Business of Charging Infrastructure for Electric Vehicle

M. Saad Alam

Director,
Centre of Advanced Research in Electrified Transportation (CARET)
Aligarh Muslim University (AMU), Aligarh
Associate Professor,
Department of Electrical Engineering, Aligarh Muslim University (AMU), Aligarh

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- Charging Infrastructure
- Battery Swapping Station
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- Case Studies

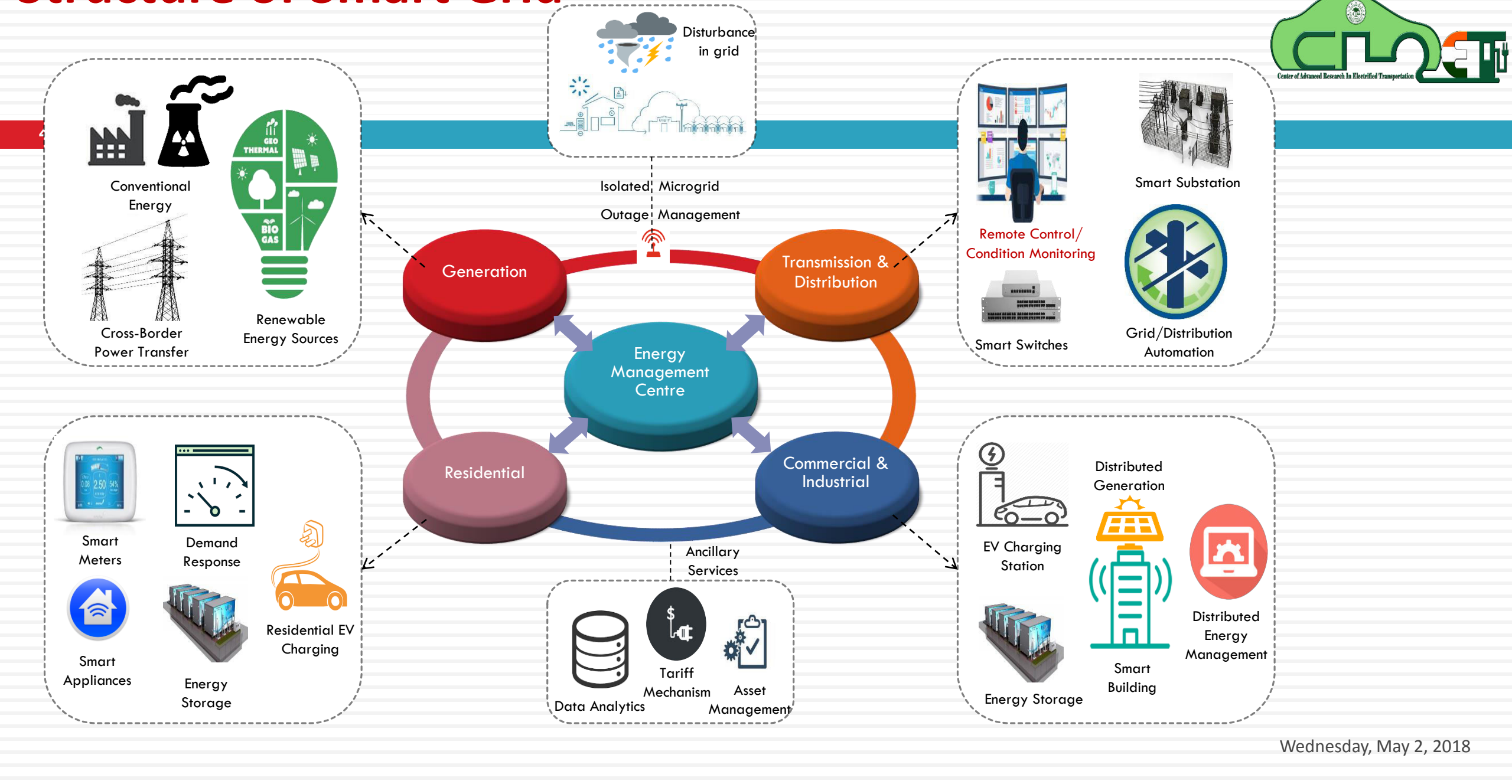
Introduction

1. The swiftly growing structure of urbanization and industrialization;
   - Facilitating the transportation era at peak; 25% GHG
   - Exponentially increasing energy demand; 33.3T kWh by 2030
2. The salient impacts of the use of fossil fuels for power generation;
   - Significant ecological degradation,
   - Fuel supply shortage,
   - Energy security crises,
   - Economic growth limitations.
3. The conventional T&D systems causes;
   - Significant amounts of energy losses,
   - Do not provide the hoped reliability & security levels,
   - Limited control and high costs of FACTS devices.

Zero-Carbon future through intelligent integration of electric vehicles, electricity, free renewable energy and market opportunities.

Smart Grid

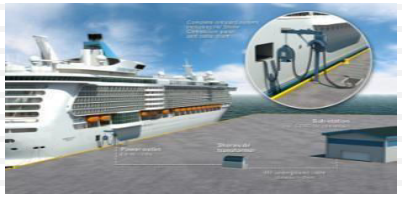
Structure of Smart Grid



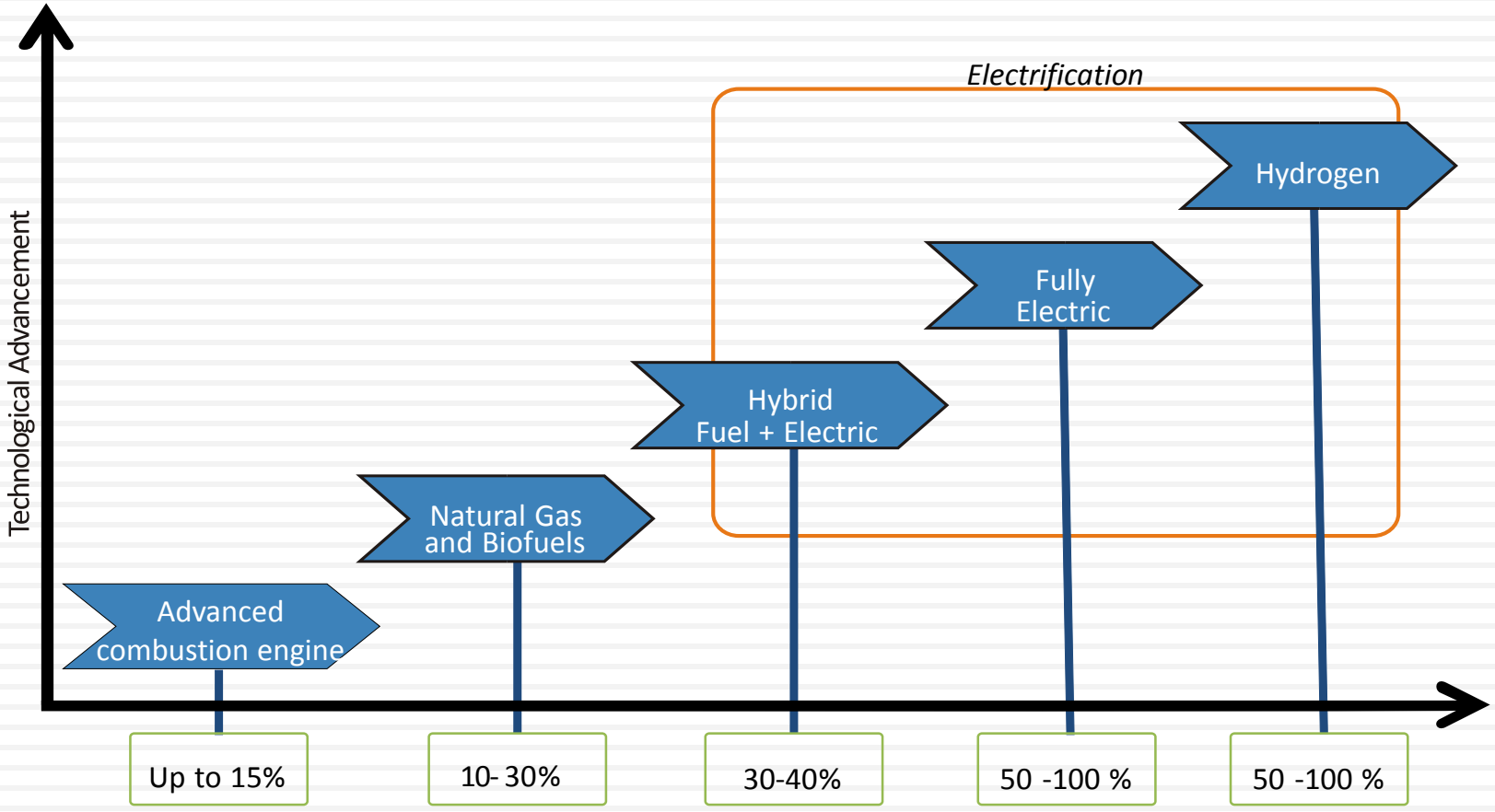
Solution Area: Electricity Grid
Solutions for evolving system demands

Power & Automation for …		Overview	Benefits
Grid Automation		§ New levels of monitoring, protection and control deeper into the distribution grid	§ Improved capacity, efficiency, reliability, sustainability
Demand Response		§ Incent customers with supply side signals to change demand or feed in generation	§ Reduced need to build new generation or grid capacity § Reduced system costs
Renewables Integration		§ Cope with renewables using voltage regulation as well as distribution grid automation	§ Improved reliability of supply § Supports higher share of renewables
Energy Storage		§ Utilize batteries in the network to address capacity constraints and improve power quality	§ Improved network stability, power quality and efficiency

Solution Area: Transport
Infrastructure to effectively electrify transportation

Power & Automation for …		Overview	Benefits
Electric Vehicle Charging		§ Charging infrastructure for 15-30 minute charges and longer	§ Foster electric vehicle uptake § Cut emissions in the city § Help integrate renewables
Electric Buses		§ Ultra-fast charging for battery powered electric buses	§ Clean, quiet public buses § No overhead cables
Electric Rail		§ Recuperate braking energy in metro trains and trams	§ Reduce energy costs by up to 30% § Potentially sell services to grid
Shore-to-Ship		§ Infrastructure to power ships with electricity from the shore when berthed	§ Eliminate 98% of emissions and all noise and vibration § Improve quality of life near port

