Electric Mobility in Indian Context

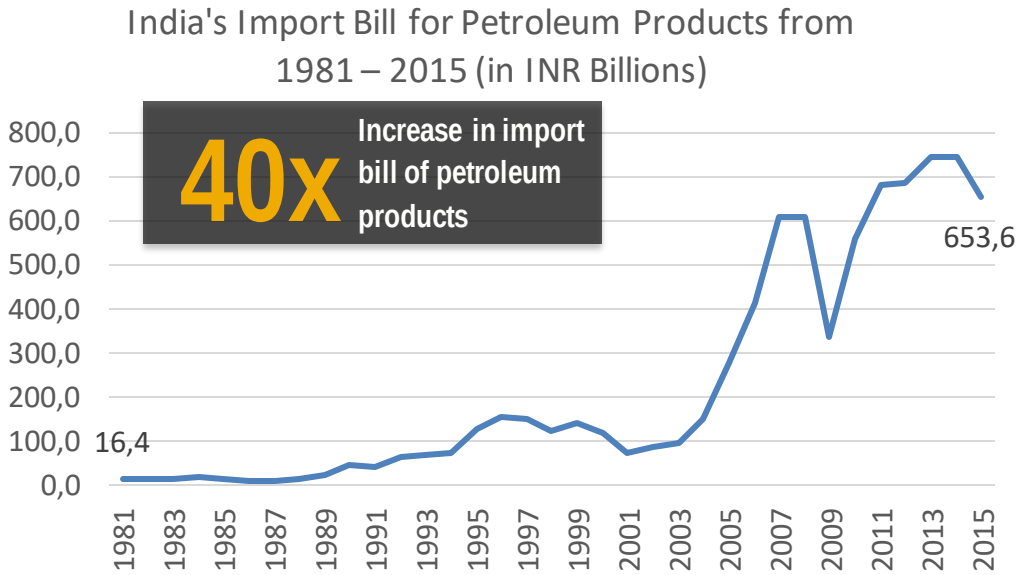
Is there only a noise or a Strategy?

Ashok Jhunjhunwala, CBEEV, IIT Madras

Why so much interest in EVs?

Pollution, Oil-import bill and

- EV is four-times as energy efficient as ICE; has 50 times less moving parts
  - ICE efficiency: 22% to 23% Vs EV motor energy efficiency: 90%



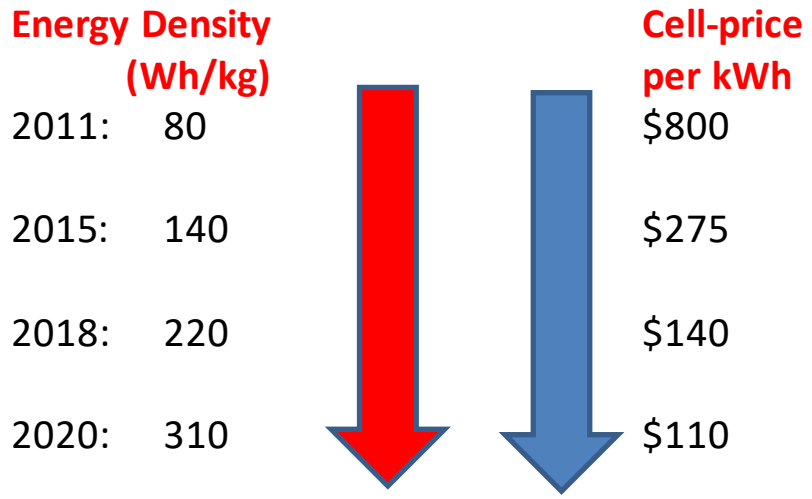
Petroleum consumption up from 32.5 mill tons in 1981 to 184.7 mill tons in 2015

Where is the problem to switch to EVs?

- Batteries: energy-storage
  - Energy-density of Li-Ion battery-cells is continuously increasing and is in between 250 to 300 Wh/kg today
    - But much less than that for petrol at 9000 Wh/kg
  - Even taking into account four times higher drive-efficiency
    - Battery weight per km is 8 to 9 times higher than that of petrol-tank per km
    - Same with the size
- And Cost of battery is inversely related to its energy density
  - Higher energy-density: lower use of materials like Lithium, Cobalt, Nickle
  - Higher energy density will have higher safety concerns

Increasing Energy Density → Affordable Batteries

- Energy density increasing rapidly: main driver for cost reduction
  - Li Ion Battery: up to 300 Wh/kg available
    - Towards 400 to 500 Wh/kg in coming years
    - NMC with Graphite-Silica anode
      - LFP is limited to 160 Wh/kg
  - Other variants of Li-battery may emerge to drive energy density higher
  - Higher energy-density: higher safety concerns



