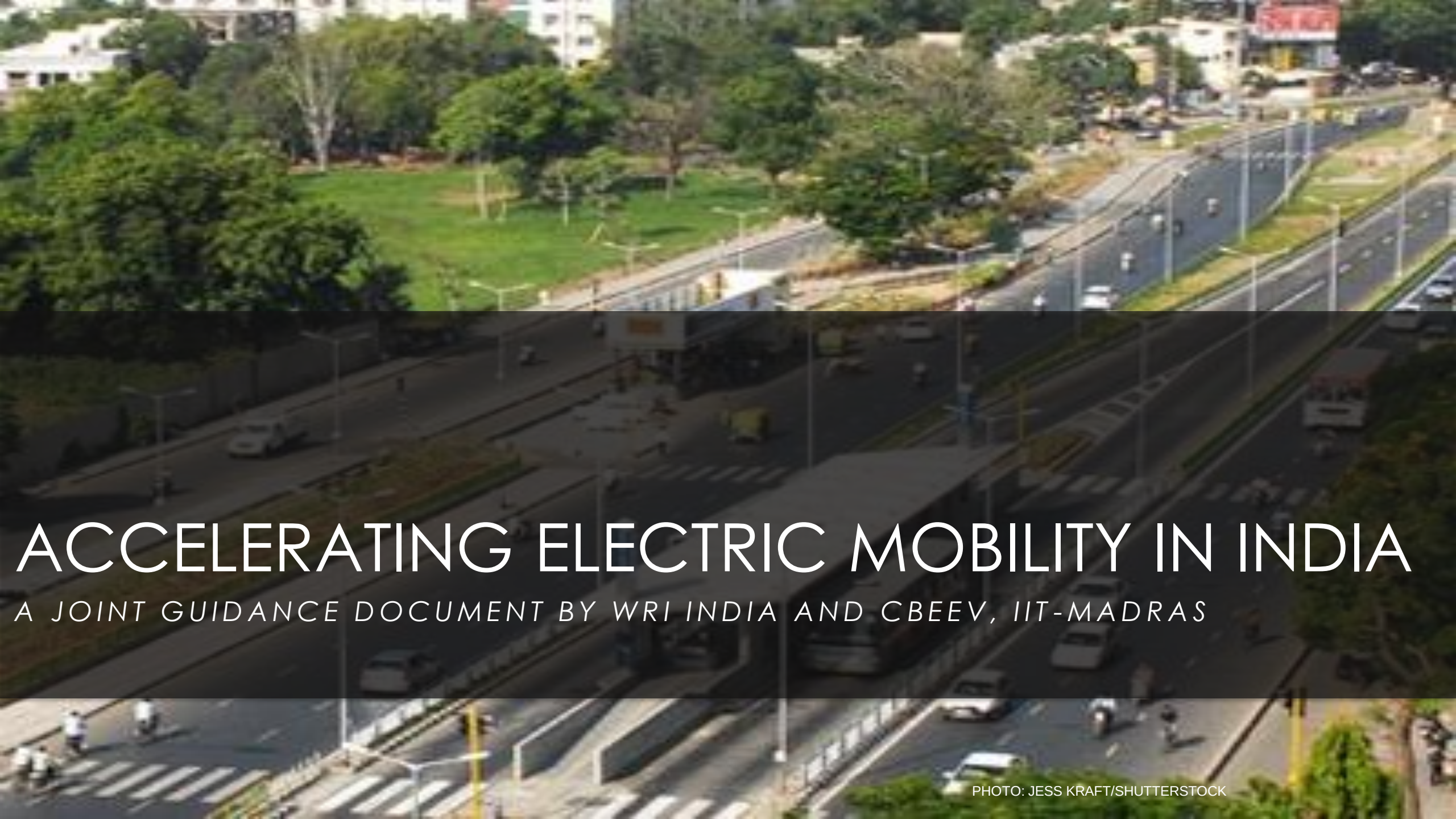


ACCELERATING ELECTRIC MOBILITY IN INDIA

A JOINT GUIDANCE DOCUMENT BY WRI INDIA AND CBEEV, IIT-MADRAS

PHOTO: JESS KRAFT/SHUTTERSTOCK

AUTHORS AND GRANTERS

Authors

WRI India

WRI INDIA

Center for Battery Engineering EVs (CBEEV), IIT Madras

Granter

Shakti Sustainable Energy Foundation (SSEF)

SHAKTI SUSTAINABLE ENERGY FOUNDATION

Cleaner energy. More power to India.

WHY THIS GUIDANCE DOCUMENT?

