Understanding the EV Elephant

with a focus on Storage

Ashok Jhunjhunwala, IIT Madras (on sabbatical)
Principal Advisor, Minister of Railways

ashok@tenet.res.in

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

- Limited / no subsidy
- Low affordability

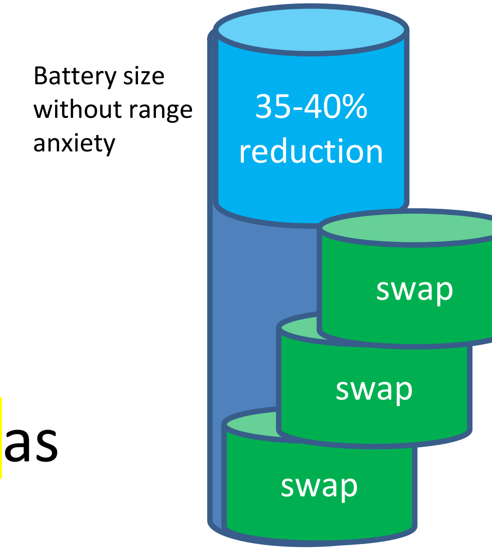
- Our driving patterns are different (average vehicle speed in city is 25 kmph as compared to 40 to 60 kmph elsewhere)
  - Will require different motors and controllers

- 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: without subsidy

- 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
- 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



Approach II

- 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

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

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

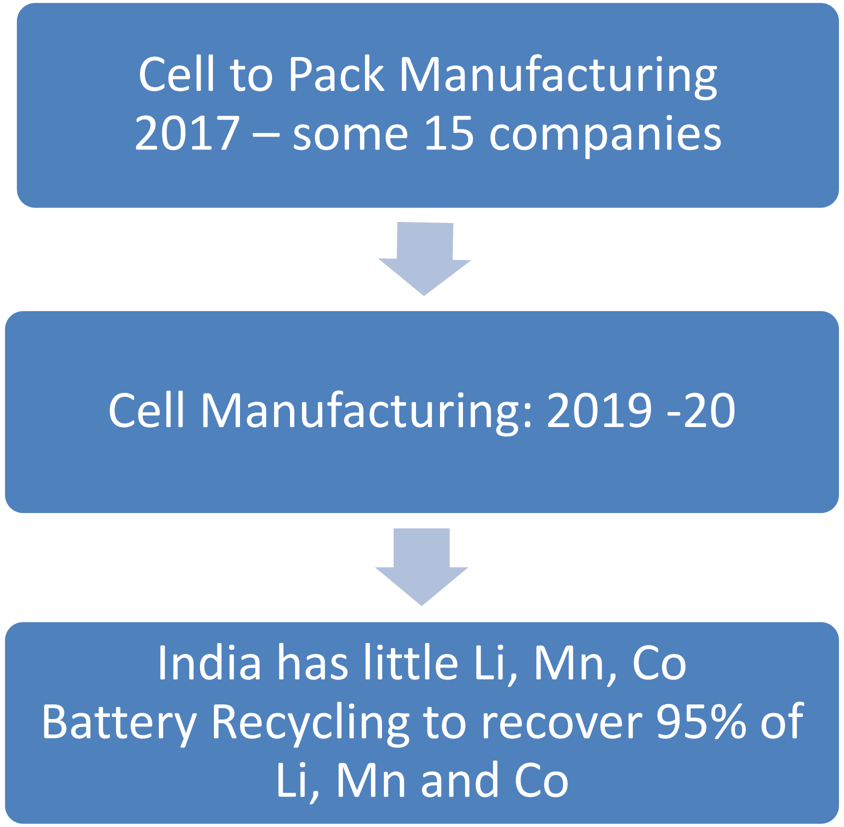
China has set a target for all EVs to have 350 Wh/kg by 2020, 400 Wh/kg by 2025 and 500 Wh/kg by 2030

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]



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

- 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)