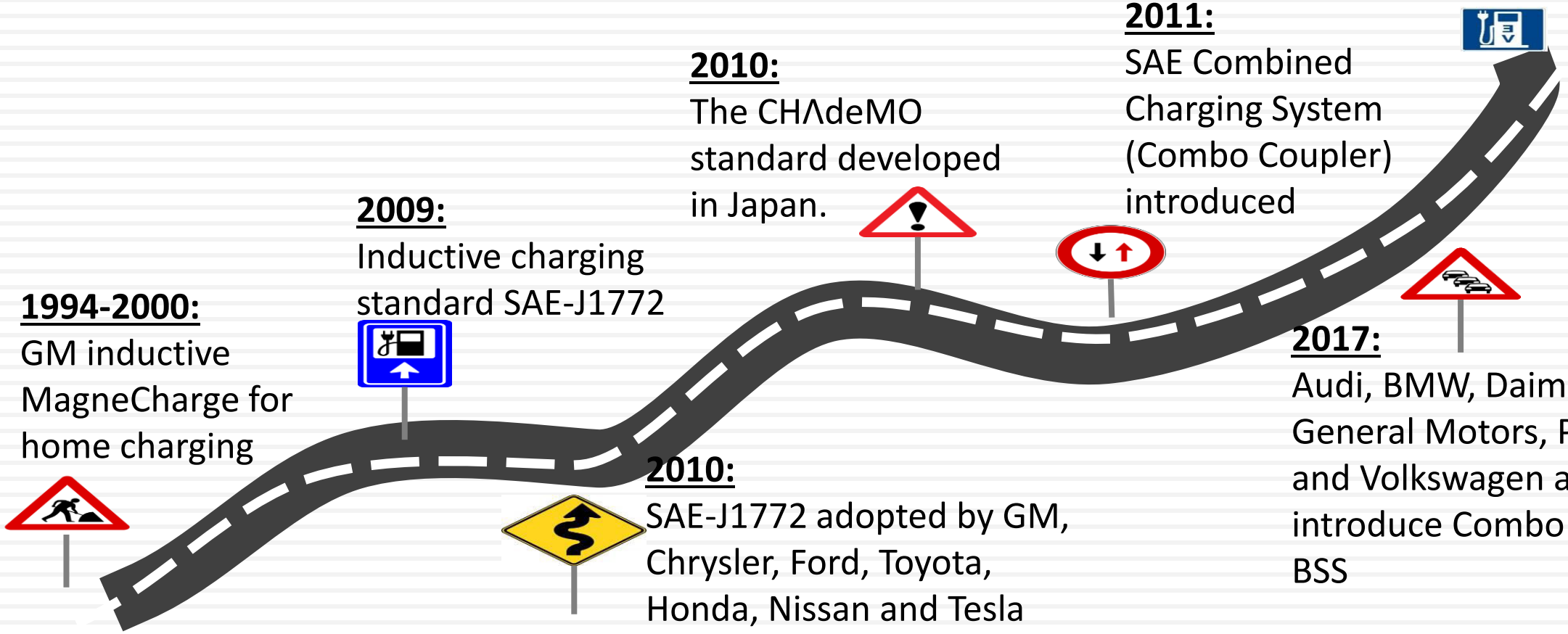
Path to Transportation Electrification



The EV value chain

- Raw Material Suppliers
- Traditional Component Suppliers
- Battery Suppliers
- OEMS
- Utilities / Infrastructure

EV Charging Infrastructure Deployment Timeline



1994-2000:
GM inductive MagneCharge for home charging

2009:
Inductive charging standard SAE-J1772

2010:
SAE-J1772 adopted by GM, Chrysler, Ford, Toyota, Honda, Nissan and Tesla

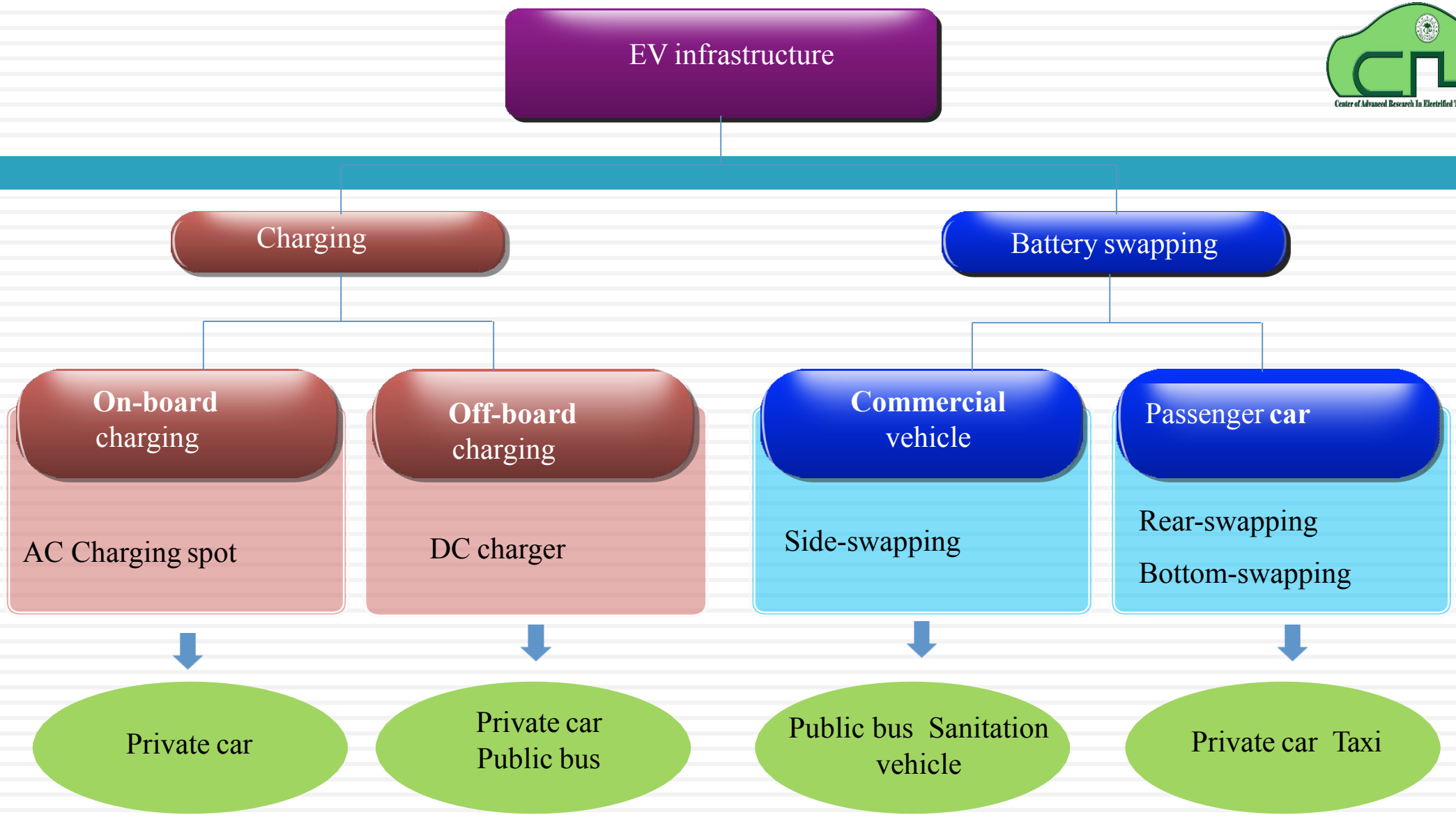
2010:
The CHΛdeMO standard developed in Japan.

2011:
SAE Combined Charging System (Combo Coupler) introduced

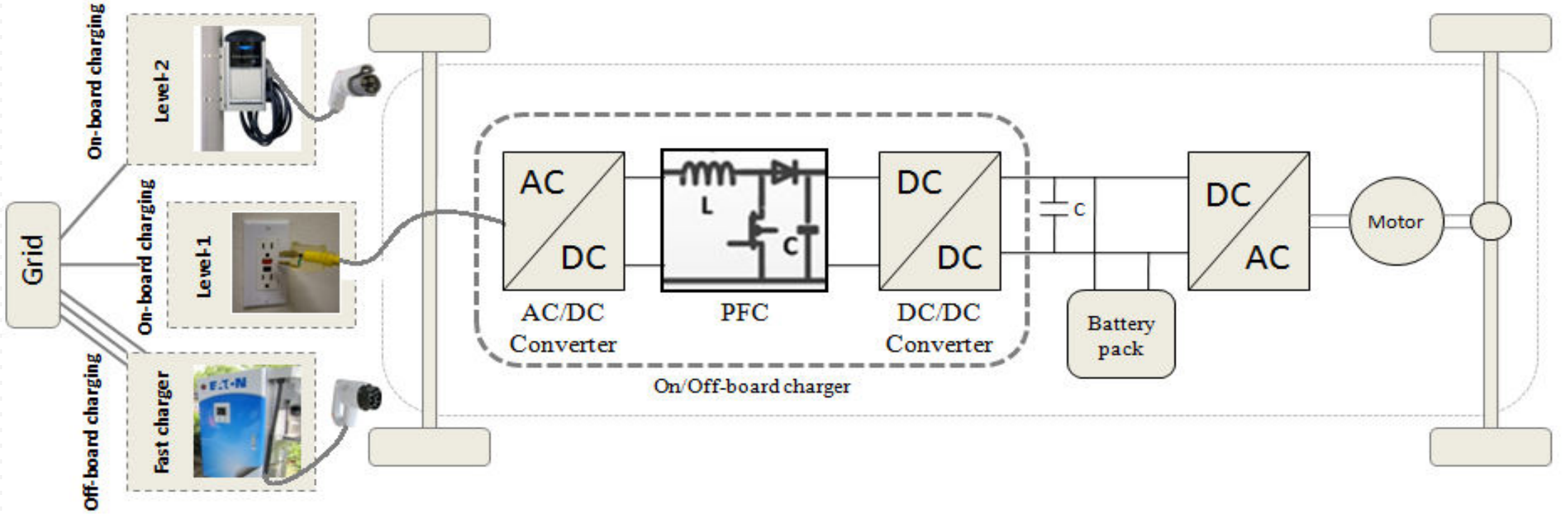
2017:
Audi, BMW, Daimler, Ford, General Motors, Porsche and Volkswagen agreed to introduce Combo Coupler/ BSS

E-mobility models: Comparison of selected countries

Lever	US	China	Japan	France
R&D	✓✓✓	✓✓✓	✓✓	✓✓
Supply Side	✓✓	✓✓✓	✓	✓
Demand side incentives	✓✓✓	✓	✓✓	✓✓✓
Infrastructure	✓✓	✓✓✓	✓✓	✓✓✓
Proposed Investment	>$5 B	>$20 B	>$1.7 B	>$3.5 B


EV infrastructure
Charging
Battery swapping
On-board charging
Off-board charging
Commercial vehicle
Passenger car
AC Charging spot
DC charger
Side-swapping
Rear-swapping
Bottom-swapping
Private car
Private car
Public bus
Public bus
Sanitation vehicle
Private car
Taxi

Typical layout of EV charging system



EV Charging Levels

Charging type	Level 1	Level 2	DC Fast
Charging Time (h)	20-22	6-8	0.2-0.5
Charger location	On-board (1- phase)	On-board (1 or 3- phase)	Off-board (3- phase)
Voltage supply (V)	120	240	208-600
Power level (kW)	1.3 to 1.9	Up to 19.2	50 to 150
Range	2-5 miles per hour of charging	10-20 miles per hour of charging	60-80 miles in < 30 minutes
Primary Use	Residential charging	Residential and public charging	Public charging