Three-fold Objective

01 Inform state and local officials, and other stakeholders, who may have embryonic knowledge, about the basics of electric mobility and what it involves

02 Present pros and cons of different options (e.g. hybrid Vs Pure EV or Swapping Vs Charging) in a neutral manner for informed decision making

03 Present a road map for making things happen at the city level

5 PARTS TO THIS GUIDANCE DOCUMENT

Part 1: Understanding India: Potential gains and unique features
Part 2: Pillars of an electric mobility eco-system
Part 3: Road map for electrification of transport in the Indian context
Part 4: Public policy measures in India and international regions
Part 5: Business models for different re-energising systems

POTENTIAL GAINS FOR INDIA

Social, Environmental and Economic

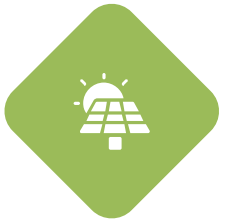
Better air quality

Improving public health in cities

GHG mitigation

Towards a greener India

Promotes renewables



Through EV batteries

Enhances energy security

Reduces imported fuel use in transport sector

Increases Plant Load Factor

Increases efficiency of power plants

Technological leadership

Position India as a leader in auto-tech

IMPROVED AIR QUALITY IN INDIAN CITIES

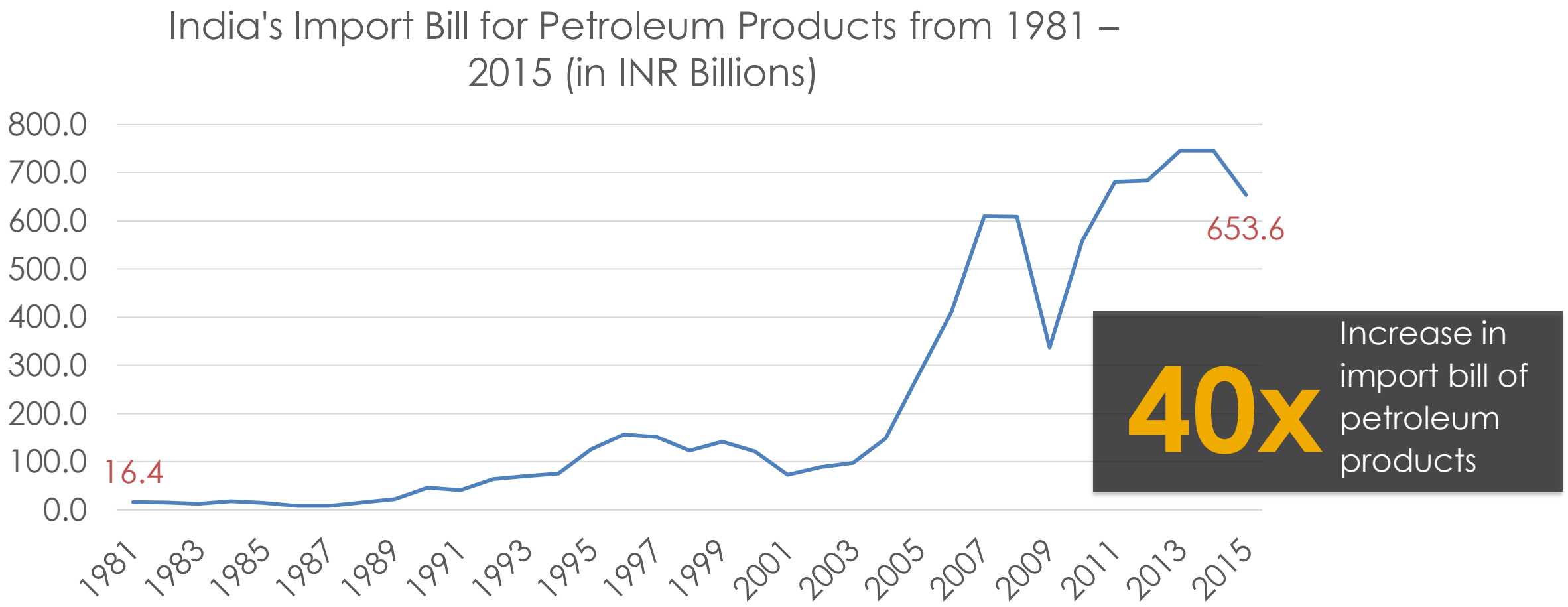
14 Out of the 15 most polluted cities of the world are in India

36% Of NOx emissions in Delhi were due to vehicles in 2016

20% Of PM2.5 emissions in Delhi were due to vehicles in 2016

The Economist, 2018

REDUCED DEPENDENCE ON IMPORTED FUEL



Consumption of petroleum fuel: 32.5 million tonnes in 1981 → 184.7 million tonnes in 2015.

Indian Petroleum and Natural Gas Statistics

REDUCED GREENHOUSE GAS EMISSIONS

- 35% of India's electricity is from non-coal sources
- Will improve as share of electricity from clean sources goes up
- India is already committed to increasing renewables; Energy mix to be cleaner with more and more electric storage brought in by EVs

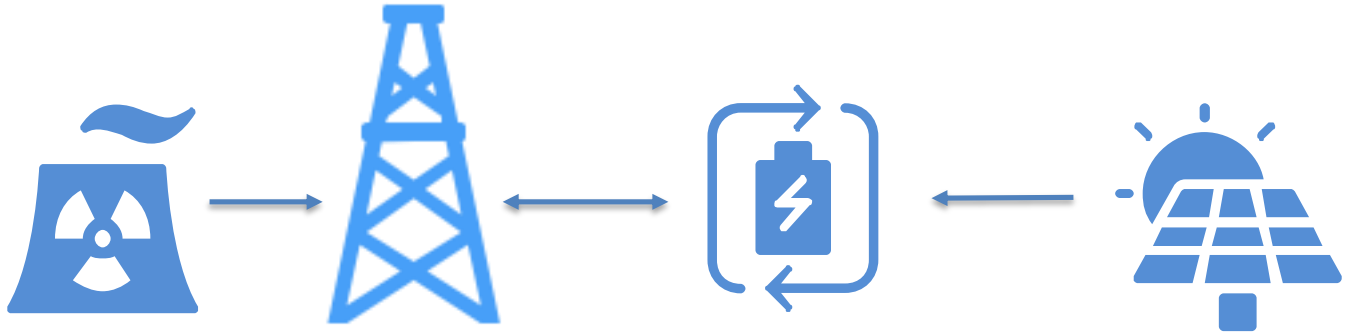
EV BATTERY: BENEFITS RENEWABLES AND POWER GRID

