

# Understanding the EV Elephant

*with special focus on Storage*

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# Why is Electric Vehicle (EV) the future transport?

*Better efficiency with less number of moving parts*

Area	Petrol / Diesel	EV
Energy efficiency	17 – 21%	90 – 95%
Moving parts (reliability)	2000+	20+

- In **five years**, EV capital costs will be less than that of petrol vehicles
  - with acceptable range and **operational costs at a fraction** of that of petrol vehicles
- But if we wait, India will **import most EV sub-systems** and batteries instead of oil

*Falling battery costs*

Year	Li battery costs per kWh
2012	USD 600
2015	USD 450
2017	USD 250
2020	USD 150
2024	< USD 100



# But before we begin: Nay-sayers

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- But Does India have enough electricity and does it not cause pollution?
- Full conversion of transport to EV will utilise **15% to 20%** of total electricity generation in 2030
  - No shortage of electricity even today: **thermal plant load factor today is 59.6%**
  - Renewable prices below that of coal-plant: future capacity from solar / wind
    - Alternatively, **rooftop solar** may provide all required electricity using **0.07% of India's geographical area**
- **Pollution:** No **tail-pipe** emission
  - **Zero** pollution levels if **renewables** used
  - If electricity is produced with current thermal plants, CO<sub>2</sub> pollution **down by 50%**

EVs: Hamare yahan hota to hai,  
dikhta nahee hai, dikhna chahiye

World-over EV is scaling driven  
by subsidies – some 30 to 40%

Subsidies is possible,  
but not at scale

- EVs happen today with 30 to 40% subsidy: India does not have enough money for subsidy
  - So how do we does one **get EV to Scale** and that too early without subsidy?
- GDP of auto-sector: **7.1% + 5% of GDP** for transport fuel processing and distribution
  - Large number of jobs
- If EV in India crawls, **imported** EV and accessories will **dominate the market in a few years**
  - Catching up with technology would become almost impossible
  - Will **impact our GDP and jobs**
- India needs to act to acquire **technology leadership** in some EV segments and build upon it
  - As far as possible, **Make in India** and develop the complete eco-system from end to end

# Some Unique aspects impacting EVs in India

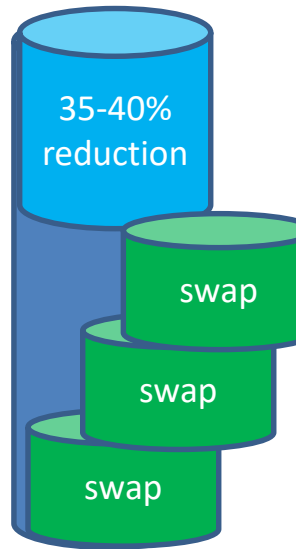
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- Limited / no **subsidy**
- Low **affordability**
- Our **driving patterns** are different (average vehicle speed in city is **25 kmph** as compared to 40 to 60 kmph elsewhere)
  - Will require different **motors and controllers**
- Our temperature **crosses 40 deg C** and even 45 deg C quite often
  - FAST Charging **full** low-cost battery (**in 10 minutes to 30 minutes**) would severely **impact battery life-time**
- Need to evolve **new approaches** in partnership with industry, R&D community and Government

# Approach 1

- Focus on higher efficiency: **Wh/km** (equivalent to kms/litre of petrol)
  - Lower Wh/km brings down **battery size, weight and cost**
  - For e-autos in last six months: from **70 to 80 Wh/km** to 45/50 Wh/km
  - E-buses: from **1600 Wh/km** to 900 Wh/km
- **Split battery** into smaller size (one third) and **swap**
  - No waiting time to charge battery; **no public infrastructure** required
- Battery-life severely affected by Fast Charging at 45 deg C: **one-third** as compared to charging in two hours below 25 deg C
  - Low temperature and slower charging **Possible** with swapping