- EV with large battery to overcome range anxiety (several hundred kms in a car) is still 1.7 to 2 times that of ICE car

Battery pack cost per km computed taking into account its life-time, depreciation and interest

India's Vehicle Composition

$1 = ₹70

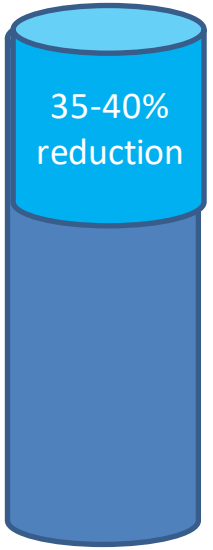
- India's auto-segment different from that in most of the world: small and affordable vehicles
  - Domination of 2-wheelers: 79%
  - Autos including small goods vehicle: 4% (rickshaw not included)
  - Economy Cars costing below ₹1 million: 12%
  - Premium Cars costing above ₹1 million: 2%
  - Buses and large goods vehicle (including trucks): 3%

95%

- 98% of public and affordable vehicles: not the focus of the rest of the world; India would attempt to get leadership here
- 2% vehicles (premium four-wheelers): similar to that in rest of world; India would learn and adopt; encourage multinationals to manufacture them in India
  - Less than 0.5% costs more than ₹1.5 million
  - Will help us build a stronger ecosystem for components and subsystems

Increase Energy-efficiency of EV

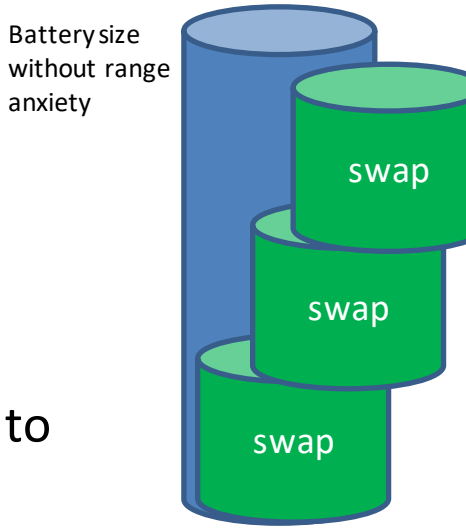
- Battery Dominates the cost of EV
- Focus on higher energy-efficiency: *Kitna deti hai* for EVs (kms/litre of petrol)
  - Lower the energy (Wh/km) used per km, lower is the battery size and its cost to drive certain range
    - size and weight of the battery reduces: in fact enhancing efficiency further
  - Efficiency improved by improving Motor and Controller efficiency, better tyres (lower rolling resistance), better vehicle-aerodynamics and lower weight
- Battery size reduced by 35% to 40% over last two years in India
  - For e-autos: 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

Approach I: Business viability for Public Transport

- To make Public Electric Vehicles more affordable
  - Split battery into smaller size (one third) and swap
    - No waiting time to charge battery: no public infrastructure required
    - Smaller Battery size makes EV highly affordable as compared to petrol vehicles
      - no further economic challenge or technical challenge
    - Engineering Challenges for battery-swapping need to be overcome
  - 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 (Energy Operator)
    - Capital and operation cost (₹/km) similar to that for petrol / diesel vehicle
      - WITH limited SUBSIDY, electric autos and buses can compete today with ICE vehicles



Approach II: Private Vehicles (4W/2W)

- Batteries dominate the cost of an EV: Tesla uses battery with 540 kms range
  - Increasing the vehicle weight (reducing the energy efficiency or kms/kWh)
  - On the other hand, Smaller battery creates range anxiety
    - 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 completely 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)
    - Swapping carried out by Energy Operators

Approach III: Conventional Approach

- Choose right size batteries
  - Slow-charge normally
  - Fast Charge when needed: may impact battery-life

- Needs chargers to be standardised: what standardisation?
  - Connector: plugs and sockets
  - Voltage, current and power (maximum)
  - Communication to vehicle?
  - Communication to charger management: charging operator or utility manager
  - Metering: how does one bill customer
  - protection

Do we have Charging Infrastructure?

Energy Operators could set up Charging / Swapping Infrastructure

But is there a business case even with subsidy?

Charging Strategy for best battery-life

- Best Charge: SLOW AC at homes in nights (requires on-board chargers)
  - or two to three hours SLOW charging at office or parking lots
    - 15 Amp single phase charging (up to 3 kW) for two-wheelers, three-wheelers or small four-wheelers
    - Three phase charging (6 kW to 20 kW) for larger vehicles with larger battery
- Only occasional FAST charging
    - Long-distance trips, vacations, restaurant visits
  - Need to consider that fast charging may impact battery-life
    - Especially for low-cost batteries
- Buses and Taxis may need regular FAST charging

Charger for Public places: Where?