Improved Plant Load Factor (PLF)

- EVs may create additional off peak demand
- Help power plants attain greater efficiency
- All-India PLF in March 2018 = 65.33;
- Hence, utility companies are entering charging infrastructure business

Increased share of renewables

- Solar and wind are intermittent
- Batteries can store renewables for prolonged use
- Retired batteries for stationery usage



LEAD THE RAPIDLY CHANGING GLOBAL MARKET

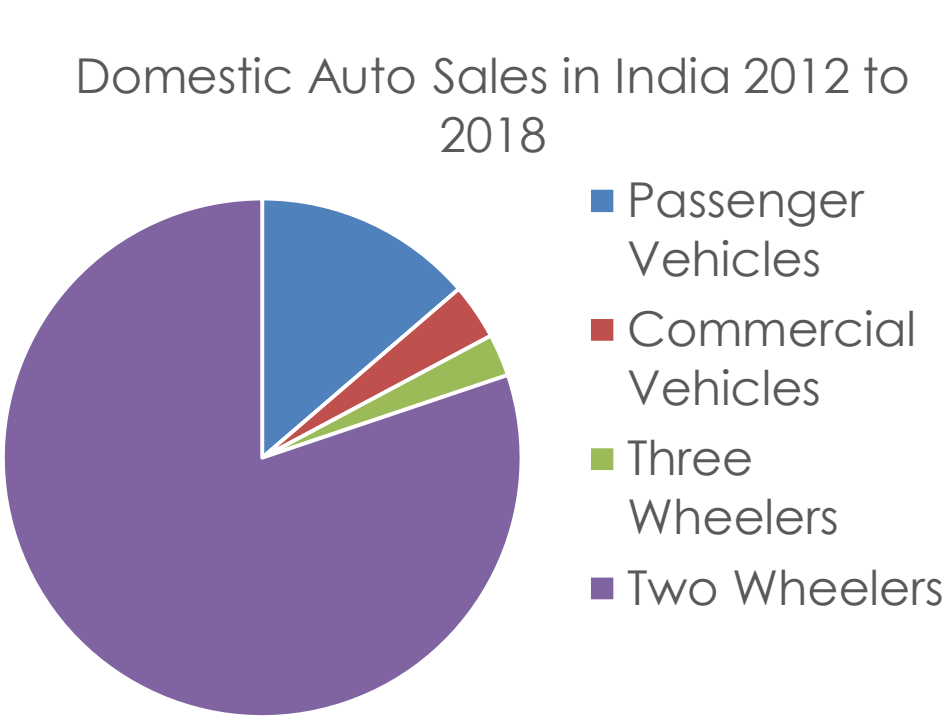
- India's auto industry -> 30 million jobs, 7.1% of GDP
- Timely shift – relevance in global and domestic markets
- Get technology leadership in at least some segments
- Do things differently from the way it is being done elsewhere
- No mineral reserves for lithium and cobalt; prevent dependency on battery imports