EV Charging Standards

Standard	Specification
SAE-J1772	EV Coupler for conductive Charging
SAE-J1773	EV Inductively Coupled Charging
SAE-J1797	Recommended Practice for EV Battery Modules Packaging
SAE-J2288	Life Cycle Testing of Battery Modules for EV
SAE-J2464	EV/HEV Rechargeable Energy Storage System (RESS) Safety & Abuse Testing
SAE-J2836 Part 1	Use Cases for Communications between PEVs and Utility Grid
SAE-J2836 Part 2	Use Cases for Communications between PEVs and Supply Equipment (EVSE)
SAE-J2836 part 3	Communications between Plug-In Vehicles and the Utility grid for Reverse Flow
SAE-J2894	Power Quality Requirements for Plug-In Vehicle Chargers- Requirements
IEC-69/156/CD:2008	Electric vehicle conductive charging system
IEC-23H/222/CD:2010	Plugs, socket-outlets, vehicle couplers and vehicle inlets - Conductive charging of EVs
JEVS-C601:2000	Plugs and receptacles for EV charging
AIS-138(Draft)	Electric Vehicle Conductive AC charging system-ARAI

Main type of charging facilities

Bus

Charging station

Taxi

Charging station

Environmental sanitation vehicles

Charging station

Estimated Cost of Charging Infrastructure

Total investment cost required for the establishment of charging infrastructure for EVs includes

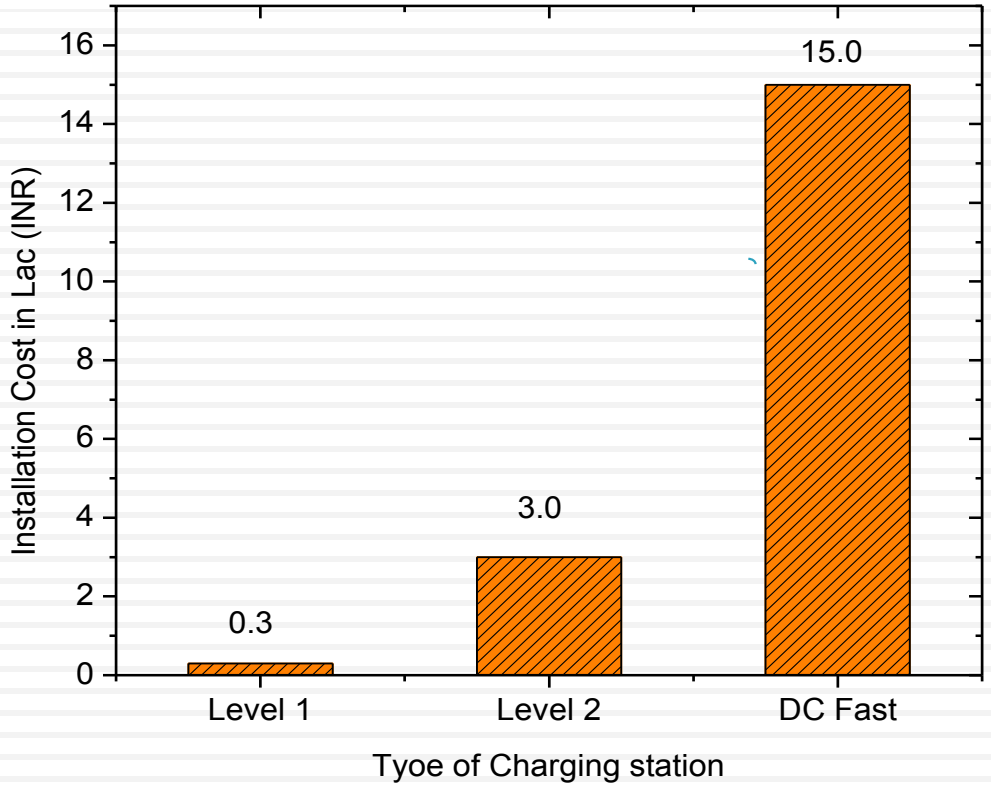
- The cost of equipments to be used,
- Installation costs
- Operation and maintenance costs.

The installation cost includes
cost of civil works, transaction cost regarding distribution system operator permission and other related costs depending on factors like requirement of a new grid connection or up gradation of the existing connection

With increase in penetration of EVs in the next few years, number of EV chargers will increase and hence the equipment cost is expected to decrease.

Estimated Cost of Charging Infrastructure

- For semi-private/semi-public places where low or medium power level chargers are required, cost varies between 500 € (Rs 36,431) and 1200 € (Rs 87,435).
- For public places where high power level chargers are required, installation cost is relatively higher ranging between 2400 € (Rs 1, 74,871) to 3600 € (Rs 2, 62,306).
- For that operation and maintenance cost is to be added, which may be taken to be 10% of the total installation cost (including equipment cost)



Level 1 charger of 1.5kW, Level 2 charger of 6.6kW and DC fast charger of 50kW capacity.

Benefits of commercialized charging stations

- They will help in diverting the peak of charging load from the demand peak of the network.
- Unpredictable mobile load in the form of EVs would be transformed into a stationary load and it would be easier to predict.
- When in the form of bulk charging load, it would be simpler to enforce regulations on harmonics and power factor.
- Implementation of V2G concept would be easy as it would eliminate the need for integration of sophisticated devices for measurement, communication, and control, up to end consumer level.

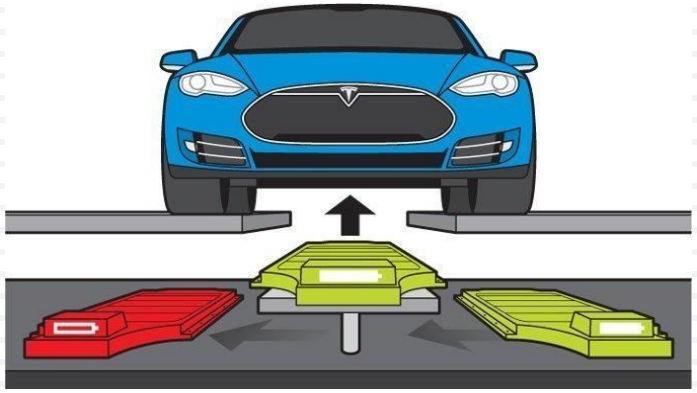
Limitation of EV Charging Station

- In general, EV charging requires a ***long charging process***. Thus far, due to policy and money constraints, the charging stations, charging piles and other charging infrastructure are not widely deployed.
- The abovementioned reasons make it probable that EV users will be forced to stop and wait, which results in ***waiting anxiety.***
- In addition, EV users trade-off between the remaining battery energy, the location distribution of charging facilities and their travel plans, which easily results in ***range anxiety***.
- Therefore, more researchers and EV operators are turning their attention to ***battery swapping***.
- Battery swapping can provide a new fully charged battery, which does not require depleting the energy of the old battery.

Type of Battery Swapping Stations

Side-swapping : applicable to as commercial electric vehicles such buses and sanitation truks which have battery packs installed in both sides of the vehicle body

Rear-swapping: applicable to electric passenger vehicles such as private cars and taxis, with battery packs installed in the trunk of the vehicle body.

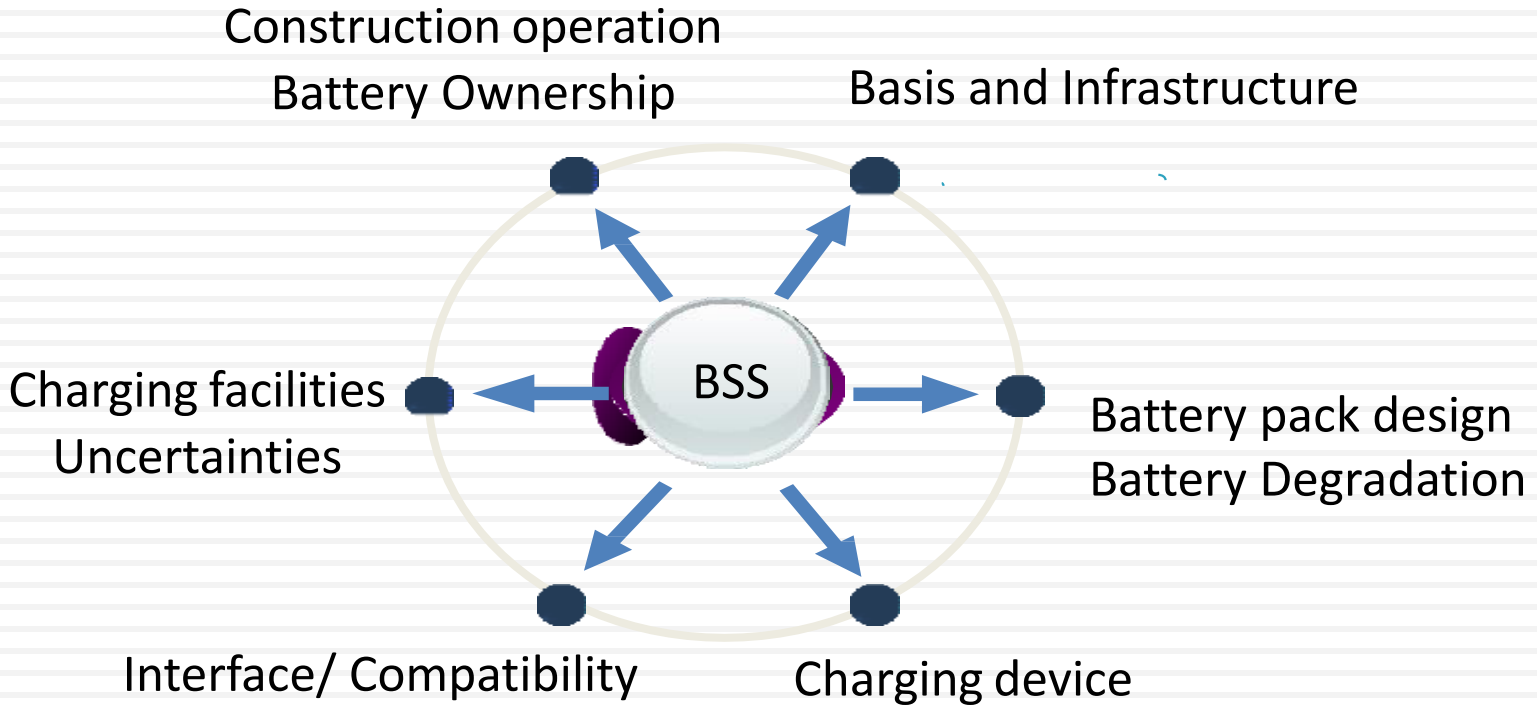


Bottom-swapping: applicable to electric passenger vehicles such as private cars and taxis, with battery packs installed in the chasiss of the vehicle body.