$1 = ₹70

- Petrol pumps: NO SPACE -- pumps designed for servicing a vehicle in 3 to 5 minutes
  - Vehicles need to keep moving IN and OUT
  - Swapping at petrol pumps in three to five minutes is OK
- Office/Street parking, Parking lots, multi-storied buildings: Yes
  - Slow Public Chargers: can be same as used in multi-storied building
  - Fast Chargers: how fast? What kind of vehicles and batteries
- DC Fast Charging: industry need to have a common answer to
  - What voltage and Power?
    - Connector?
    - Protocols between vehicle - charger and charger - utility back-end
  - Costs about ₹7000 to 10000 per kW
    - 50 kW charger will cost ₹400,000 to ₹500,000: When will there be a business case?

How should India Standardise?

- AC Charger standard is a mere metered outlet, with charger being on-board
  - A vehicle can charge, irrespective of standards, drawing current from AC meter
  - Finalise and proliferate AC chargers and work to make business case for that
    - Must be metered and communicate with payment gateway and to CMS on OCPP

- Finalise and notify following as first charging standards
  - AC-001 or AC-001-1 (single charger version) is already defined by DHI: proliferate it
    - Provides up to 3 kW to a vehicle on-board charger, has metering including ToD and communications to CMS
  - Define AC-002 as Level 2 fast AC charging with Mennekes Type 2 connector, used by Europe
    - *power between 3.7 kW to 22 kW*
    - *Type 2 as described in standard EN 62196-2 with optional mechanical Shutters*
  - *At suitable point, define AC-003 as AC charger* for charging beyond 22 kW AC

DC Chargers

- Let industry come to consensus for each voltage range
  - DC-001 (already defined by DHI) and used today for charging up to 15 kW at 48/72V
  - DC-002, when industry comes to consensus
    - for charging at 30 kW and beyond with Voltage beyond 300V
    - Voltage range, power-range, connector, protocols for communications to vehicle / CMS

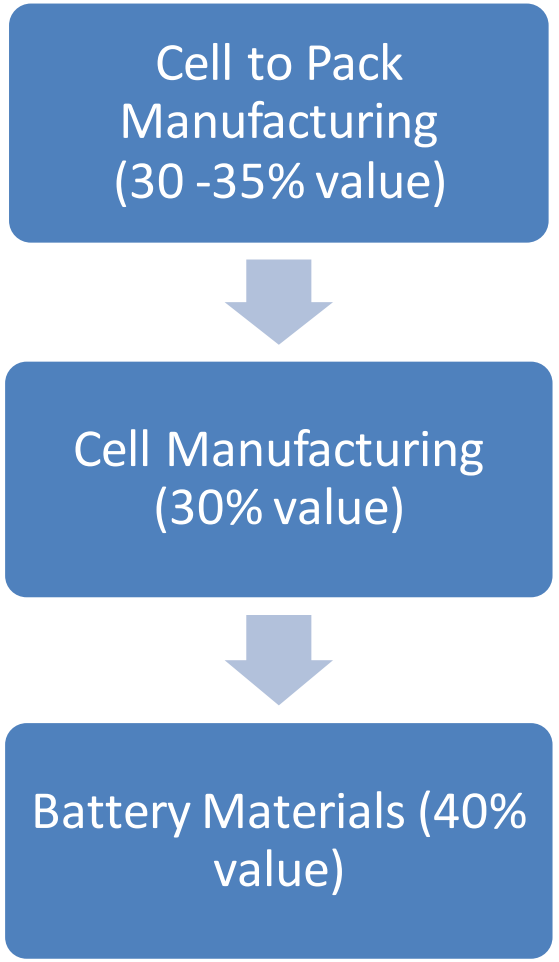
How do we make battery safe? Where will we get Lithium for batteries?

or will we for-ever import Lithium, Nickle, Cobalt, Manganese and Graphite!