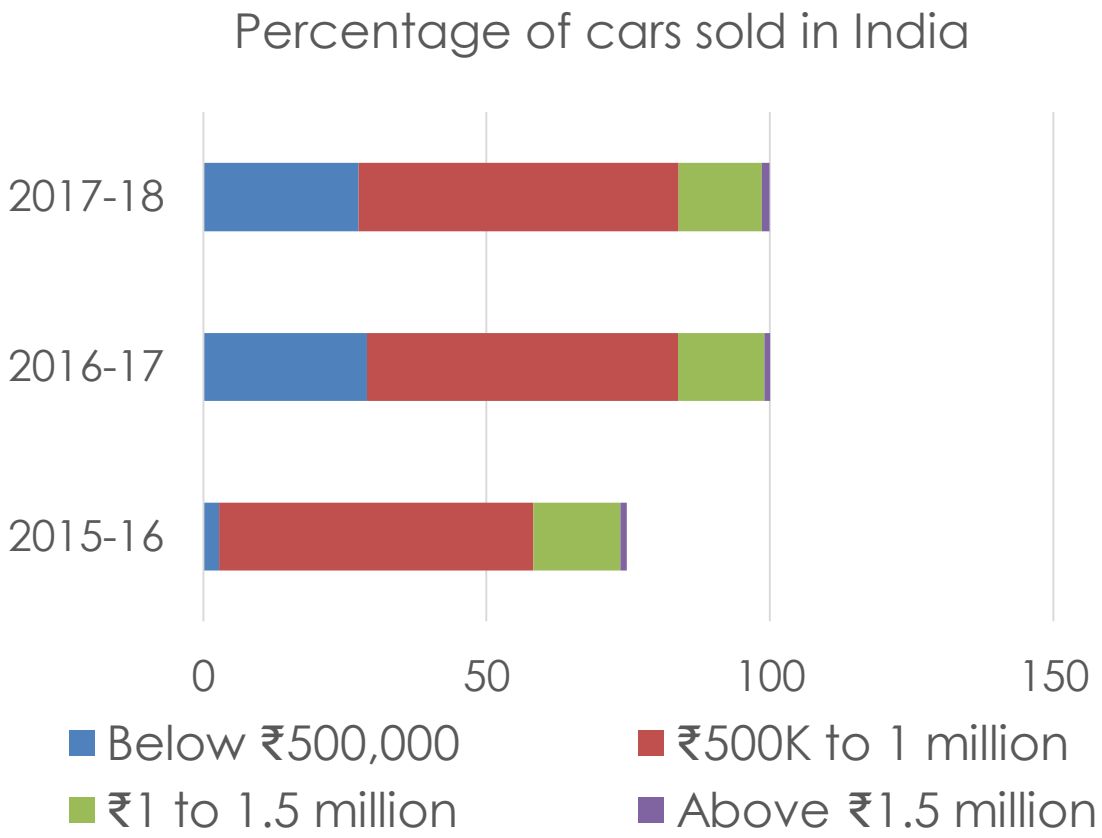
PROFESSOR JHUNJHUNWALA TO PRESENT FROM HERE ON

INDIA'S UNIQUENESS

- Small and affordable vehicles
- Drives slower and smaller distance a day
- Have higher temperatures
- Have higher interest costs
- Can not afford to subsidise as much

COMPOSITION OF THE VEHICLE FLEET





- 98% of the vehicles:
  - small and affordable vehicles (two-wheelers and economy cars)
  - public transport
  - goods vehicles (three-wheelers, small goods vehicles, buses and trucks)
- Only 2% of the vehicles are high end cars, unlike in developed countries

SIAM 2017, Jhunjhunwala and Kaur 2018

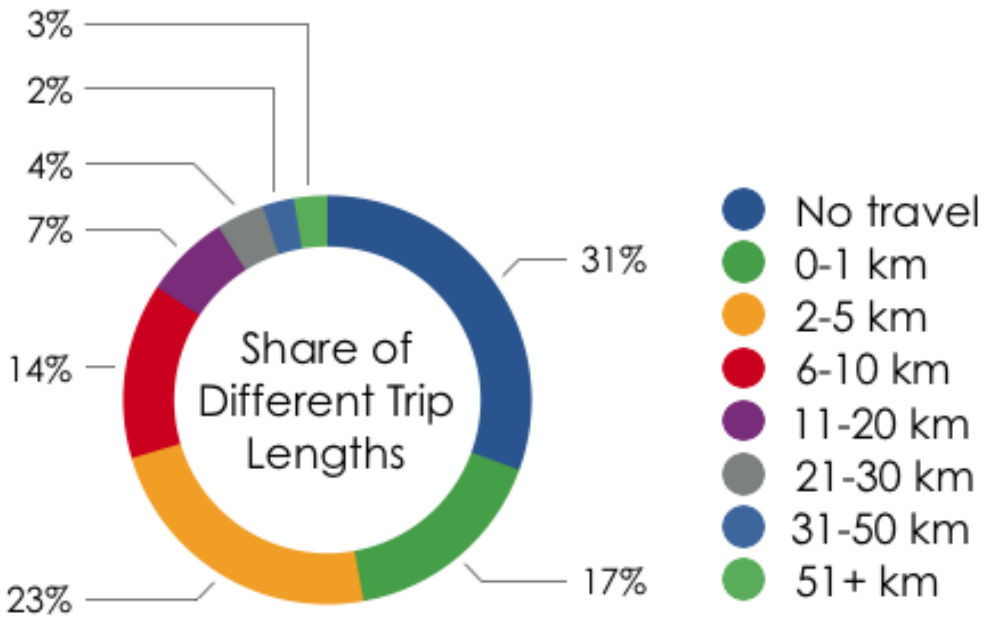
DOMINANT TRAVEL MODES

Dominant travel modes in cities with 5+ Million population	
Walking	15-35%
Public transport	30-60%
Motorized 2-wheelers	10-22%
Motorized 3-wheelers	5-15%
Cars	5-15%

In smaller cities: share of walking and motorized 3 and 2 wheelers is greater than that of cars and public transport

NTDPC, 2013, p. 387

TRIP LENGTHS



- High urban densities. India lives and moves differently.
- An average vehicle would travel much less in India as compared to the developed world

71% **Of the trips are of less than 5 km**

16% **Of the trips are of length greater than 10 km**

Takeaway Short trip lengths mean that EV owners can do several journeys on a single charge. Policy decisions on battery size and range for electric vehicles will need to account for this

Census 2011

TRAVEL SPEEDS AND AMBIENT TEMPERATURES

- India's average vehicle speed in a city is less than 25 kmph
  - Significantly different from developed countries where avg speeds are 40 to 60 kmph
- Ambient temperature: exceeds 40 °C and sometimes even 45 °C.
  - Excessive heating and cooling severely impacts battery life
  - Shorter battery life -> frequent replacement -> increased costs of ownership

