Nayudamma was not just a top scientist of the country. He also was able to convert knowledge into industry and created one of largest industry in the country, benefiting rural and disadvantaged people

EVs in India: The Current State

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India Recognises

Business needs to depend upon itself. Some help from state governments (local manufacturing + promotion)

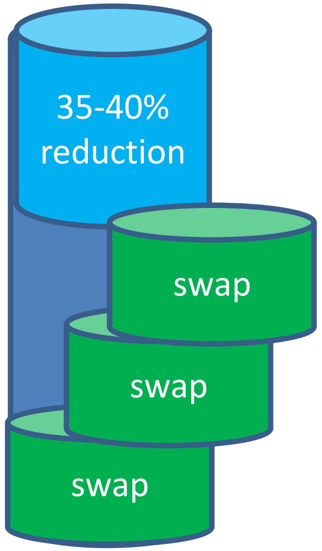
- India imports most of its oil impacting its economy badly
  - It has 14 of 20 most polluted cities in the world
  - EV is the future: four times higher energy efficiency and 50% less moving parts
- India's vehicles different from that in most of the world
  - 79% two-wheelers, 5% Autos and e-rickshaw, 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

Battery size without range anxiety



- 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 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

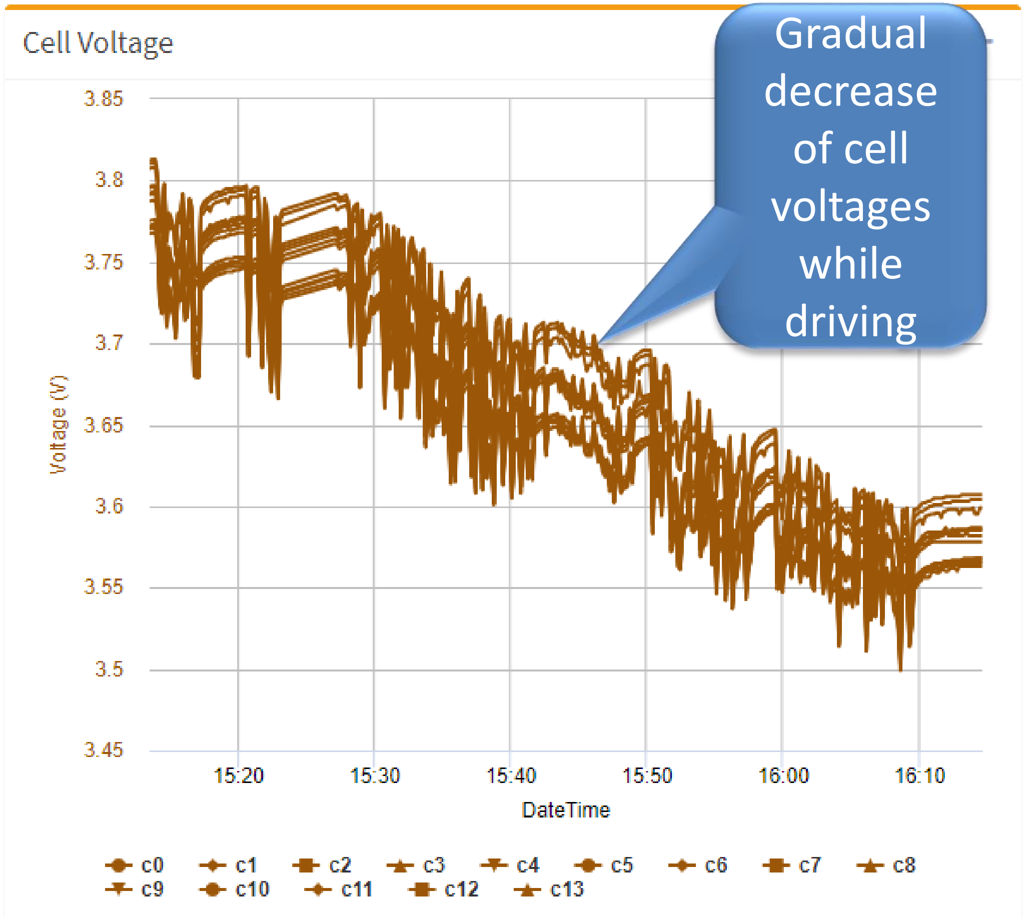
1. Most Energy Efficient Vehicles: low Wh/km will reduce the size of the battery
   - Better motor and drive (power-train), better tyres, lower weight and better aerodynamics
2. Battery ecosystem: Pack manufacturing (30-35%), cell-making (30%), materials and chemicals (40%)
3. Charging and swapping Infrastructure for range-extension
   - Slow-charging, fast charging and battery swapping
4. Demand Generation and Policies