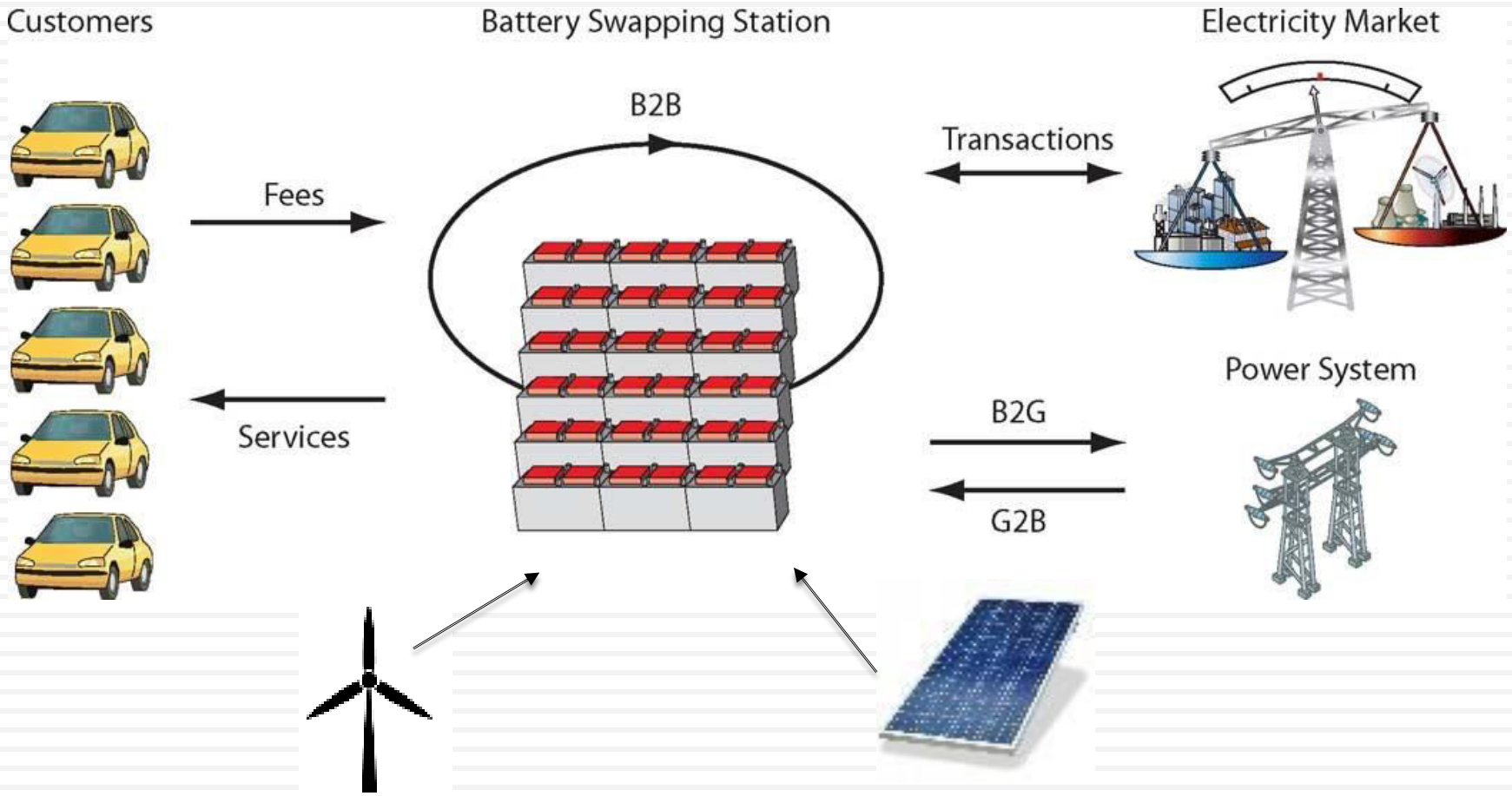
Challenges of Battery Swapping Station

However, before the benefit of battery swapping becomes a reality, two problems need to be solved.

- One is the EV battery technology, which is fundamental for battery swapping.
- A standardized EV battery with the characteristic of high mileage, high energy density, high recycling ratio, high recovery ratio, environmentally friendly ability and security needs to be developed



Complexity of EV/BSS Integration



Benefit of Battery Swapping Stations

Costumer Prospective

- In BSS scheme, the customers would lease the battery from the BSS and avoid a lump investment.
- The other aspects that concern potential EV owners are the long charging times, the costs of upgrading household installations to high power chargers, and the limited number of public charging stations.
- Another concern of the EV owners is the limited range due to the relative small capacity of the batteries. In order to ease this concern, the owners would need to have access to public charging stations, which are translated into requiring heavy infrastructure investments. These concerns could be eliminated if an EV owner has access to BSSs in the areas where they usually travel.

Benefit of Battery Swapping Stations

Power System Operator Prospective

- Sifting power demand form one duration to another
- Prediction of EV load demand is easy
- Furthermore, the BSS is an aggregator of batteries, and these stations could also be used to provide services to the system as a whole.
- The BSS can inject power back into the power system to smooth the net daily demand curve, if the BSS perceives a benefit in doing so.
- In addition to acting as a storage device, the BSS can also provide a share of the required ancillary services in different intervals, e.g., frequency regulation, load following, and voluntary reserve provisions.

Impact of charging on Power system

- Increases the *difficulty of distribution network planning*. New constraints in the form of electricity demand and the layout of charging stations need to be considered, which add to the *complexity of network planning.*
- *Improved quality equipments with high ratings are required* in the distribution network to facilitate interconnection of charging infrastructure.
- Requires *distribution transformer with larger capacity* and distribution line of larger cross section *to avoid problems like overloading, voltage deviation* etc.
- It may lead to a decrease in the economy of distribution system operation. As charging load exhibits large volatility, it is difficult to confine charging behavior to low load periods, leading to greater system peak difference. This would ultimately result in lower utilization efficiency of distribution network equipment.
- *Power quality of the distribution network is affected*. Charger uses several power electronic conversion devices in the form of converters which *induce harmonics in the source side current*.

Recommendations for EV charging/BSS

Most research is this area is focused on the following issues:

- Battery logistics strategy, battery swapping station planning and construction strategy,
- battery charging strategy for the battery swapping stations

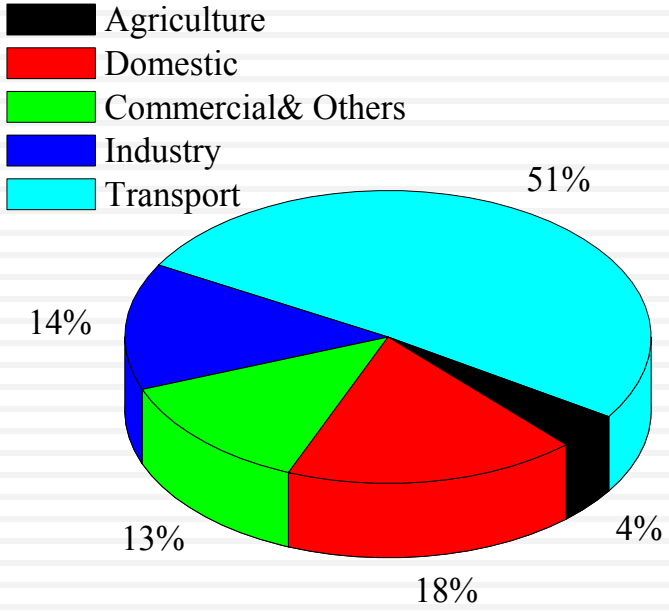
The abovementioned research intends to improve the coverage and service of a battery swapping system. However, these approaches ***do not realize*** the objective of "**get energy replenishment anytime and anywhere**."

Switching from the existing passive battery swapping mode to the active battery swapping mode