Takeaway Policies should promote vehicles and battery packs designed to function in these conditions

INDIA'S NEEDS A DIFFERENT APPROACH FROM THE WEST

- EV costs today may be 1.5 to 2 times or even more of petrol vehicles
  - Battery pricing falling rapidly: but will take considerable time for parity
  - Our affordability is low: most can not afford expensive EVs
  - Up to 40% subsidy in US, China and Europe, bringing down the gap
    - Subsidy in India will be limited
- India's approach has to be different
  - If we wait for battery prices to fall, we will land up importing vehicles and technology
  - Will hurt our GDP and jobs

HOW INDIA'S APPROACH CAN BE DIFFERENT

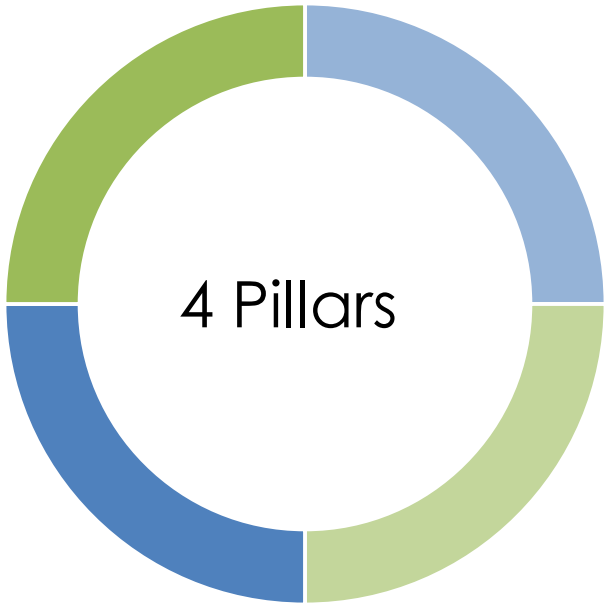
While no options are closed, India's approach could be different.

- World uses large battery to overcome range-anxiety: increase costs / weight
- We can not afford it and will do it differently
  - Make vehicle lighter and more energy efficient to reduce battery size
  - Use small batteries and not large in affordable vehicles
    - Will often tackle range anxiety by battery swapping rather than Fast charging
    - Use lower-cost NMC / NCA batteries: even if they can not be very-fast charged
  - To maximise battery life, we will tend to charge slow, rather than fast
  - To handle higher temperature impacting battery-life, we will charge swapped battery after cooling in a conditioned environment
  - Will convert battery capital costs into operational costs as charged battery is leased
    - A Battery not dedicated to a vehicle and therefore usage not limited to a single vehicle: larger use of a battery reduces interest costs in a high interest-rate environment
    - Battery used for longer hours imply faster depreciation and replacement in shorter time frame – works well in falling-costs situation
  - Overall make EV capital costs similar to that for petrol-vehicles and operational costs for EVs equal or lower than that for petrol vehicles with swapping

PILLARS OF AN ELECTRIC MOBILITY ECOSYSTEM

ELECTRIC VEHICLE
All-electric, plug-in hybrid, hybrid

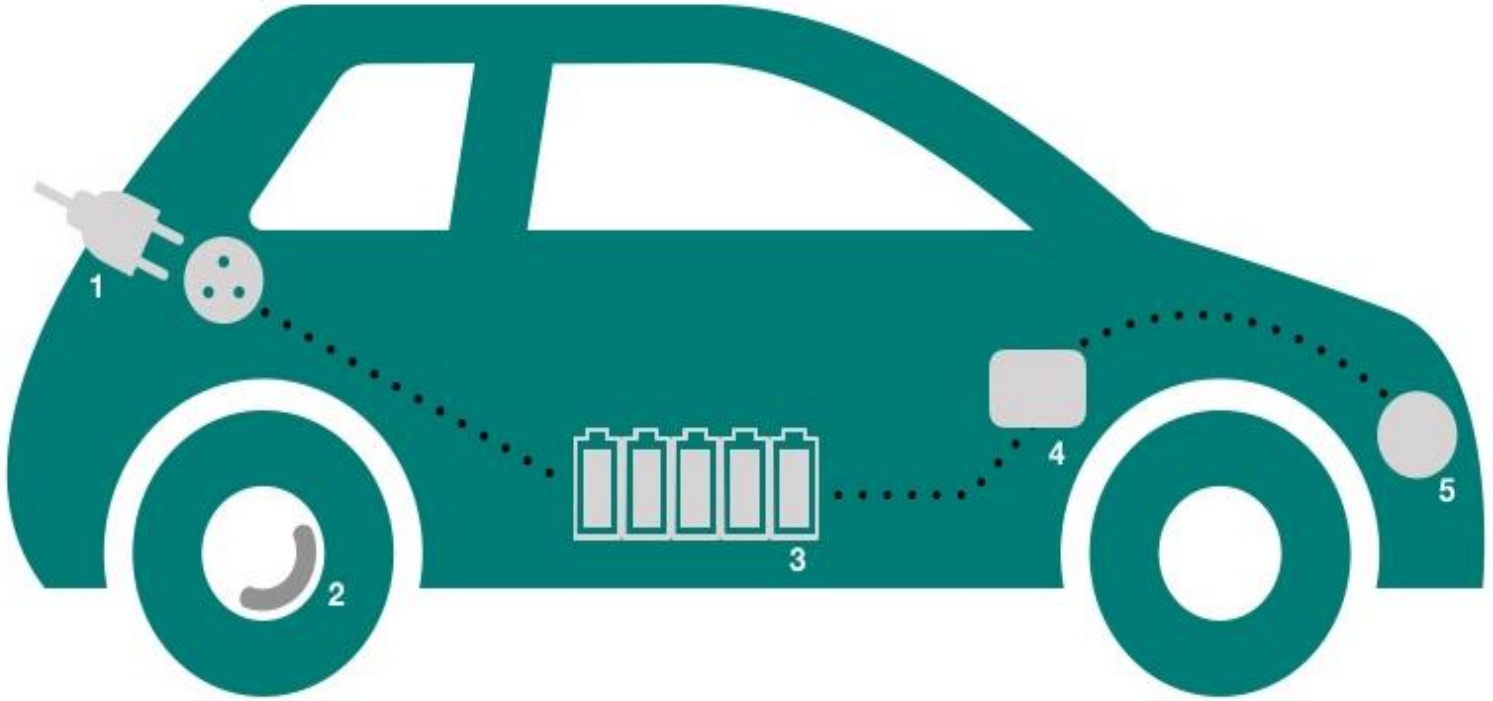
RE-ENERGISING SYSTEMS
Charging and swapping infrastructure



