How will India scale its Electric Vehicles

Is 2030 deadline feasible?

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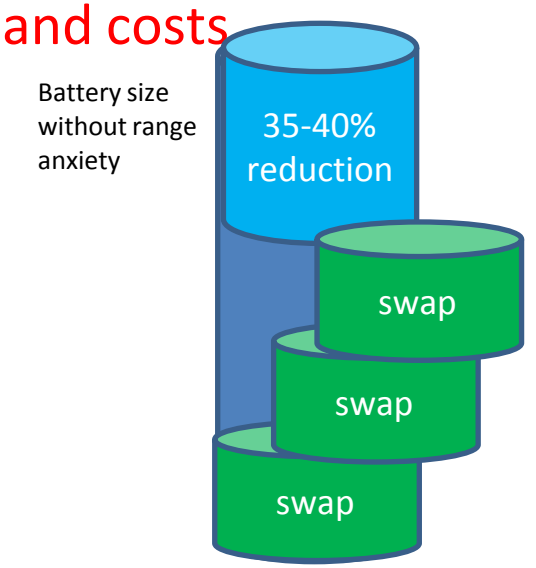
India Recognises

- India imports most of its oil impacting its economy badly
  - It has 14 of 20 most polluted cities in the world
  - EV is the future: four times higher energy efficiency and 50% less moving parts
- India's vehicles different from that in most of the world
  - 79% two-wheelers, 5% Autos and e-rickshaw, 3% Buses and large goods vehicle
  - 12% Economy Cars (< $13000) and 2% Premium Cars (> $13000)
  - 98% of public and affordable vehicles: not the focus of the rest of the world; India could attempt to get leadership here
- India has low affordability and can afford minimal subsidy
  - EV must make business sense: How?
  - Battery contributes to 50% of costs
    - falling rapidly over last five years but still expensive

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

Strategy for EVs for Public Transport

- Higher efficiency Wh/km (kms/litre of petrol) reduces battery size, weight and costs
  - For e-autos in last one year: 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
  - Swapped battery can be charged in conditioned environment and in two hours to maximise its life
- 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 aided by Public procurement



EV Strategy for Private Transport (2/4-wheelers)

- Batteries dominate the cost of an EV: Tesla uses battery with 540 kms range
  - and also vehicle weight (reducing the energy efficiency or kms/kWh)
  - Smaller battery creates range anxiety
    - Use Public Fast Charger: waiting time + public charging infrastructure: takes an hour to charge battery
    - Fast Charge in 15 to 20 minutes: needs expensive batteries (life impacted as temperature crosses 40°C)
- Suppose EVs have a small low-cost battery with limited range built-in: Affordable
  - Example: 100/ 50 km range for e-car / e-scooter: Enough 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)
  - use a RANGE EXTENDER battery to overcome range anxiety
    - Swap-in a second (swappable) battery doubling the range at a petrol pump (3 to 5 minutes)
    - Swap the swappable battery again for still longer range (300 kms or 400 kms)

Strategy for EV 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 [30-35% value add]
- Battery Cell Development
  - JV with external tie-ups [30% value add]
- Battery Material Development: great progress with battery recycling (urban mining) [40% value add]
  - scaling on way

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, and 93% of Ni and Mn and 90% Graphite

Materials for Batteries (40% costs)

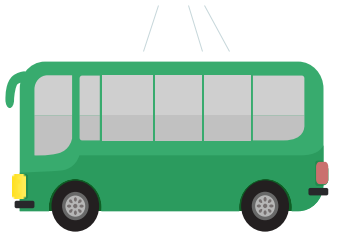
- Li-Ion batteries today use Lithium, Cobalt, Manganese, Nickel and Graphite
  - India does not have much of the mines for any these
    - Import bill could sky-rocket if we import all the materials
  - India may need up to 25 GWh per year by 2025
- Focus on recycling of used batteries (urban mining)
  - A start-up is recovering 95% of Li and Co, and 93% of Ni and Mn and 90% Graphite: being scaled today
  - Need R&D to set-up large number of recycling plants with ZERO EFFLUENT
- India could import used batteries and become the urban-mining capital of the world for Li-Ion battery-materials

Summing up: India's Tasks

1. Most Energy Efficient Vehicles: low Wh/km will reduce the size of the battery
   - Better motor and drive (power-train), better tyres, lower weight and better aerodynamics
2. Battery ecosystem: Pack manufacturing (30-35%), 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

Current Status: Vehicles and Demand generation

- E-rickshaw & e-auto: just started to deployed with battery swapping – will scale
- 2-wheelers with RE battery swap: will launch in next few months
- 4-wheeelers with RE battery swap: to be ready in six months
- 9m / 12 m city buses
  - being deployed with fast charger (requires 1 hour charging every 100 kms)
  - With battery swapping at end of each trip: to be deployed in six to nine months