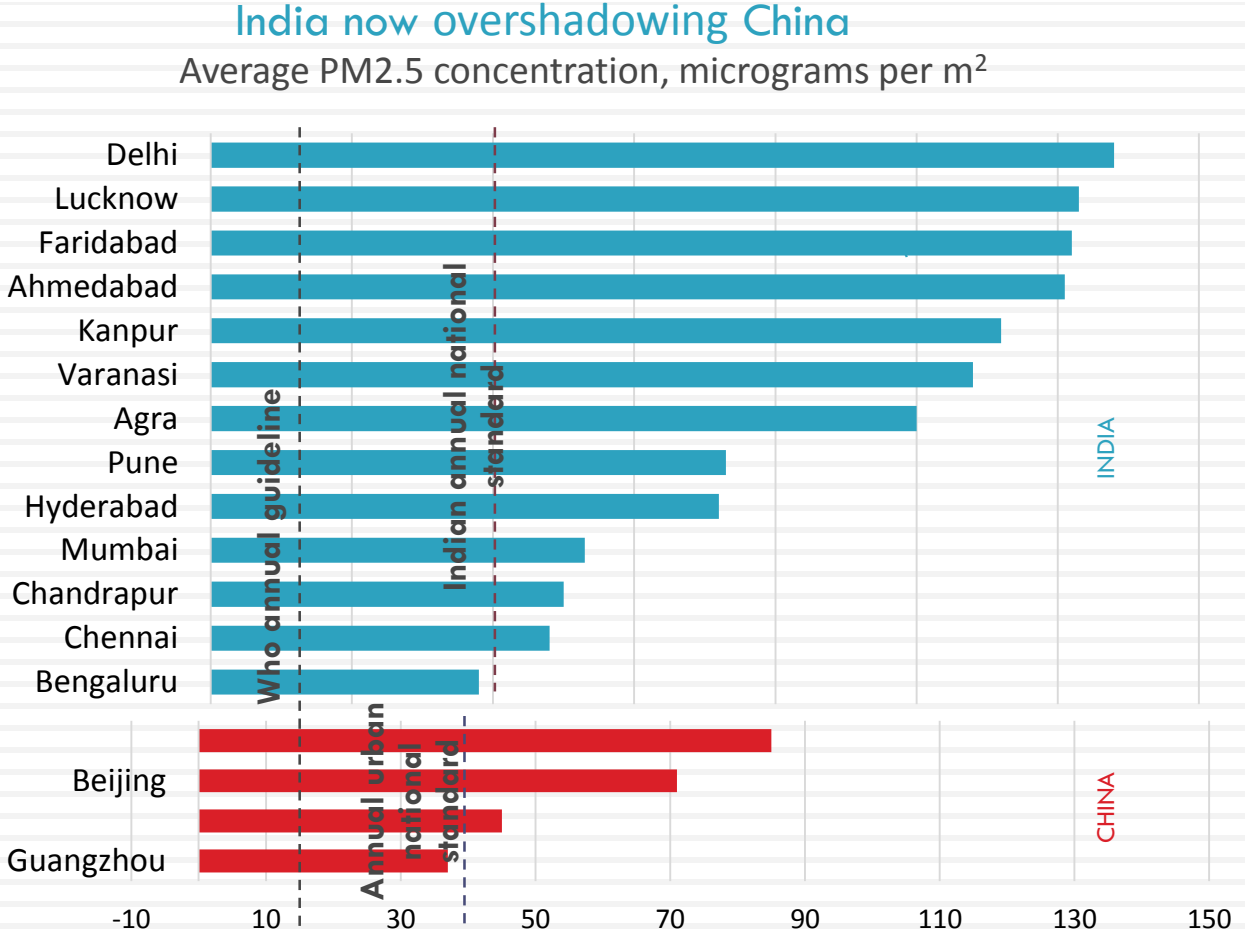
Mobile Battery Swapping Stations

Electric Vehicle Infrastructure in India

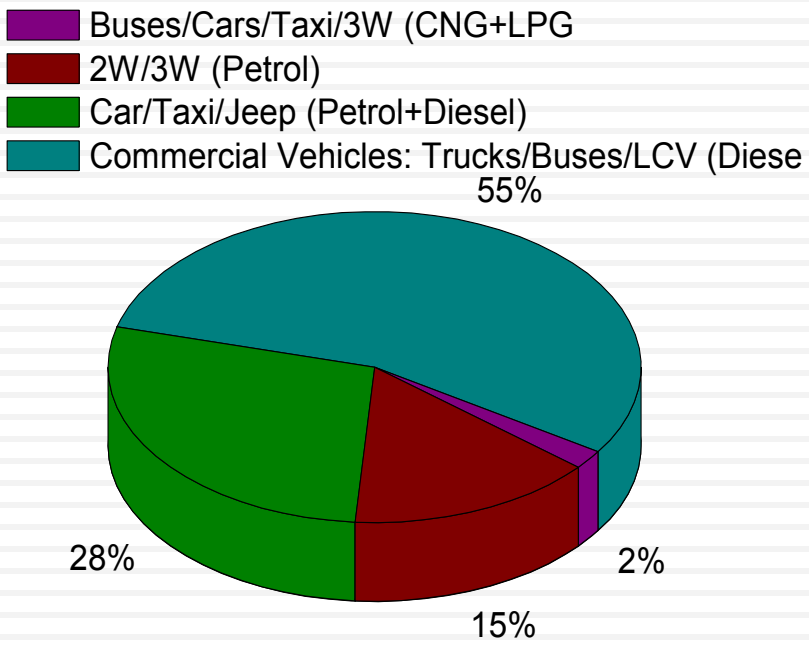
Air Pollution in India

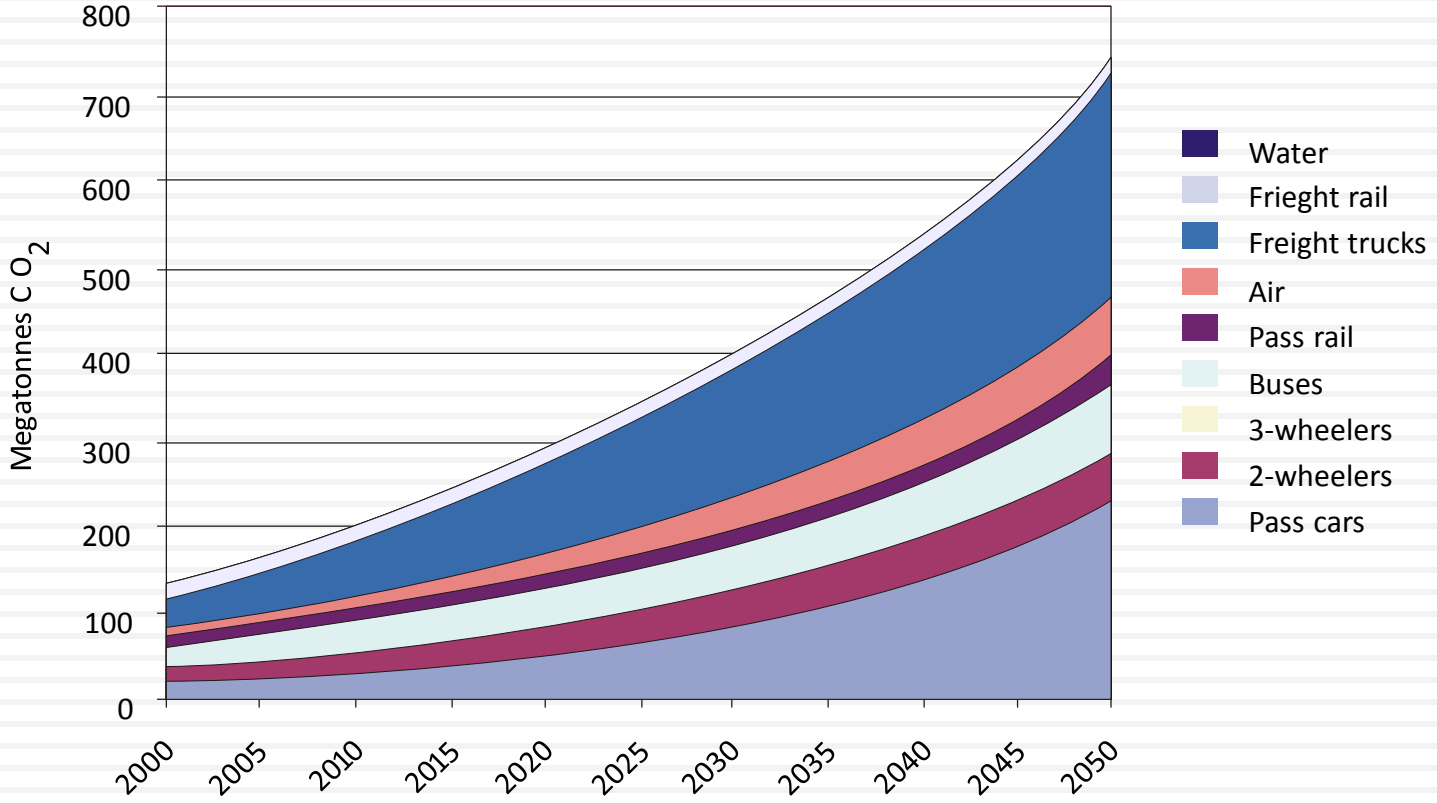


Air Pollution from various sectors

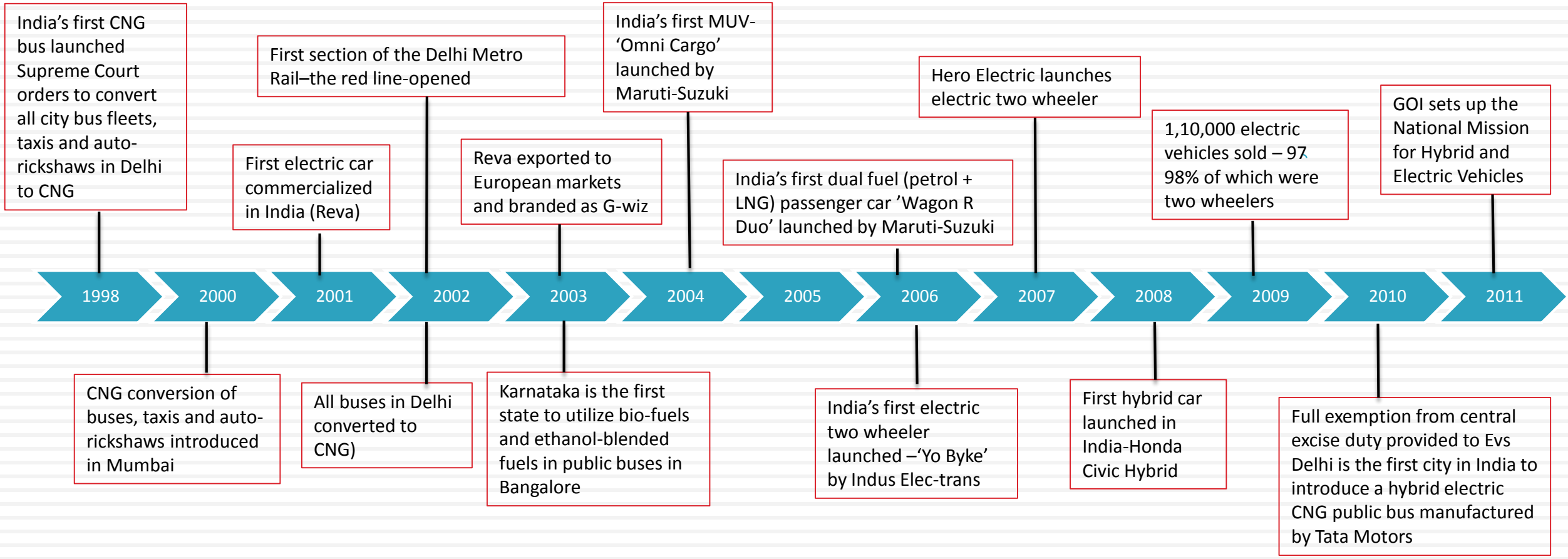


Road Transport: CO_2 Emissions by Fuel type





Green Transport in India

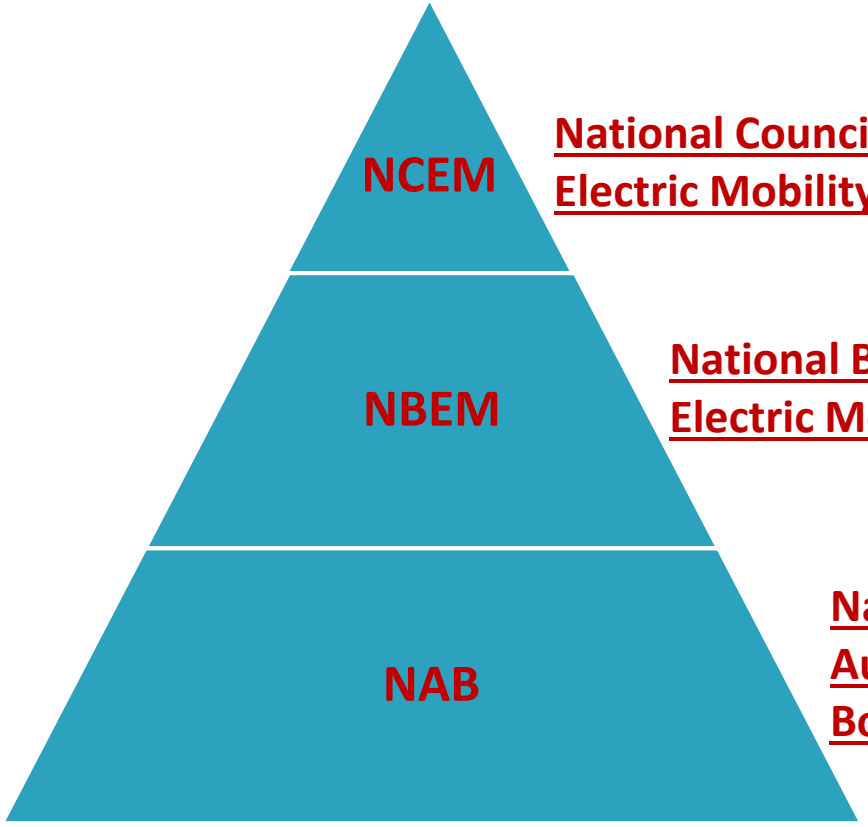


National Mission for Electric Mobility Structure

NCEM is a Government body made up of 18 members including 8 Cabinet Ministers

25 members, comprising of secretaries of stakeholder Central Ministries and academia

The expert body to assist NCEM and NBEM



National Council for Electric Mobility

National Board for Electric Mobility

National Automotive Board (NAB)

National Electric Mobility Mission Plan 2020 (NEMMP 2020)

Total Investment Proposed under National Mission for Electric Mobility (Rs in Crores)

NMEM (Rs in Crores)

Area	4W		2W	3W		Buses		LCV		Total	
	HG/ HEV	HG/HEV /BEV	HG/ HEV	HG/ HEV	HG/HEV/BEV	HG/ HEV	HG/HEV/BEV	HG/ HEV	HG/HEV/BEV	HG/ HEV	HG/HEV /BEV
Demand Incentives	4900-5000	5600-5700	5200-5300	400-450	700-750	500-550	500-550	1250 - 1300	1500 - 1550	12,250-12,600	13,500 -13,850
R&D Investment	500-600	500-600	500-600	-	-	500-600	500-600	-	-	1500-1800	1500-1800
Power Infrastructure	700-800	1200-1300	3300-3400	40-50	75-85	5-10	20-30	55-65	90-100	4100-4325	4685-4915
Charging Infrastructure	700-800	950-1000		40-50	70-80	5-10	10-20	70-80	115-125	815-940	1145-1225

Government Funded

Government & Industry Funded

How fast will EV market share grow ??