BATTERIES
Lithium Ion batteries – NMC, LTO, LFP
Battery Management System

OTHER FACTORS
Manufacturing capacity, research and development, power grid

THE ELECTRIC VEHICLE

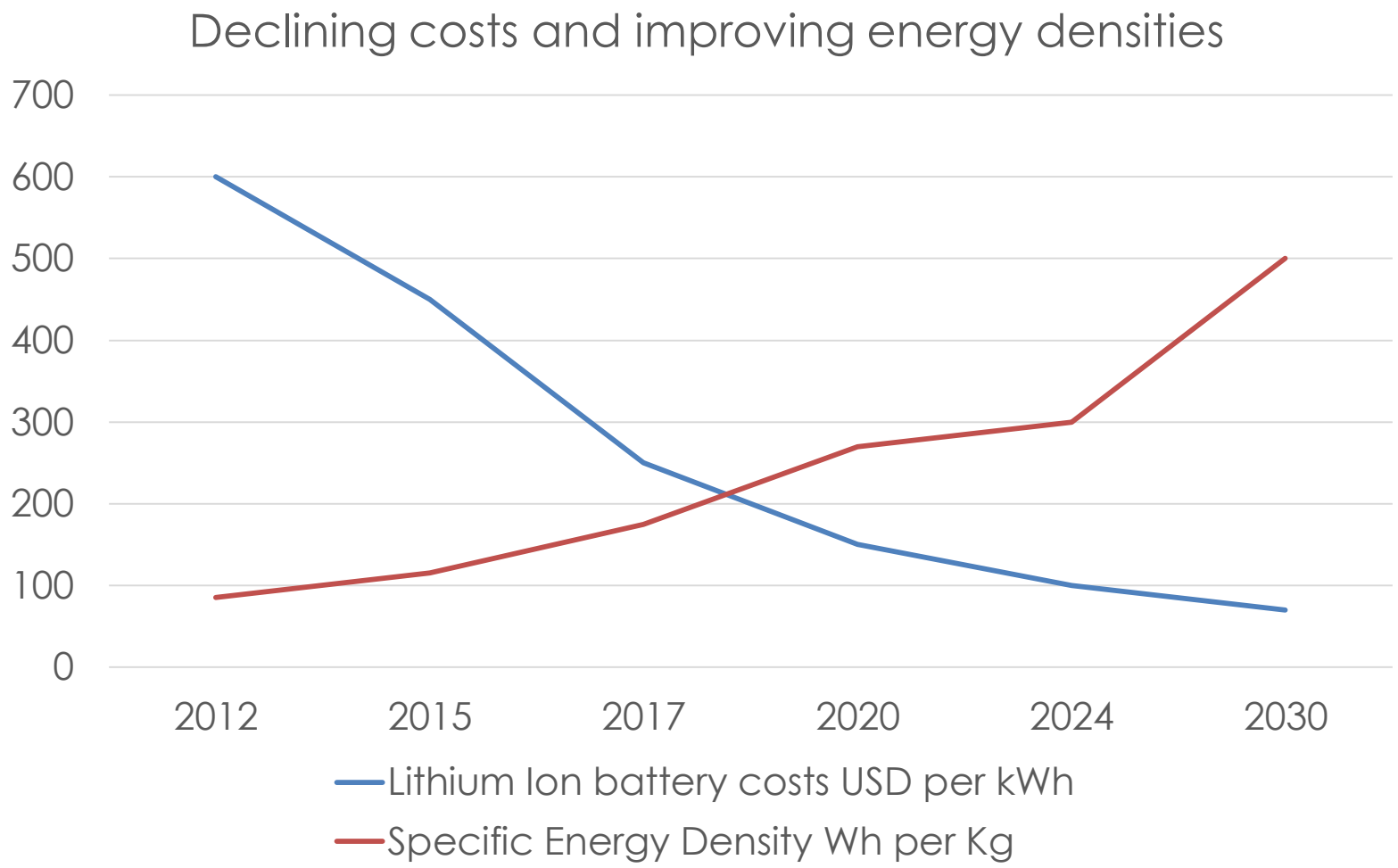


1. **Plug:** Used for plugging into electric outlets at home or at a public charging station
2. **Regeneration brakes:** Capture energy lost when braking and store it in battery
3. **Rechargeable battery:** Energy storage unit of the car; built from chemical cells
4. **Controller and electronics:** Regulates the supply of power from the battery to the electric motor
5. **Electric motors:** Obtains electrical energy from the battery to move the steering and power the vehicles

