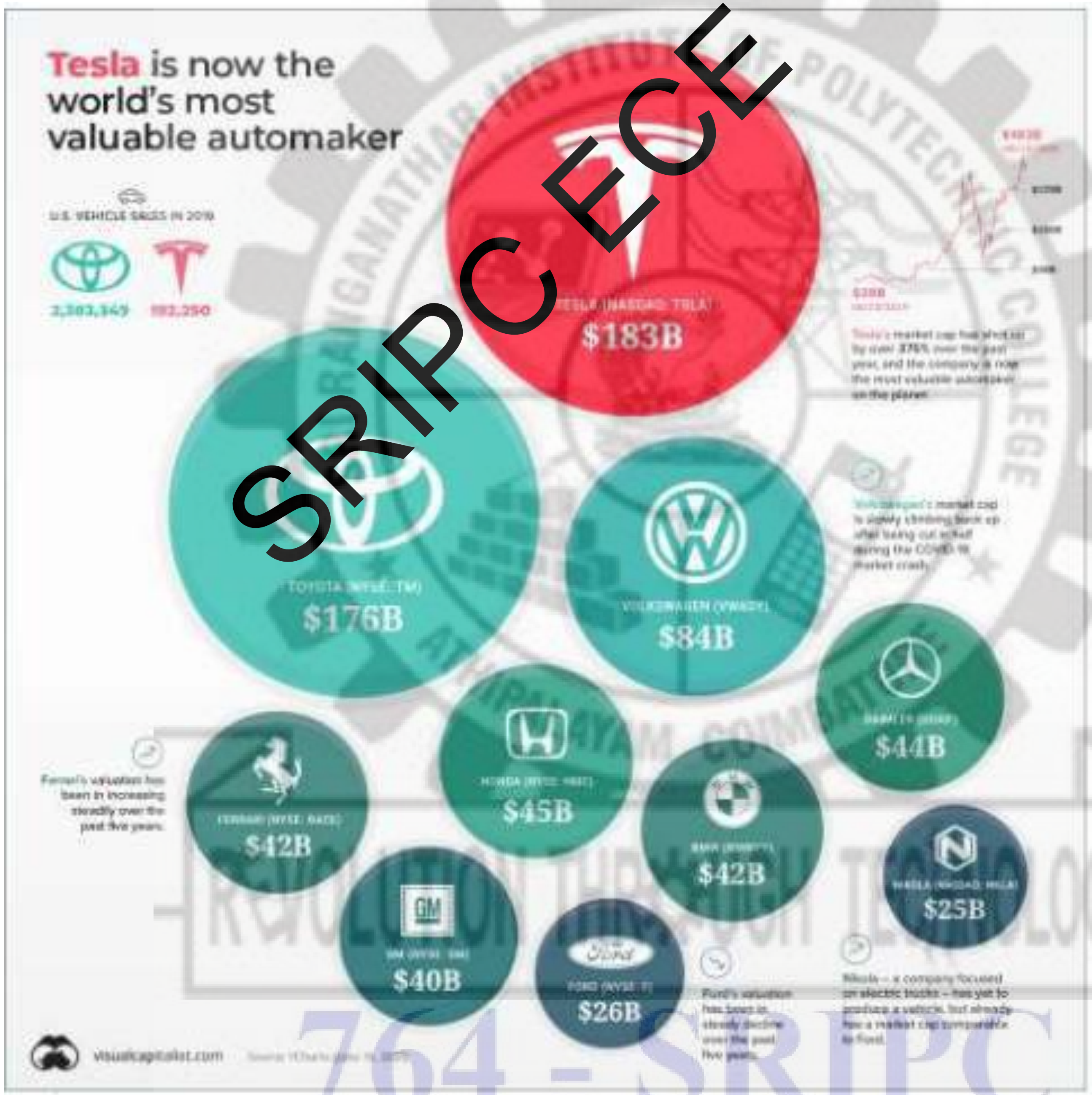
The *CASE* Disruption Is Already Underway

Business + Customer shifts

"Usership" "Sharing"	Emission efficient	Connected & Safe	"Electronified"	+ Experience