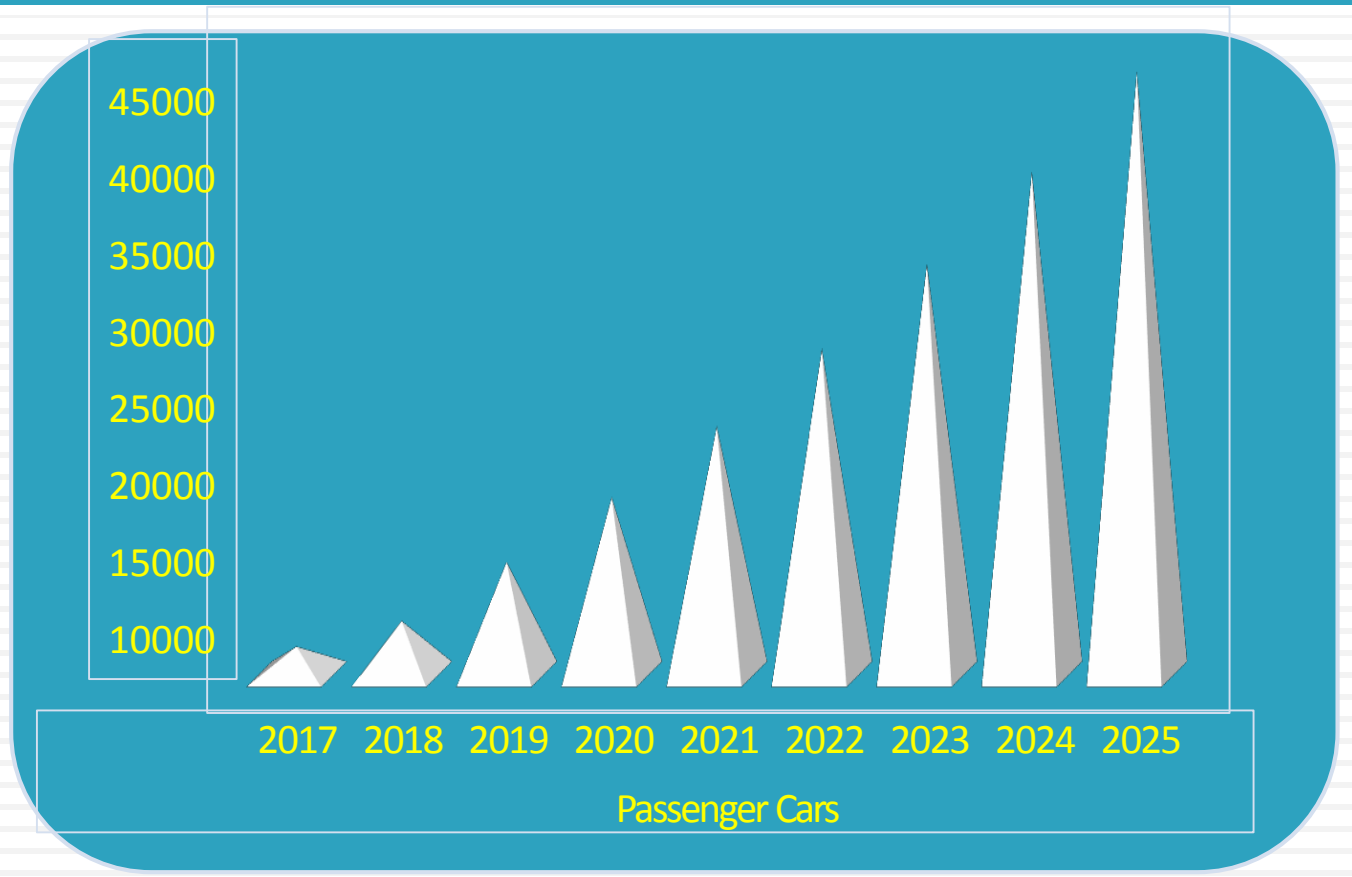
India and global xEV demand projections for 2020 (Nos in Millions)

Vehicle seg./country		2W	4W Range		Buses	Total Range	
India xEV projections 2020	Numbers	4.8	1.6	1.7	0.002	5	7
penetration of xEV India	%	15.0%	17.8%	18.9%	-	14-16%	
Total vehicle Sales India	Numbers	32	9	9	-	43	
Global xEV projections 2020	Numbers	27	5	13	0.12	32.12	40.12
Global penetration of xEV	%	35.5%	7%	19%	20%		
Total vehicles 2020	Numbers	76	70	70	0.57		
India Share as per above	%	17.8%	12.8% -30%		-		

- 2.4 million EVs to be sold by 2020
- 6% displacement of global gasoline demand
- $100/Kwh battery pack costs in 10 years

- Expect the global EV fleet to rise from 2 million vehicles today to 125 million by 2035

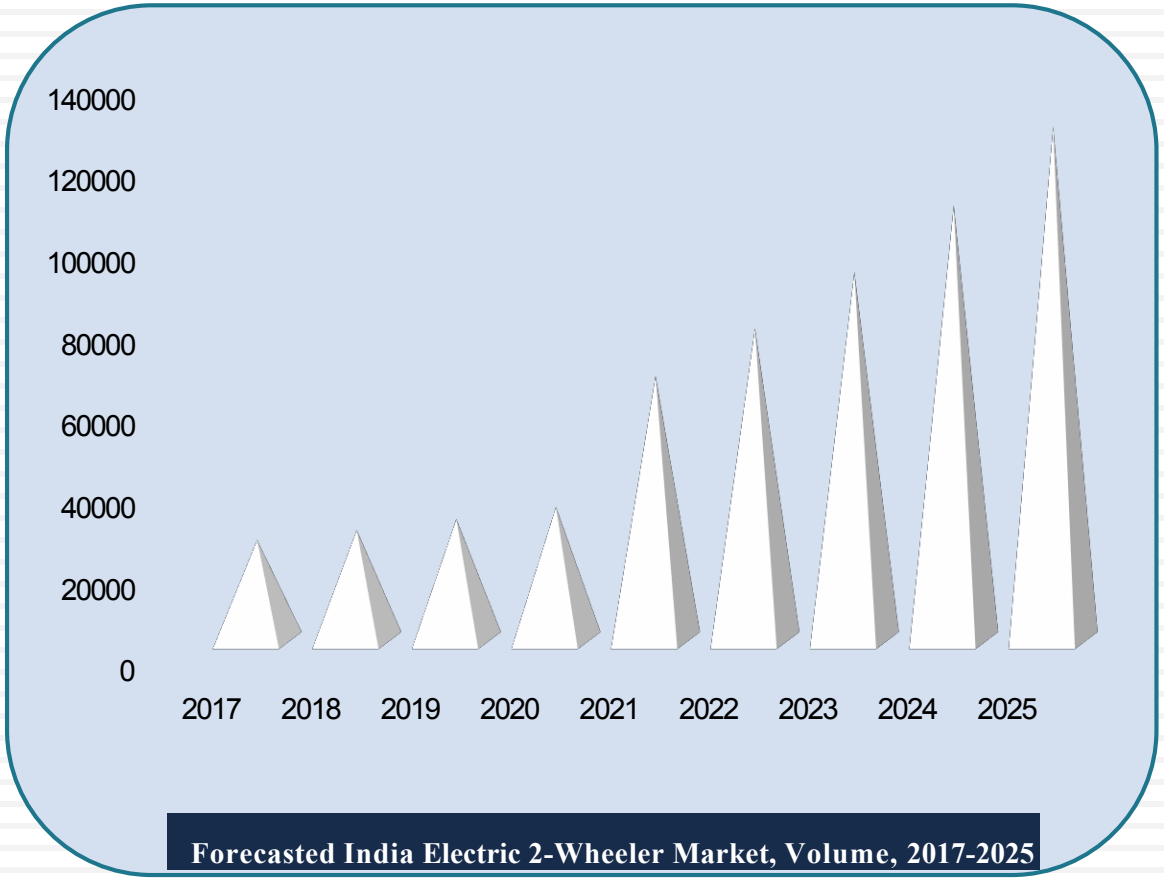
How fast will EV market share grow: India



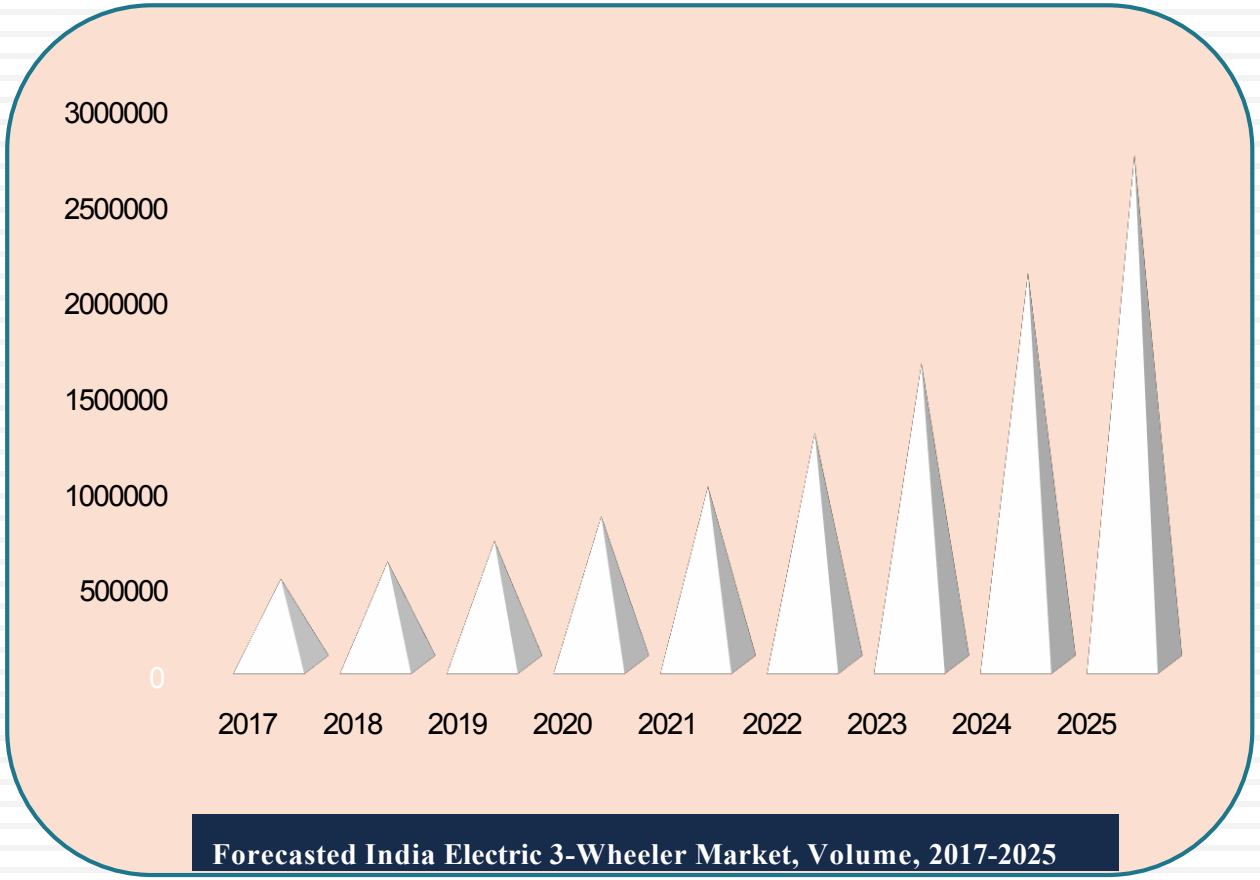
Forecasted India Passenger Car Electric Vehicle Market, Volume, 2017-2025