Li Ion Batteries for EV

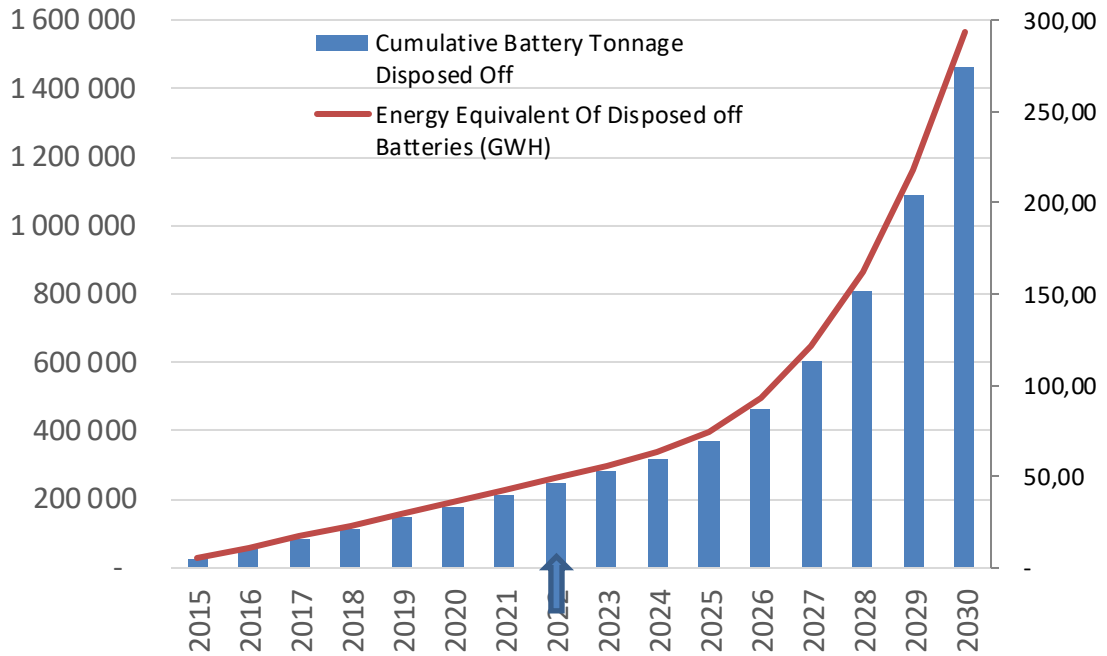
- Battery-pack development involves
  - thermal design as per Indian temperature and driving conditions
    - Low-cost Cooling mechanism to withstand 45°C ambient
  - mechanical design to ensure cells do not bulge
  - Battery Management Systems to get the best out of each cell
  - Safety is a major concern: handled by BMS
  - established and start-ups making waves in making BMS

- Cell manufacturing: technology changes every two years
  - Need technology which stays ahead in energy density
  - $50M per GWh Capital investment: JV with external tie-ups