Battery size  
without range  
anxiety



# Approach I (contd)

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- Separate **vehicle business** (without battery) & **energy business** (battery)
    - Capital cost similar to that for petrol / diesel vehicle
    - Operation cost today same as petrol / diesel vehicle
      - WITH **no SUBSIDY**; but **lower GST** for strictly **three years**
  - Drive Volumes using public vehicles
    - Get companies to buy vehicles in bulk (100,000 plus) and lease
    - Get companies to buy batteries in bulk and set up energy business
    - Private vehicles to leverage the eco-system
- No subsidy needed as with these 5 steps, capital cost of vehicle similar to that for petrol vehicles, and ₹/km operation costs same as petrol / diesel / CNG
  - Manufacture motors and drives, chargers, batteries, cells and battery-chemicals in India

# Approach II

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- Focus on vehicles with **larger drive-distance per day**
  - Taxis with 200 kms
  - Buses with 200 plus kms
- Possible to work towards solution where **total cost of ownership per km** comparable to that of petrol vehicles with
  - Some **slow** (overnight) charging
  - Some **fast** charging / or **top-up** charging (**top-up with small batteries possible**)
    - need to **overcome high temperature barrier**: may be higher-cost LTO batteries
  - Some **combination** of slow-charging and swapping



# India's Strategy

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1. Most **Energy Efficient** Vehicles: low Wh/km will reduce the size of the **battery, the most expensive component**
  - Better motor and drive (**power-train**), better tyres, lower weight and better aerodynamics
2. Battery ecosystem: **Pack manufacturing (30%), cell-making (30%), materials and chemicals (40%)**
3. Charging and **swapping** Infrastructure for range-extension
  - Slow-charging, fast charging and battery swapping
4. **Demand Generation and Policies**



# TASKS

# Tasks I: Technology- Power train and Infra

- Build vehicles with higher efficiency (low Wh/km)
  - Some excellent progress by industry; more needed; competition helps
  - much more needed in developing high-efficiency motors and controllers
- Develop Low-cost Swapping infrastructure
  - Ready to launch and scale
- Develop Chargers at affordable costs
  - Overnight chargers: standards defined; product ready and affordable
  - Fast chargers under 100V / 15 kW (DC-001): standards defined; product ready and affordable
    - Test set up at ARAI and IITM -- costs about ₹1.25 lakhs in volume
  - Fast Chargers from 100V to 400V: standards to be defined; product to be developed and made affordable over next one year
  - Fast Chargers for buses: standards to be defined; product to be developed and made affordable over next one year
- Develop communication protocols to get highest performance: good progress



*from 80Wh/km to 52 Wh/km*

# Storage Options

Li-Ion Cell Chemistry	LCO/Graphite or NCA/Graphite	NMC/Graphite	LFP/Graphite	NMC/LTO	LFP/LTO (Nb doped)
Operating V	3.6-3.7	3.6-3.7	2.5-3.6	1.8-2.8	1.5-2.3
Spec. Energy (Wh/kg)	150 -300	150-300	90-120 (150 with Silica in anode)	60 -100	50 -80
Charge/disc rate	0.5C/1C	1C/1C (2C with Silica in anode)	1C/2C (4C with Silica in anode)	4C/4C	5C/10C
Life-cycles	1000	2000 (8000 with Silica)	3000 (4000 with Silica)	10000	20000
safety	Cell* < 55°C	Cell* < 55°C	safer	safest	safest
Cell costs / kWh	\$120	\$140	\$225	\$500 plus	High???