Source: ANS MarketPro Analytics

How fast will EV market share grow: India



Forecasted India Electric 2-Wheeler Market, Volume, 2017-2025



Forecasted India Electric 3-Wheeler Market, Volume, 2017-2025

Source: ANS MarketPro Analytics

The broad methodology for xEVs deployments

India HEV / EV Market and Challenges

Consumer Acceptability
- Detailed Consumer Research Insights

Production Capability
- Scale effects
- Technologies considered

Price-performance evolution
- Battery price evolution
- Performance evolution

Infrastructure requirement
- Power
- Charging terminals

Technology capability
- Importance of technologies for India
- India's right to win

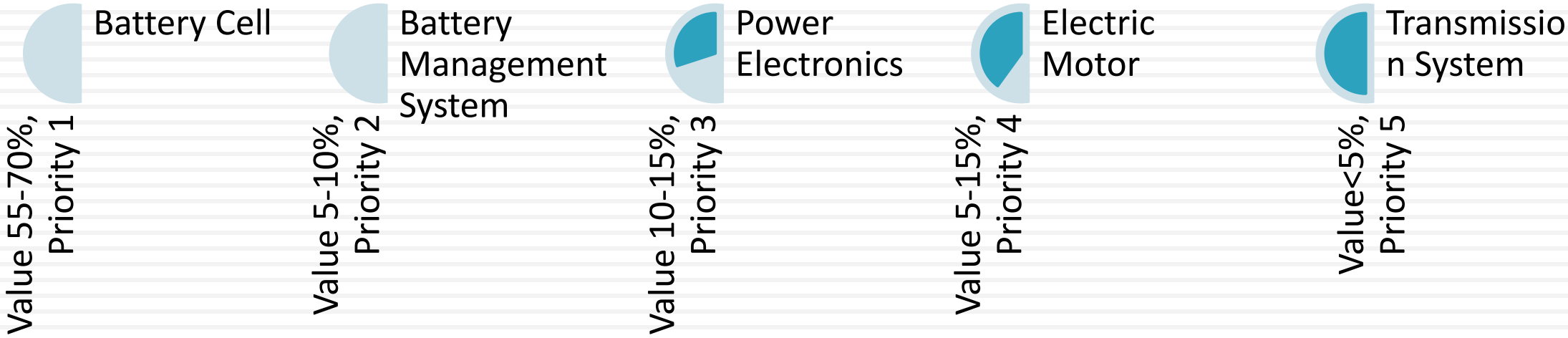
Recommended interventions

Potential framework to unlock xEV potential
- Demand incentives
- Supply incentives
- R&D
- Infrastructure

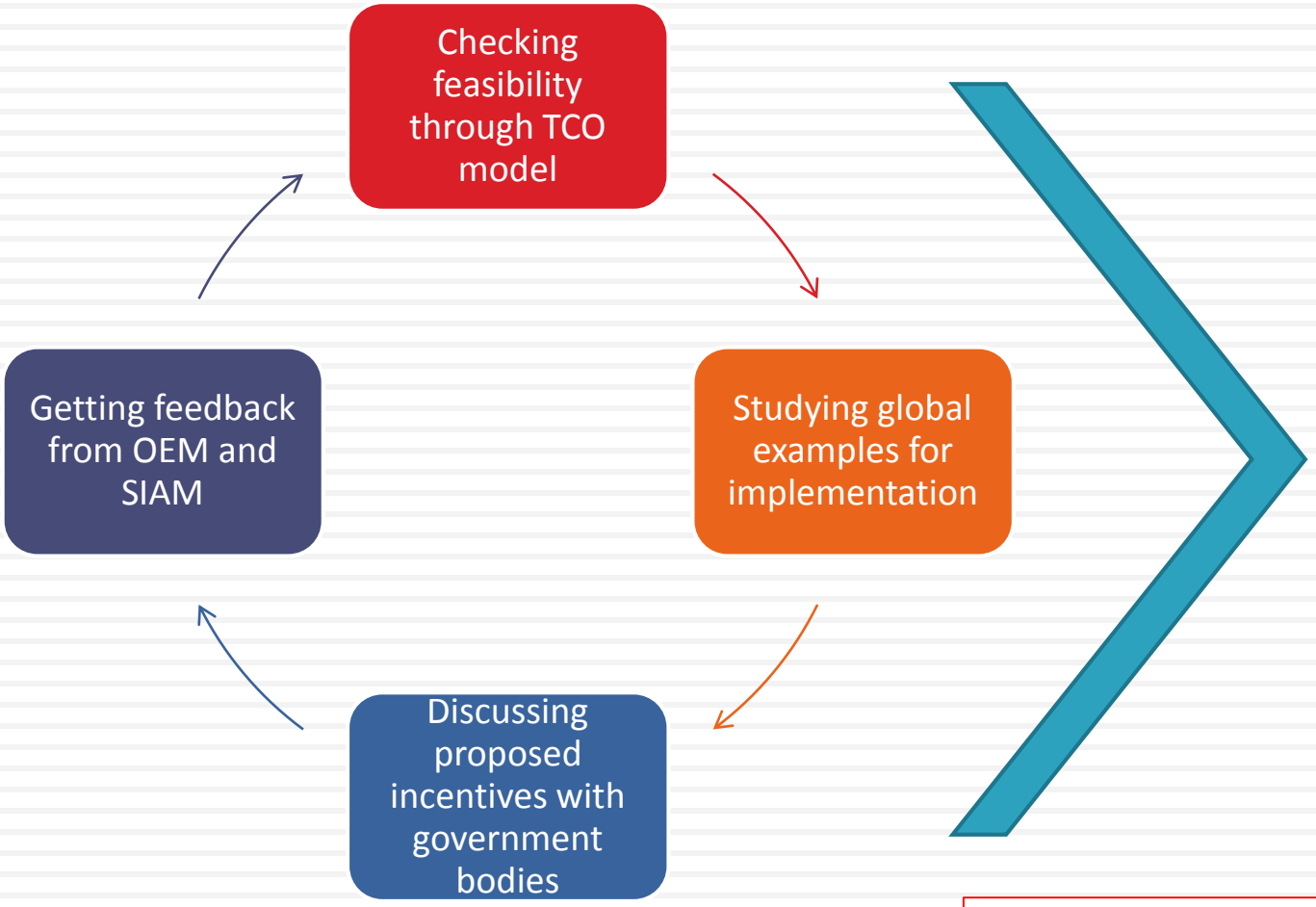
Cost benefit analysis and challenges
- Net present value
- Fuel savings
- Investments

Net benefit from xEVs
- Fuel security
- Carbon dioxide emissions
- Job creations

Technology priority areas



The broad methodology for xEVs deployments



Demand side incentives	*Promote initial sales*
Manufacturing incentives	*Promote local manufacturing*
R&D incentives	*Promote local battery and power train research*
Infrastructure support	*Develop power generation and charging infrastructure*

TCO: Totalcostofownership
SIAM: Society of Indian automotive manufacturing

Emerging Business Model for EV

Direct Vehicle Sales:

- Provide autonomy and flexibility to sell or trade the car whenever they consumers desire.
- Requires a high level of consumer education and awareness to effectively communicate the low operating cost of an EV when compared to conventional vehicles

EV Leasing:

- Ownership of the vehicle primarily remains with OEM or authorized service providers that lease out the vehicle for a predetermined period of time.
- It reduces the upfront purchase price (which is prohibitive for a large proportion of consumers in India) by spreading it over the lease period.

Emerging Business Model for EV

Battery Leasing and Swap Schemes:

- It help negate consumer concerns about battery durability and performance, while simultaneously reducing the initial/upfront EV purchase price.
- Service providers retain the ownership of batteries.
- This model puts the operational costs of an EV on par with conventional ICEs,
- It allows manufacturers to retain ownership of the battery for various '***second-life***' applications that would provide additional value
- At the end of the contracted subscription/rental period, the EVs would then return back to the franchised dealer network, giving them greater control over its assets
- Manufacturers, battery suppliers and service operators can partner to collectively develop 'battery swap/ switiching stations

Emerging Business Model for EV

Infrastructure Service Models

Public Infrastructure Model –

- Provides EV station at public parking spaces.
- Only EVs are allowed to park at these spots, they are likely to act as an incentive to consumers in urban cities.
- This model would have to be supported by local municipalities in partnership with infrastructure providers.
- It seeks to provide access to charging for those consumers that lack home charging.

Private Infrastructure Model –

- More preferable in the early stages of EV adoption as it responds to direct consumer demand.
- It involves installing charging points for EV adopters at their residence or at private sites such as malls, office parking etc.
- This ensures higher usage of charging points based on actual demand, as reflected by EV purchases, thus providing a greater return on investment.

Emerging Business Model for EV

End-to-End Solution –

- Involves close partnerships between OEMs, infrastructure facility providers, maintenance services providers and local Governments
- provide consumers with an integrated package of end-to-end value added services, ***thereby minimizing the number of interfaces that the consumer has to manage.***
- ***Evolve as a subscription service*** where EV adopters pay a monthly/annual fee for an integrated services package that involves access to charging facilities, vehicle maintenance services and free parking at public pay-and-park lots, that are managed by local municipalities

Road Blocks for Charging Infrastructure in India

- EVs are to be taxed at 12%, hybrid vehicles are taxed at 28% plus a 15% cess.
- Consumers are more likely to try hybrid vehicles, but that sector is not being encouraged by the current tax structure
- Most of the chargers being installed across the country, however, are AC chargers.
- Battery technology is yet another aspect that needs to be looked into
- Yet another issue is that simply shifting the fleet to electric will not address the impact on the environment.

Viability of xEVs in India: A Public Opinion Survey

Survey methodology

The survey was conducted majorly at events-

- EV Boot Camp, AMU, Aligarh, 2016
- ISGF week 2016, New Delhi
- SIAT, ARAI, Pune, 2017

SURVEY FOR ELECTRIC VEHICLE VIABILITY IN INDIA – A PUBLIC OPINION

Name: ..... **Designation:** .....

Email: .....

1. Type, Brand and Model of your current Vehicle:

.....