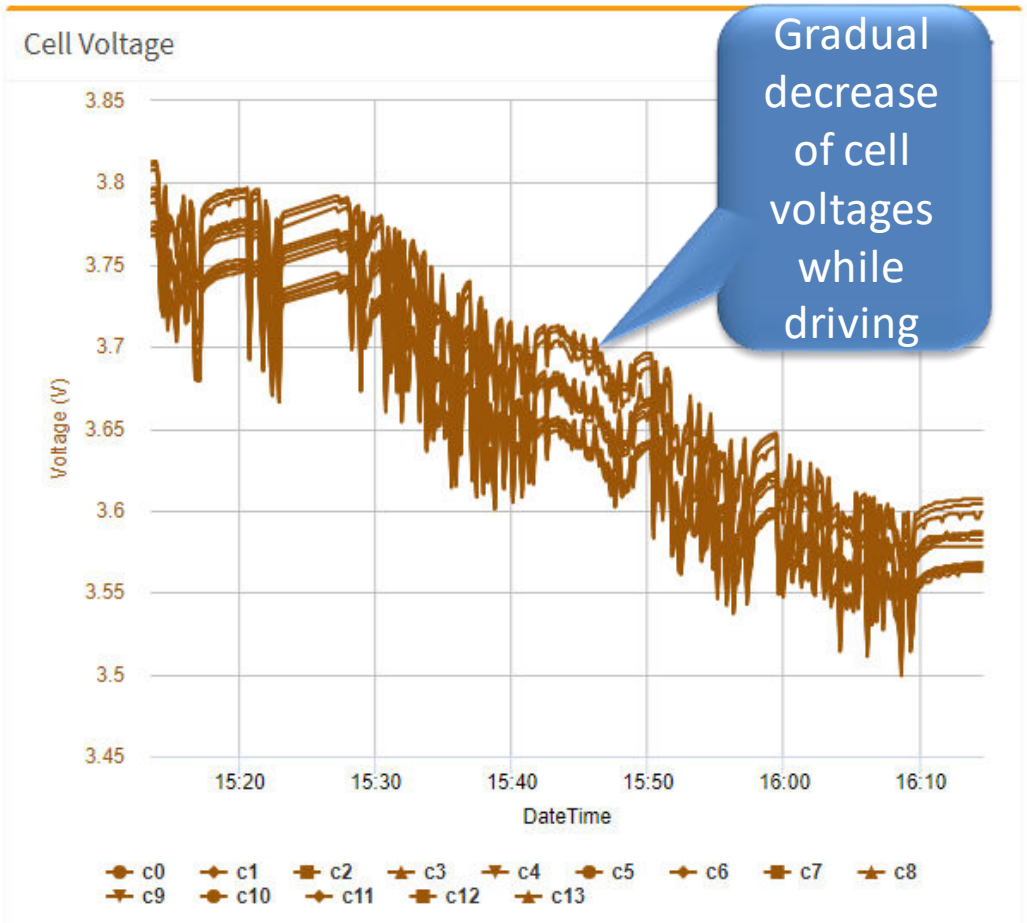
Materials for Batetries

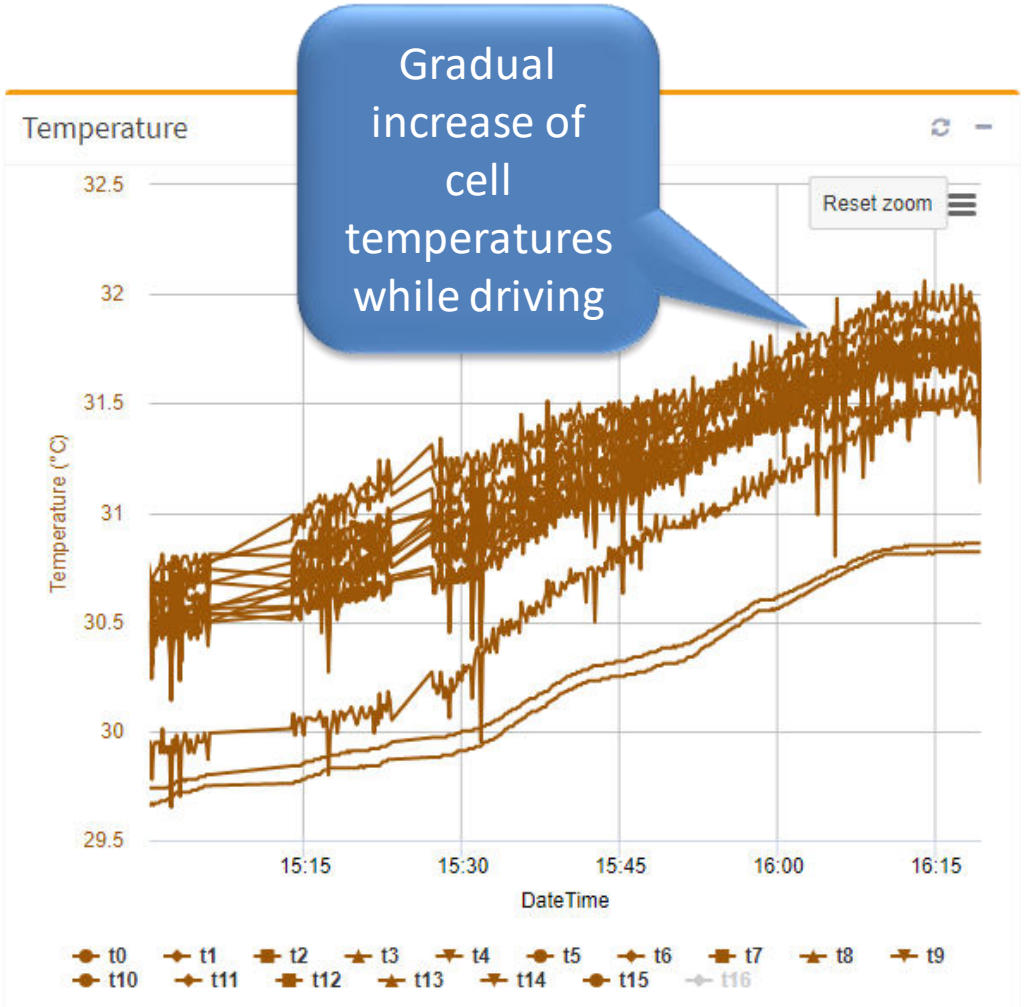
- Li-Ion batteries today use
  - Lithium, Cobalt, Manganese, Nickel and Graphite
  - India does not have much of the mines for any these
  - Import bill could sky-rocket : 25 GWh per year by 2025
- Recycle used batteries (urban mining)
  - 90% of Li and Co, Ni, Mn and Graphite being recovered
  - Need 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



Over 1 Lakh tons of recyclable batteries are currently available in the market

Cell voltage/ temperature monitoring to maximise battery-life





EV threatens India's GDP (auto-sector 7.1% + 5% transport fuel processing / distribution) and large number of jobs

Will we lose jobs and GDP?