Source: Authors

BATTERIES

- Account for 50% of vehicle cost
- Falling battery prices and rising energy densities



COMPARISON BETWEEN VARIOUS LITHIUM ION BATTERIES

	Unit	Nickel Manganese Cobalt (NMC)	Li Titanate Oxide (LTO)	Li Phosphate (LFP)
Cost of Cells	USD per kWh	130	400	175
Energy-density	Wh per Kg	250	<100	125 -150
Charge-Discharge Cycles	Number	2500	10000 +	2500
Charging Time without impacting life	Mins	45 to 60 mins fast charge	10 to 20 mins	45 to 60 mins
Impact of Fast Charging	--	Impacts appreciably	No impact	Impacts appreciably
Bulkiness (Size and Weight)	--	Compact and low wt	Large size and wt	Medium size and wt
Impact of high temperature (45 deg C)	--	High	Low	Medium
Inherent Safety	--	Low	High	Medium

FACILITIES FOR RE-ENERGISING BATTERIES

Charging

- Slow charging (at-home or designated parking spots in universities or offices)
- Fast charging (at public stations)

Swapping

- A discharged battery is exchanged for a charged battery at swapping facilities.

Range Extension

- Intermediate option

Image source: PulginIndia (left), Nikkei Asia (right)

SLOW CHARGING, FAST CHARGING AND RANGE EXTENSION

Slow Chargers

- Charge batteries at 0.1C to 0.2C
- Charge batteries up to 80-90% of capacity in 4 to 8 hours
- Best for preserving the life of any kind of battery

Fast Chargers

- Charges batteries fully in about an hour.
- Can be AC or DC
- Need an external charger which converts AC input to the DC output for charging the battery

Swapping

- Swapping a discharged battery with a fully charged one
- Takes only few mins; eliminates waiting time for drivers
- Battery cost is separated from vehicle's
- Battery is owned by an Energy Operator (EO) – gives charged battery as a service

Slow Charging with Range Extension (RE)

- Charge batteries at 0.1C to 0.2C
- Charge batteries up to 80-90% of capacity in 4 to 8 hours
- Best for preserving the life of any kind of battery

SWAPPING BATTERY MAKES BUSINESS SENSE

An Energy Operator (EO) purchases battery and leases charged batteries taking into account depreciation, interest costs and charging and swapping costs

- Most sensitive element impacting charge per km is vehicle efficiency (km/kWh).
- Battery costs per kWh, battery life cycles, air-conditioning costs and electricity costs matter

- As price of battery decreases, swappable battery could cost lesser
  - margins for energy operator would improve
- As swappable Batteries have small life of about 4 years, early-investment not much affected

Swapping will work, only when a user finds close-by station to swap batteries

- In the beginning, existing petrol stations could be used side-by side selling petrol
  - Next, expand to more stations as demand grows

For an electric bus, swapping facility could be installed and operated at the bus-depot

- To begin with few routes of one depot can be fully electrified and be given swapping infra
- Gradually all routes and all buses of the depot can be electrified

OTHER FACTORS

- Manufacturing
  - Vehicles, battery pack assembly, controllers, motors
- Research and development
  - Industry, academia and government tie-ups
- Impacts on the Power Grid

DR OP AGARWAL TO PRESENT FROM HERE ON

WHAT ARE THE CHALLENGES WITH ADOPTION OF ELECTRIC MOBILITY IN INDIA?

CHALLENGES → **STRATEGY** → **THREE PHASED ROADMAP**

Limited Driving Range
Long Recharge Time
High capital cost
Resistance to Change
Availability of battery materials

Recognize India's uniqueness
Adapt to our context
Delink capital cost of battery from that of vehicle

I Pilot
II Scaling-up
III Self Propelled

ROAD MAP FOR ELECTRIFICATION

PILOT PHASE

- Short phase
- Vehicles with high demo value are deployed
- Intra city bus fleets
- Fleet cars belonging to public agencies
- 2 and 3 wheelers with RE-swap and battery swap

SCALING -UP

- Incentives and persuasion to reach tipping point
- May need financial incentives
- Free parking, easier permits, feebates, low off peak electricity charges
- public investment in charging/swapping
- Good candidates: auto rickshaws and small taxi owners

SELF - PROPELLED

- Technology is established
- Used by people in normal course
- All parts of e-mobility will have become financial sustainable

POLICIES AND REGULATIONS - WHAT IS NEEDED?