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

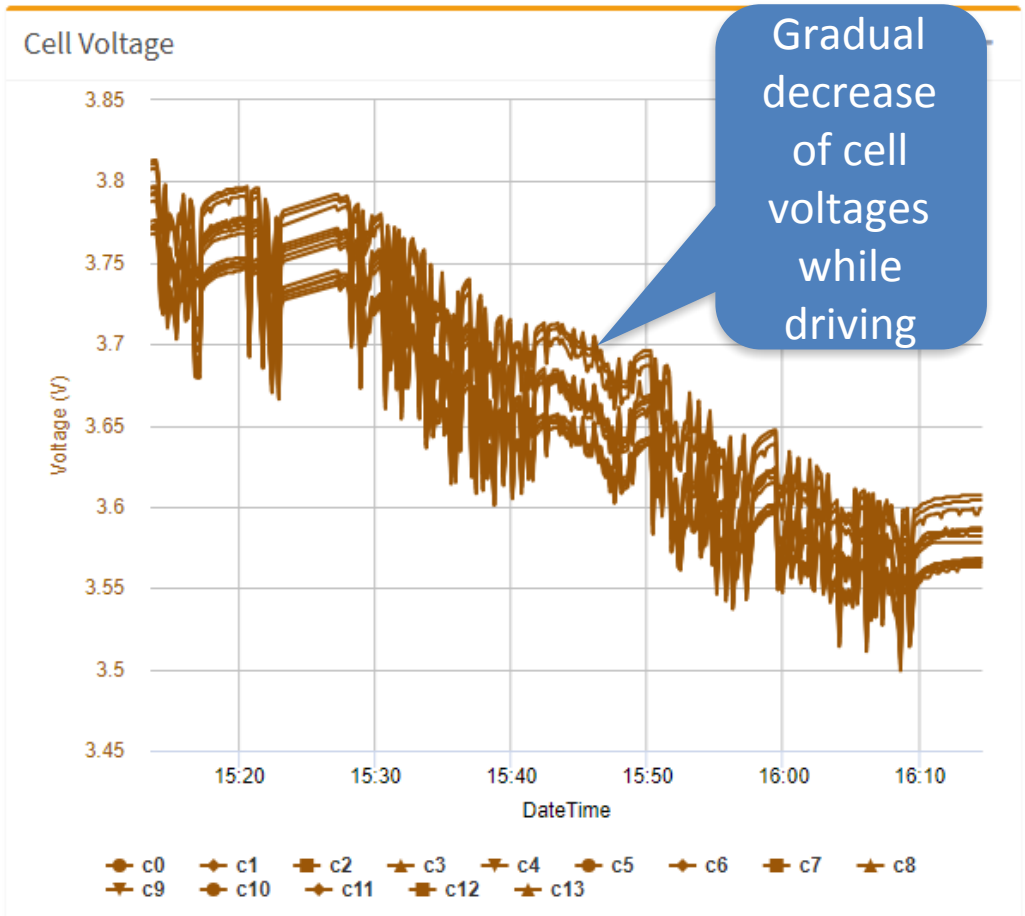
- Chargers at affordable costs
  - AC-001 Charger: product ready and affordable – single AC charger at < ₹5000
  - DC Fast chargers under 15 kW (DC-001): product about ₹1.25 lakhs in volumes
  - Fast Chargers with higher powers for larger cars / buses: need standards and making it affordable