Depends upon whether we design and manufacture sub-systems within India

Not if we make every component

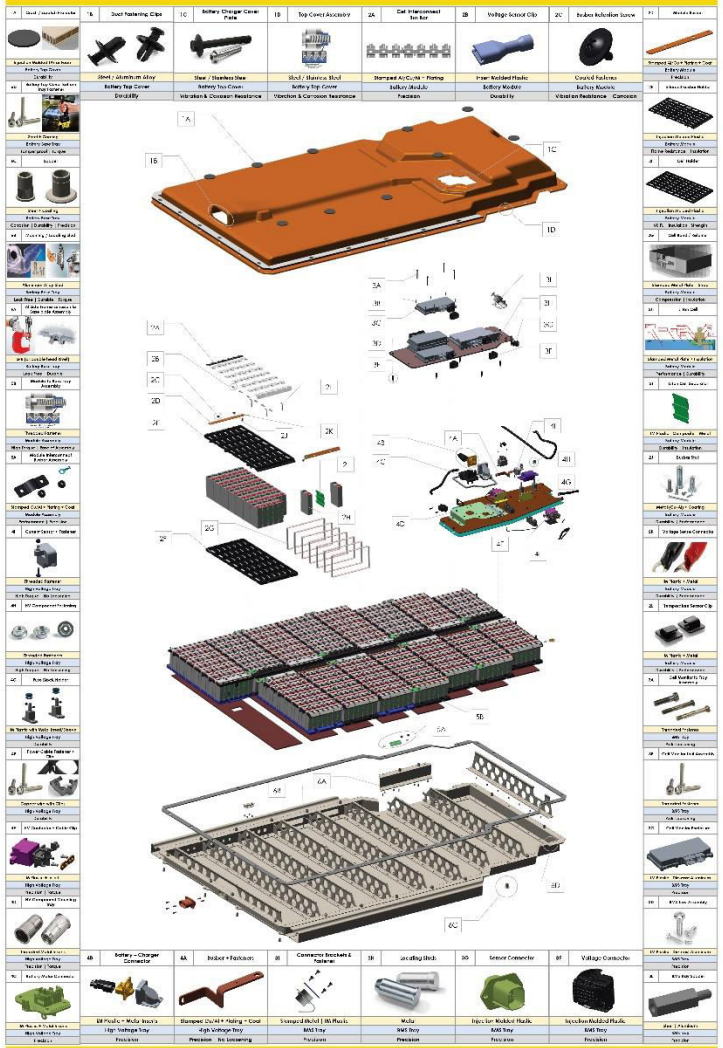
- Every Electric Vehicle needs a Battery Pack
  - Battery-pack manufacturing involves large number of components
    - Large number of ancillary industry
    - Large number of jobs
  - Battery-packs need to be designed for India's environment conditions
    - Involves quality thermal design
    - Careful mechanical design
    - BMS to ensure cell life maximised and safe operations under all conditions
- Every Vehicle needs Motors and Controllers
  - Need motors and controllers for
    - Two-wheelers
    - Three-wheelers
    - Four-wheelers
    - Buses & Trucks
  - Hundreds of subsystems and components
- India would need a large number of Chargers
  - A variety of chargers