	Connected	Autonomous	Shared	Electric
Global	• **5G enabled** vehicles are expected to **dominate** sales by **2030**	• Automated driving tech. market for cars to be worth **$270 billion** by **2030**	• **Shared mobility models** expected to account for **15-24%** of vehicle-based mobility by 2030	• **Range anxiety** still a concern. **FCEV** can smoothen transition
India	• **New entrants** in India offering **"connected"** services reported **superior sales**	• **Level 1/Level 2** autonomous vehicles to hit Indian roads **circa 2027**	• **Micro-mobility start-ups** increasing acceptability in India	• **e – 3Wheelers** leading adoption in India – **83%** of total sales in FY19

Source: PwC research & analysis , PwC Strategy& 2019 Digital Auto Report


Tesla is now the world's most valuable automaker
U.S. VEHICLE SALES IN 2019
2,383,349
192,250
TESLA (NASDAQ: TSLA)
$183B
TOYOTA (NYSE: TM)
$176B
VOLKSWAGEN (VWAGY)
$84B
$44B
HONDA (NYSE: HMC)
$45B
FERRARI (NYSE: RACE)
$42B
$42B
$25B
GM (NYSE: GM)
$40B
FORD (NYSE: F)
$26B
visualcapitalist.com

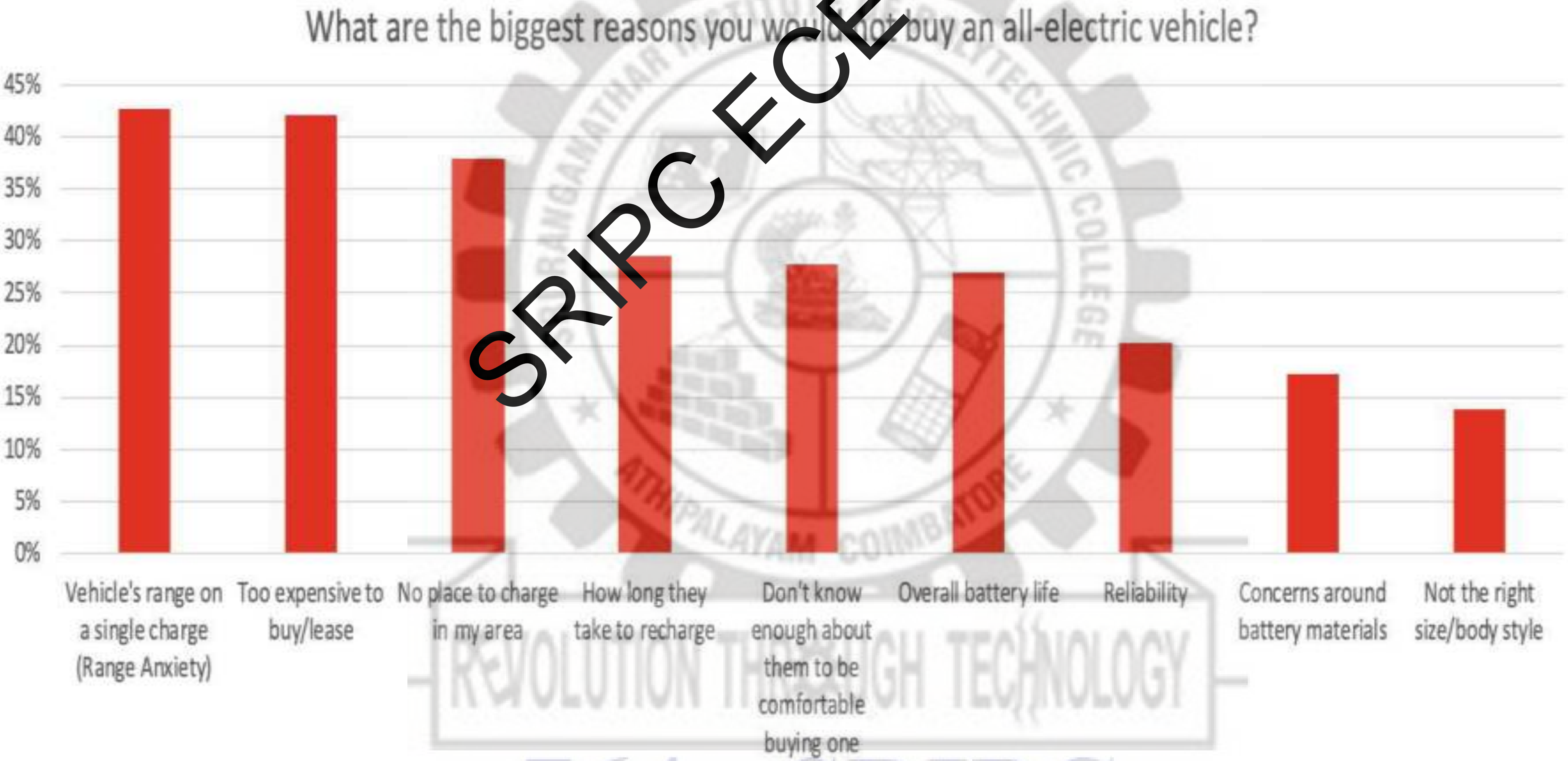

FROST & SULLIVAN
INDIA'S AUTOMOTIVE STARTUP ECOSYSTEM -
The Major disruptive start-ups transforming the Indian Automotive Landscape
NEW MOBILITY SERVICE
CONNECTED SOLUTIONS
RETAIL & AFTERSALES
LOGISTICS & SUPPLYCHAIN
AUTO IoT
ELECTRIC VEHICLES
AUTONOMOUS TECHNOLOGY
BOUNCE
DRIVE
ZONE
REV
LIGHT METRICS
get my PARKING
CarTrade
CarDekho
PORTER
DELHIVERY
BLACKBUCK
lets transport
RIVIGO
REVOLT
SOFOCLE
BANGALORE THE INDIAN HUB FOR AUTOMOTIVE START-UPs IN INDIA
INVESTMENT
START-UPs
DELHI
$ 16.35 Million
24
GURUGRAM
$1635.43 Million
20