- Comprehensive action on many fronts
- Recognition:
  - public good of electrification > price disadvantages to market
- A strong case for public policies to:
  - Absorb the price risks of a new technology
  - Bring it to parity with its traditional counterpart

EV POLICIES OF STATE/REGIONAL GOVERNMENTS IN INDIA

Demand side interventions

- Purchase incentive for EVs
- Higher taxes on diesel and petrol cars,
- Scrapping incentive to ICE vehicle owners,
- Creating app-based cab aggregation, Subsidies for purchasing last mile electric vehicles (e.g. autos)

E.g. Delhi Electric Vehicle Policy 2018

Supply side interventions

- Incentives to EV and battery manufacturers
- Creating EV manufacturing zones
- Reimbursing 100% land conversion fee
- Faster approval of applications for setting up charging stations
- Zero wheeling charges for supplying renewables to re-energizing stations

E.g. Telangana, Karnataka, Maharashtra

POLICIES AND REGULATIONS – WHAT EXISTS INTERNATIONALLY?

The Case of Norway

- EV policy part of the larger GHG abatement goal
- ZEV policies began in 1990s
- BEVs = 47% of fleet in 2018
- Political unity on 'polluter pays principle'
- Stringent green tax system -> all new cars sold by 2025 are either zero or low emission
- Exemption from purchase tax, road tax
- 100% government support for installing normal and high power charging

POLICIES AND REGULATIONS – WHAT EXISTS INTERNATIONALLY?

The Case of Shenzhen, China

- 100% electric bus fleet
- National and local subsidies
- Buses are leased to cut costs
- Cooperation between bus operator and charging infra provider
- Charging facilities to private cars as for optimal use of the system

WAY FORWARD

- Several States have already formulated EV policies
- Actions towards implementation will require coordinated action by multiple departments
- Need for a multi-department and high level EV mission in the State to oversee and direct implementation
- A detailed road map needs to be developed in one or two cities by the states
- This will include decisions on:
  - Vehicle segments to be electrified in the first phase
  - Identifying locations for charging and swapping facilities
  - Inviting potential businesses to set up charging and swapping facilities
  - Awareness campaigns

QUESTIONS

PROS AND CONS OF SLOW AND FAST CHARGING AND RE

	EVs with Slow + Fast Charging (EV-F)	*EVs with swapping (EV-S)*	*EVs with slow charging plus range-extension swapping (EV-RE)*
Battery Size in kWh	Medium to Large	Small	Small
Cost of Battery for vehicle-owner	Medium to Large	Nil (Energy Operator will invest in battery)	Small
Home Charging time and impact on Battery-life	Night time 6 hours: best for battery	NA	Night time 6 hours: best for battery
Infrastructure required at home	15A power plug	None	15A power plug
Range Extension by	Fast Charge	Swapping	Add-on battery swapping
Wait-time for range extension and impact on battery life	1.5 hours low impact <30 min severe impact	Few minutes	Few minutes
High temperature (45°C) Impact	High	Low	Low
How often range extension required	Could be less than 5%, if vehicle has large battery	Frequently	5 to 10%
User Convenience	Range extension pain	daily swapping pain, but no home charging	High
Can you go unlimited range?	Not unless you keep stopping for fast charge	Yes, with repeated swap	Yes with repeated swap of Range-extension battery

Number of vehciles served per charger / swapper in 10 hours	10	120	120
Infrastructure for charging / swapping	Fast Charger at many locations	Battery swapping at reasonable number of locations, existing petrol pumps inadequate	Battery swapping at limited locations (swap in minutes); existing petrol pumps will do
Need for Infra-investment	Medium	Very High	High
Business viability in India	Not clear unless charges for fast charging is high	Viable	Viable
Vehicle Capital Cost for user	Large	Low	Medium
Vehicle Operation Cost	Low (cost of electricity) for 90 to 95% time	Close to petrol cost	Low for 90 to 95% of time (electricity cost only), but close to petrol cost for range extension (5 to 10% of time)
Business of existing (57000) petrol pumps and jobs	No	Will preserve	Will preserve
EV batteries as Grid-storage	Difficult	Swap-batteries in charger-cum-swapper station can be used as storage	Swap-batteries in charger-cum-swapper station can be used as storage

POLICIES AND REGULATIONS – WHAT IS NEEDED?

Central Government

- Set vehicle and charging standards
- Create tax incentives for EVs in recognition of their contribution to public good
- Mandate an increasing share of EVs in sale of motor vehicles and public fleets
- Strategic international tie-ups
- Collaborative R and D
- Procurement of EVs for Govt of India vehicles

State and Local Government

- Procure electric buses for SRTUs and mandate all buses to be electric
- Create infrastructure for re-energizing
- Establish preferential permits and tax breaks
- Require procurement of EVs for government
- Mandate registration of certain segments only as EVs from a certain date

POLICIES AND REGULATIONS – WHAT EXISTS IN INDIA?

Ministry of Power

- Electricity as a Service - Amendment of EC Act 2001
- Charging infrastructure for EVs– Guidelines and Standards

Ministry of Heavy Industries

- Faster Adoption and Manufacturing of (Hybrid &) Electric Vehicles (FAME 1) Scheme
- Charging standards for slow and fast chargers, communication protocols
- National Electric Mobility Mission Plan for 2020