Make every EV-subsystem in India
Nurture Ancillary Industry

JOBS

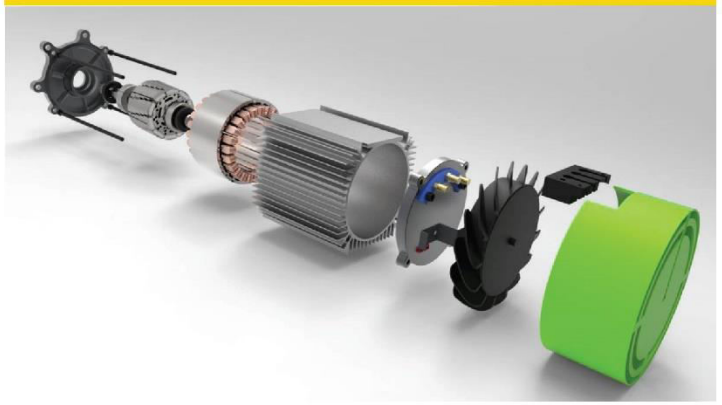
GDP

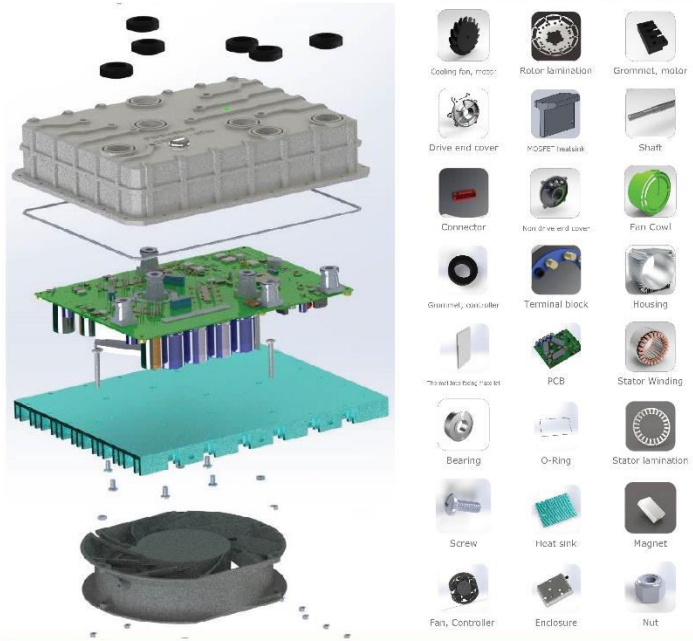
BATTERY SYSTEM COMPONENTS



STANLEY
Engineered Fastening

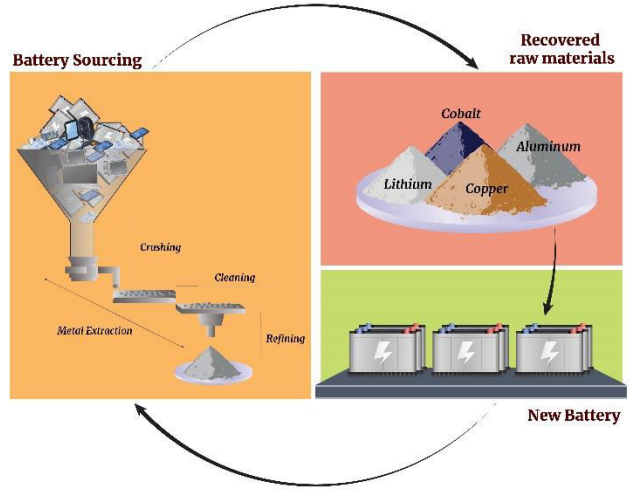
ELECTRIC MOTOR AND CONTROLLER

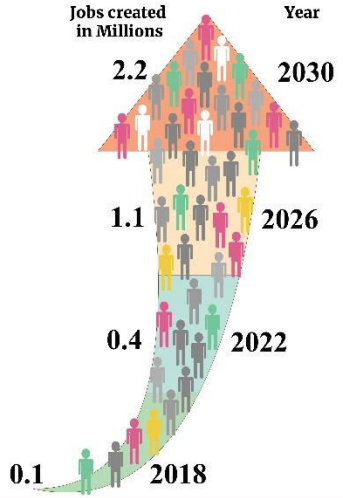




motorz
Electric Motor Components

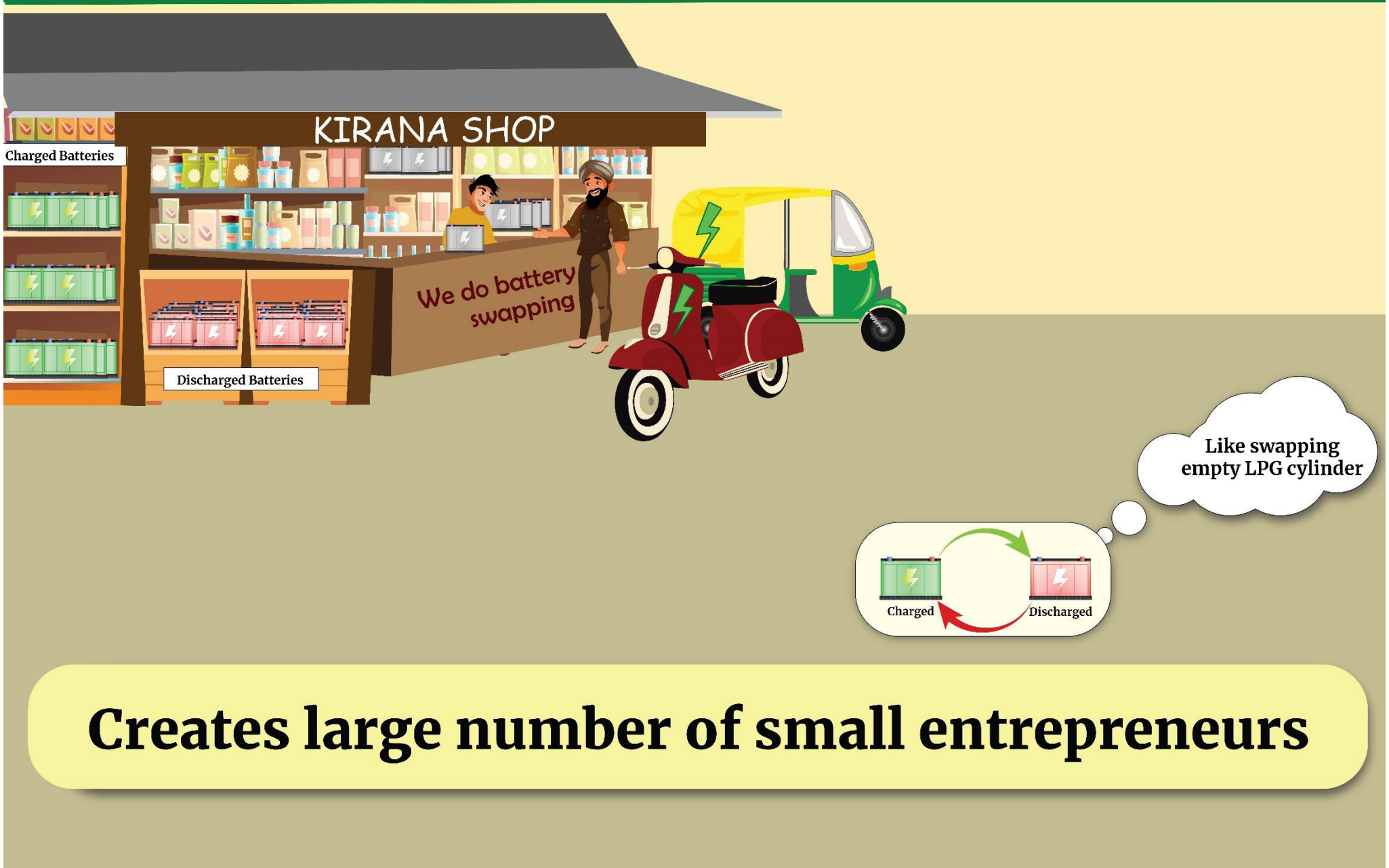
LITHIUM ION BATTERY RECYCLING





POTENTIAL TO CREATE 2 MILLION JOBS BY 2030

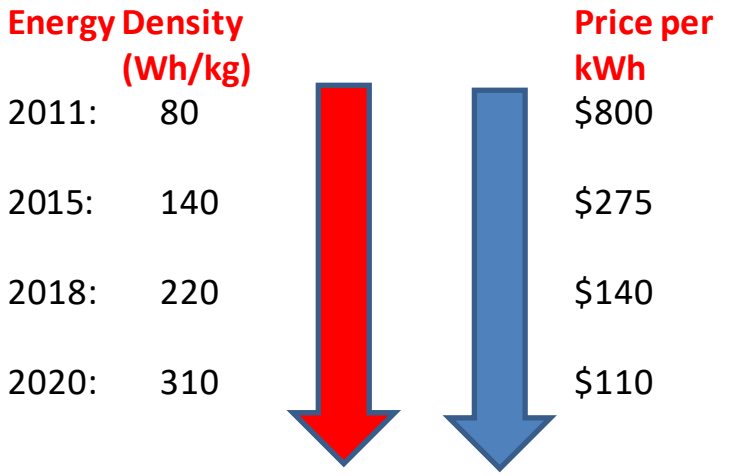
Battery Swapping at every Street Corner



Creates large number of small entrepreneurs

Cell-manufacturing: Requires Large plants for

- India needs over 100 GWh of cell manufacturing every year
  - Prismatic, Pouch and Cylindrical
- Battery cell manufacturing like a large process industry
  - High investments
  - Technology changes very rapidly
  - Cost falling rapidly
  - Will require lots of ancillary industries
    - Lots of jobs



Will we have to import all Battery raw materials?

- Not if we recycle all used battery with ZERO effluent
  - Can recover over 90% of Lithium, Manganese, Cobalt, Nickle and Germanium
  - And reuse in new batteries
- Highly manual-intensive work: will create huge number of jobs
  - India could become Urban mining capital of the world
    - Import used battery and recover materials
- Battery Recycling market: $100M today, over $1B by 2030
  - 1 lakh ton battery waste available today: 23 GWh of batteries
  - Near Term Driver: Consumer Electronics and laptop battery
  - Long term Driver: Electric Vehicles & Stationary Storage Energy

- Need to recycle each battery
- Ensure that all spent Li Ion batteries are sent for recycling
  - Manufacture's obligation

To Conclude

- Possible to make two / three-wheelers EV affordable in India today: 4-wheelers will follow
  - Aided by FAME-II and GST subsidies and smaller swappable battery
  - Charging Infrastructure not a limitation
- Possible to make high energy-density battery affordable and safe
- Possible for India to recover Li, Co, Ni etc form used batteries: urban mining
- Will it impact our GDP? No, if we make all subsystems

- Time is of essence: In four years, may be flooded with imported EVs / subsystems
- Can we do it by 2030: Certainly

EV article in recent 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/