2. What is your general opinion on the future of Electric Vehicles (EVs) in the Indian scenario?

a). They will completely replace gasoline-powered cars in the following years

b). They will be a part of the transportation system but will never take over the throne from the gasoline-powered vehicles

c). They will always be limited to research and will remain beyond the reach of masses.

3. Assuming EVS reduce the cost per 100km of driving (initial car price and maintenance cost neglected), how much reduction would be enough for you to switch to an EV in India?

a). up to 10% b). up to 25%

c). up to 50% d). up to 100%

4. How much more would you be willing to pay for a new EV instead of new gasoline-powered vehicle?

a). up to 10% b). up to 25%

c). up to 50% d). up to 100%

5. What according to you are the main reason for people not buying an EV in India?

a). Not interested in a new car at all/ I am perfectly satisfied with my current vehicle

b). Expensive when paralleled to conventional Internal Combustion cars

c). Lack of charging infrastructure

d). Lower range with fully charged EV available as compared to fully tanked gasoline vehicle

e). Reason not mentioned above

6. In case you owned an EV, where will you be charging it?

a). Home/Parking lot of an Office or Apartment b)/ Public Charging Infrastructure

7. In case you went on a longer trip with an EV, would you consider using only superchargers i.e. pulling over for half an hour every 200km in order to recharge at nominal cost, or would you insist on using a battery swapping station as a mean for receiving a full charge within a minute and pay higher tariff?

a). I am perfectly fine with only superchargers

b). I would like to have a choice, but I would always use a supercharger as it is cost effective

c). I would definitely use a battery swapping station whenever I can, even if it is costlier than supercharger.

Survey Results

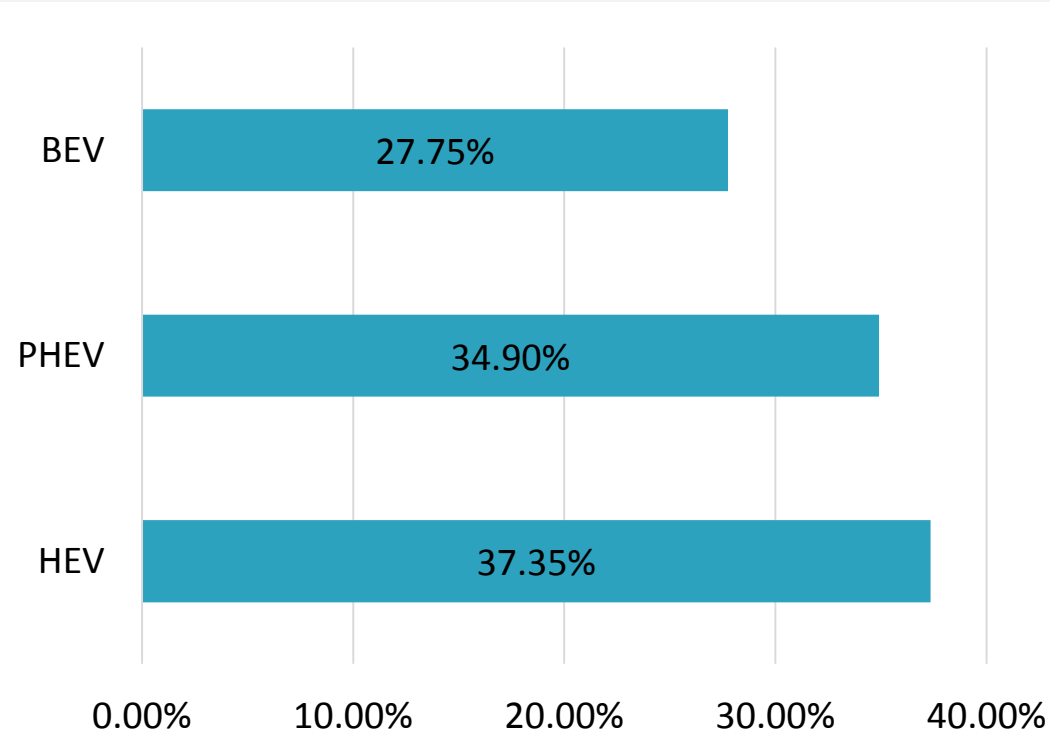


Fig: Demand for different xEVs type

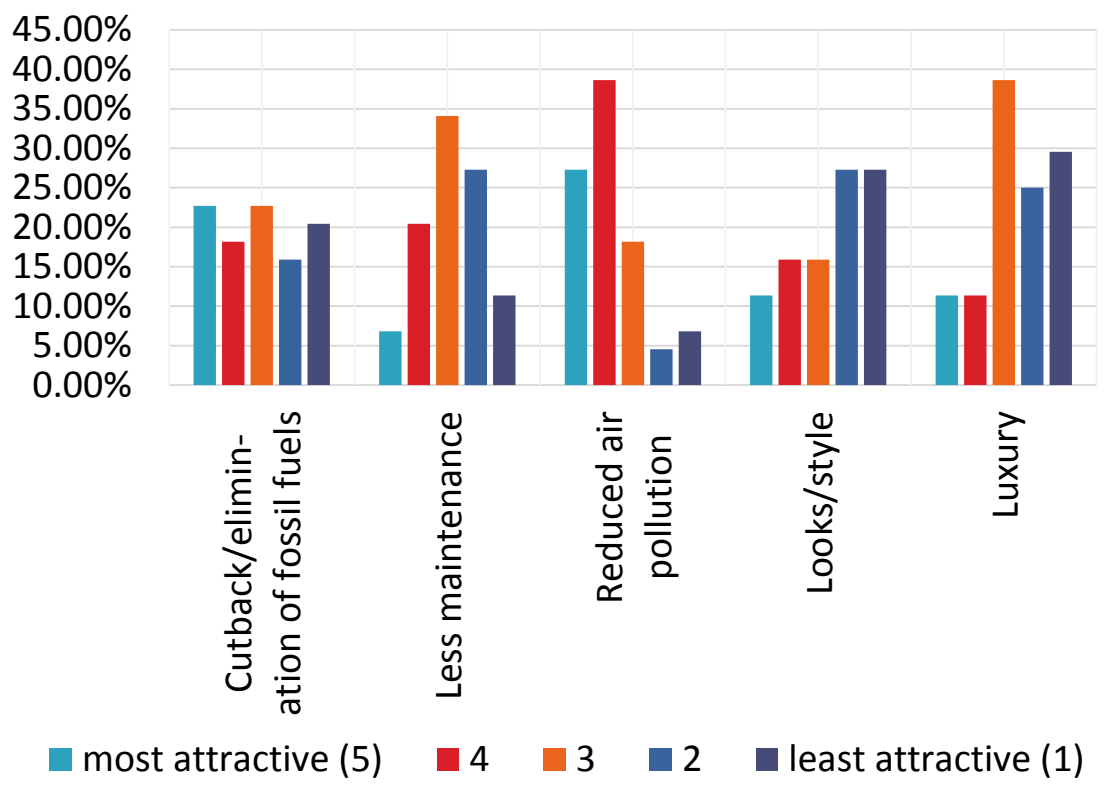
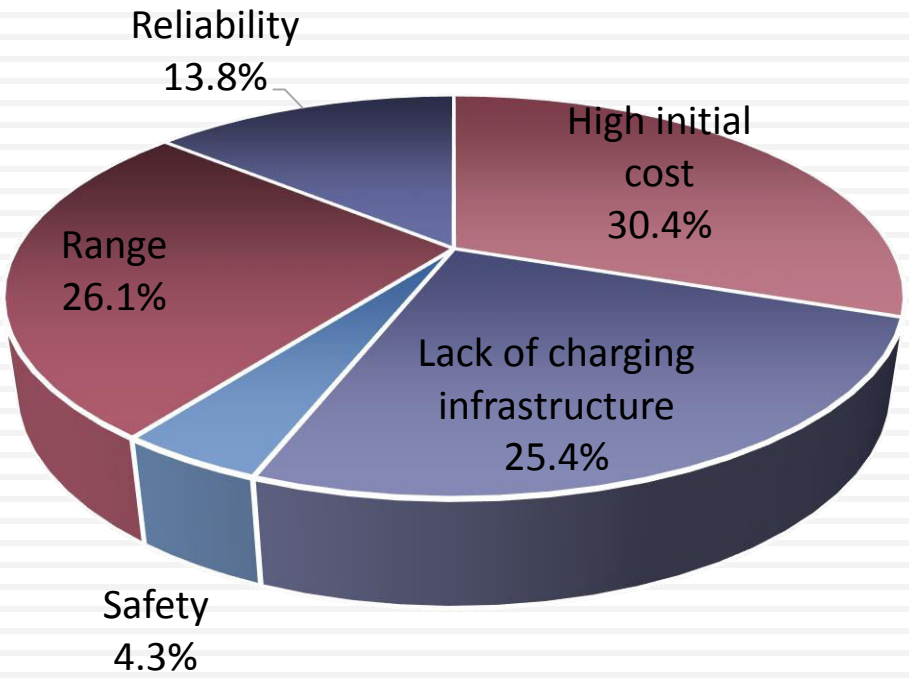
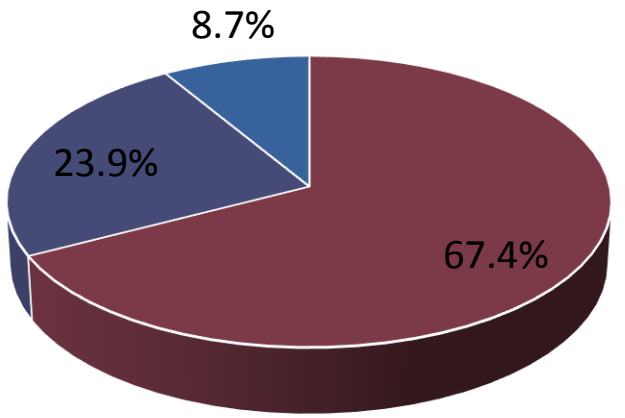


Fig: Key characteristics of xEVs

Survey Results





- Will be limited to research only
- Completely replace ICE vehicles
- Will be part of transportation system but only next to ICE vehicles

Potential solutions

- Advertising of vehicle manufacturer, internet resources etc. should be made available for consumers for decision making.
- Using media and social networks, public attitude can be influenced for non-financial advantages of adopting xEVs.
- Opportunities to develop local EV experience facility to offer essential test-drive prospects can be explored.
- By adding xEVs to public fleets and establishing charging infrastructure at various facilities, visibility and confidence of masses in GoI's initiative can be improved.
- Other measures include bigger investments in xEV technology, infrastructure and battery swapping programs, strong warranties on the xEV batteries and tax waiver to reduce the cost of xEVs.

QUESTIONS for Workshop Participants

Barriers ?

Road Blocks??

Solutions……

CENTRE OF EXCELLENCE FOR CHARGING INFRASTRUCTURE

CENTRE OF ADVANCED RESEARCH IN ELECTRIFIED TRANSPORTATION
ALIGARH MUSLIM UNIVRSITY

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UNDER FAME MISSION

EXPLORING…….

- AVENUES FOR COLLABORATION
- CONSORTIUM PARTICIPATION

Any questions?

Thanks!