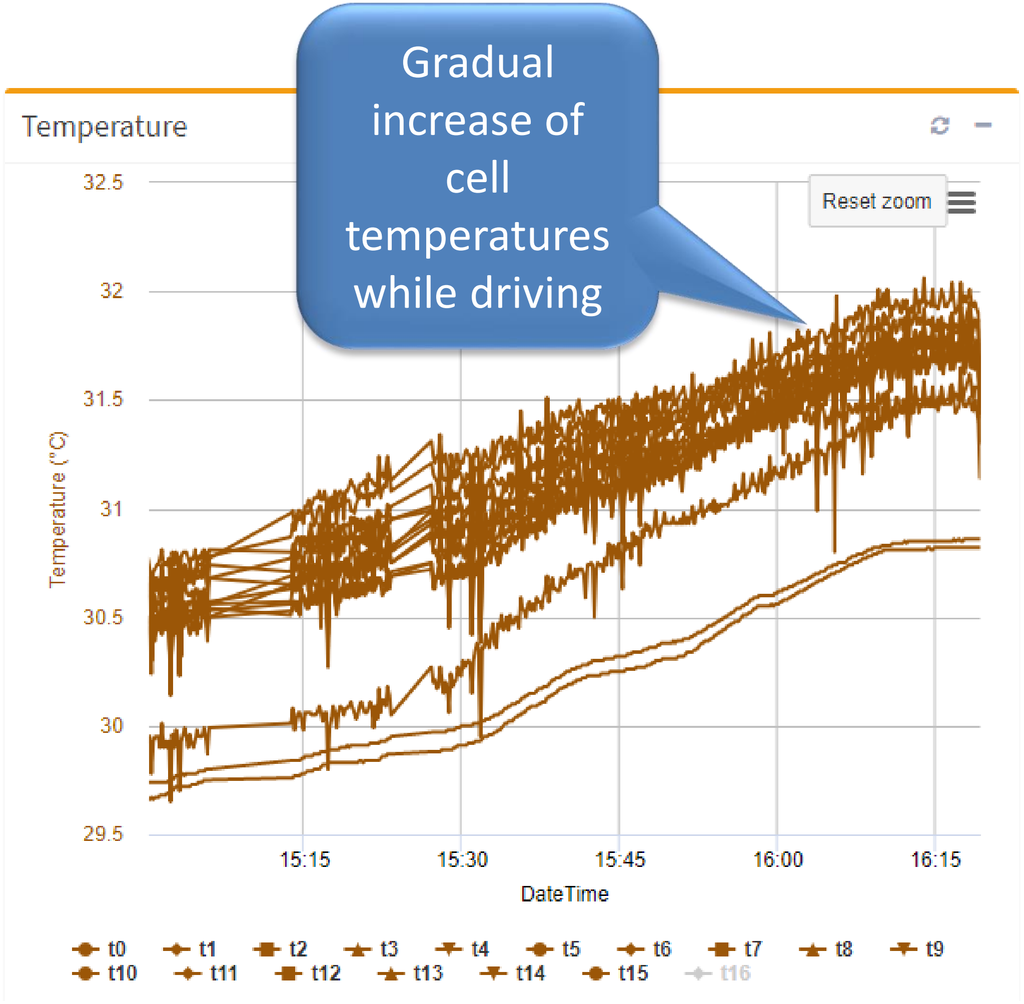
Vehicles on Drive

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





Current State and Scaling by better battery utilisation

- Electric three-wheelers with battery swapping will scale soon
- Electric two-wheelers (78% of vehicles) would make maximum impact in short run and would require some innovation to scale
- Buses would still take time to scale: battery-swapping will emerge in 2019 and would compete with fixed-battery buses
- End of 2019: first signs of scaling of 4-wheelers
  - Battery pack manufacturing will start-scaling
  - Battery recycling would bring-up urban mining
- Industry and local governments would push EV forward

To Conclude

- India needs innovative approach to get its EV to scale today: Not follow the West
  - Or will be flooded by imports in four to five years
  - 7.1% (auto-sector) + 5% GDP (fuel-processing & distribution) + millions of jobs may be impacted
- Time is of essence
  - Several industries and start-ups 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 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