\*difficult to Fast Charge when ambient temperature exceeds 40°C

China has set a target for all EVs to have 350 Wh/kg by 2020, 400 Wh/kg by 2025 and 500 Wh/kg by 2030

# Tasks I: Technology - batteries

- Battery pack development: **thermal** design, **mechanical** design and **Battery Management** System to get the best out of low-cost cell: **largely ready**
  - established and start-ups moving **[30% value add]**
- Battery Cell Development: strategy to be worked out
  - **need outside help** -- evolve as demand grows
    - Will work out strategy over next one year **[30% value add]**
- Battery Material Development: **great progress** with battery recycling (**urban mining**); scaling on way **[40% value add]**

Cell to Pack Manufacturing  
2017 – some 15 companies



Cell Manufacturing: 2019 -20

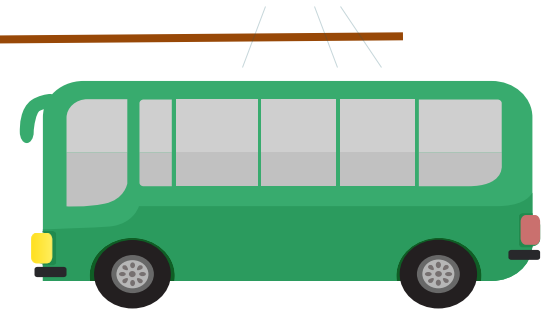


India has little Li, Mn, Co  
Battery Recycling to recover 95% of  
Li, Mn and Co

# Task II: Industry

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- Creating charger service industry: to be done over next year
- Creating charging and swapping industry: to be done over next year
- Demand generation
  - Volume Buying and leasing 4-wheelers: started with EESL tender
  - Volume Buying and leasing 3-wheelers (e-rick and e-auto): ready to be started over next three months
  - Volume buying and leasing buses: ready to be started over next six months
  - Volume buying and leasing of small cargo vehicles: to be started over nine months
  - 4-wheeler personal vehicle strategy: a proposal to use Range-Extension Batteries
  - 2-wheeler personal vehicle strategy: a proposal to use Range-Extension Batteries



- Most City buses travel 30 km /trip
- Typical 8 trips per day
  - Swap at each trip

# Task II: Industry

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- Waking up auto industry: **done**
- Waking up large auto-companies: **done**
- Waking up large battery industries: **done**
- Transforming small and medium sub-system and auto-component industries: **not begun**
- Developing new Electrical (power-electronics ) industries: **to be done over next two years**

# Other tasks

Biggest Threat: Policy paralysis  
allowing massive Chinese Imports

- Develop Comprehensive **long-term and stable policy for EVs**
  - Including policy to incentivise setting up new technology industry in order to attract investment
- Develop **strong R&D** to commercialisation in EV subsystems
- Encourage electricity production from **Renewables**
  - Encourage solar-PV modules being **manufactured locally**
- Watch out for new approaches and technologies



# A new approach: EV Batteries, costs and range-anxiety

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- Batteries **dominate** the cost of an EV
  - Larger battery will increase costs
    - And also **vehicle weight** (reducing the **energy efficiency or kms/kWh** of energy)
- Suppose a car has a **small** low-cost battery with limited range (range-anxiety): example 100 km range
  - **Enough to drive** within cities for **90% of days**
  - Use only night-time **Slow** Charging: **maximising** battery life
- When one needs to drive longer distances (10% of days)
  - Option 1: Stop and find a public fast charger (**1 hour waiting time**) giving another 100 kms
    - Another hour wait for a fast charge if one drives longer than 200 kms
    - Fast Charger at 4C in 15 minutes will hurt battery-life; LTO battery costs are high
  - Option 2: use a **RANGE EXTENDER** to overcomes complete range anxiety
    - **Swap-in a second (swappable) battery doubling the range** at a petrol pump (**3 to 5 minutes**), enabling another 100 kms range
    - **Swap the swappable battery again** for still longer range (**300 kms or 400 kms**)

# To Conclude

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- Future Technology Tasks
  - Hydrogen driven EVs, Distributed Motors for EVs, Motors without (or with small) rare-earth magnet, cells handling high temperature at low cost, second use of batteries, battery characteristics in different usage, EV trucks and agri-equipment
- Time is of essence
  - Several industries have worked hard over the last few years
    - They need to be encouraged and see a continuous forward movement
  - More focus on Make in India and start-ups

For deeper understanding, look at the blog: <https://electric-vehicles-in-india.blogspot.in/2017/12/>