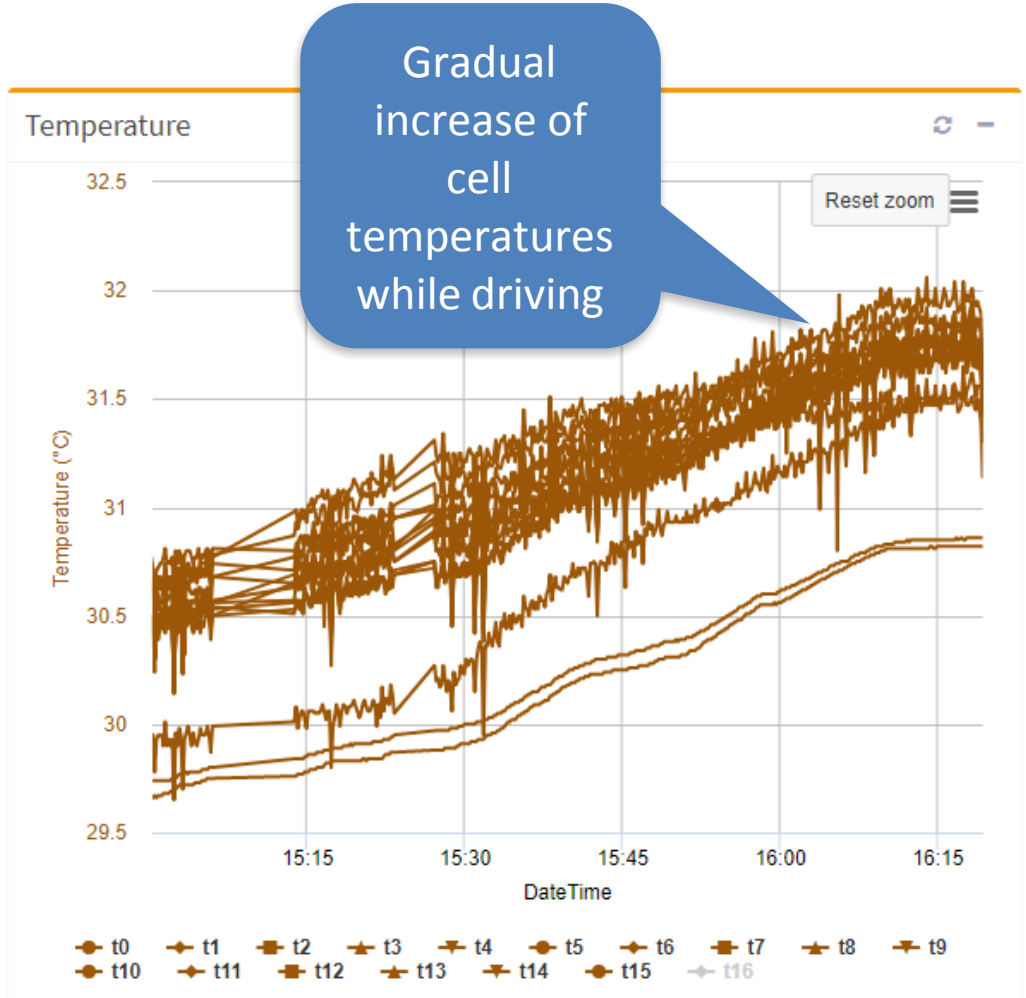
Vehicles on Drive

Pilot with Battery swapping at CBEEV, IITM Campus

Test vehicle with school kids, residents and staff in IITM campus

Cell voltage and temperature monitoring during driving





R&D required for EV sub-systems

- Drive train: Motors and Controllers, distributed motors
- DC-DC Converters and Battery-Chargers and Battery Swapping systems
- Electrically driven Power-steering, power-brakes, and air-conditioning
- Battery Packs and Battery Cells
  - Battery Materials: Li, Mn, Co, Ni and Graphite, new Chemistries
- Materials for light-weighting vehicles
- Materials for better insulation to reduce heat-load
  - air-conditioning competes with drive train for battery-power
- Better tyres and better aerodynamics enhances energy-efficiency of EVs
- Vehicle Controller Software, integration
- Future technologies: Hydrogen Fuel Cells, battery chemistry handling 45°C, Grid-integration etc.

Power Electronics is key

- Higher motor + controller efficiency at all velocities (full drive cycle)
  - Not a efficiency figure at a single velocity: India drives at lower velocity
  - Motor types: Nb permanent magnets Vs ferrite magnets Vs no magnets
  - Efficient Regeneration: recover energy during deceleration, braking and climbing down
- Need Motors and Controllers for two-wheelers, three-wheelers, small, medium and large cars, buses and trucks
  - Testing facility and Skill development
- Chargers: on-board and off-board and bulk chargers
  - 1 kW to 300 kW chargers: Charging and charger-management protocols
  - Bulk-chargers for multiple batteries with built-in cooling of batteries
  - Locked-smart battery protocols to ensure authorised charging / discharging
- High volume but low cost: must make EVs affordable and compete with imported products

To

- India needs innovative approach to
  - Or will be flooded by imports in four
- Time is of essence
  - Several industries and start-ups have
    - They need to be encouraged and see a continuous forward movement
  - More focus on Make in India and start-ups and R&D institutions
    - With attempts to preserve India's GDP and grow jobs
- Can we do it by 2030: Certainly
- EV article in latest IEEE Electrification Magazine: https://ieeexplore.ieee.org/document/8546812

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

- Vehicles: Ashok Leyland, Tata Motors, Mahindra, Eicher, Bajaj, Kinetic, Lohia, Electrotherm, Goenka, Hero-Eco, Okinawa, Ather, Avon Cycles, TVS Motors
- Li Ion Battery and recycling: Exide, Amar Raja, Exicom, ACME, Grintech, Greenfuel, Ion Batteries, Attero, Sun-mobility
- Energy Operators: Essel Infra, Sun-mobility, BPCL, NTPC, PGCIL, Kerala DISCOM, Goldstone
- Chargers, Motors and Monitoring: Delta, ACME, Exicom, TVS Motors, Esmito
- Most State Governments, STUs

Additional slide

- Three years directed program at a cost of ₹200 Crores per year
  - Additional directed program of same amount in fourth and fifth years
    - Multiple R&D institutions and industry to drive all the way from innovation to market
  - Directed by an individual researcher under guidance of a small committee
  - Long term research on battery-chemistry, fuel-cells and other areas to be driven by DST