MUMBAI
$ 330.40 Million
15
HYDERABAD
$ 35.0 Million
09
BENGALURU
$ 6626.88 Million
54
CHENNAI
$ 6.23 Million
06


e-Trio


Car Conversion Kit
BHARAT MOBI
: ADDRESS :
2-1813/3/5/A Road No: 1 Opp. SBI Bank,
Czech Colony, Sanath Nagar, Hyderabad,
Telangana 500081
ELECTRIFYING MOBILITY WITH
BHARAT KIT
ARAI & ICAT
Approved


INDIA'S FIRST CERTIFIED EV RETROFITTING COMPANY
IS LOOKING FOR FRANCHISE PARTNERS
Investment
2 crores?
e-Trio
JOIN HANDS WITH E-TRIO TO TRANSFORM CONVENTIONAL CARS INTO PURE ELECTRIC CAR
REASONS TO PARTNER


POSH
Target Price
Rs.50,000.00
PUNE
Develops
Electric Car
Conversion
Kit


What are the biggest reasons you would not buy an all-electric vehicle?
45%
40%
35%
30%
25%
20%
15%
10%
5%
0%
Vehicle's range on a single charge (Range Anxiety)
Too expensive to buy/lease
No place to charge in my area
How long they take to recharge
Don't know enough about them to be comfortable buying one
Overall battery life
Reliability
Concerns around battery materials
Not the right size/body style

Objectives

- To learn the environmental impact and history of Electric Vehicles
- To understand the concept of Electric Vehicle and its types
- To study the configurations of Electric Vehicles
- To acquire knowledge about Energy Storages, Charging System, Effects and Impacts
- To appreciate the Electric Mobility Policy Frame work India and EV Policy Tamil Nadu 2019.

Outcomes

- Appreciate the need of an Electric Vehicle
- Compare the different EV vehicle specifications in the market
- Choose the right motor, inverter and battery systems for EVs
- Workout the benefits of EV cost based on the Govt policy


Thank You!