Limited subsidy and Low-affordability imperatives for EVs in India

Can we still scale quickly?

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The talk around a year back

- EV will not happen in India soon; will take the hybrid route; requires 30 to 40% subsidy (as in rest of the world); Charging infrastructure not ready
  - Industry was largely disinterested

- Today: some **50 Indian companies** going hammer and tongs on EV, believing that India will charter its own path
  - 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
  - Chargers & Motors: Delta, ACME, Exicom, TVS Motors, Consulneowatt, Valeo Compageautomation
  - Most State Governments, STUs

How did this happen?

- Recognition that EV is the future
  - Four times higher energy efficiency and far higher reliability (50 times less moving parts)
  - will threaten India's GDP (auto-sector 7.1% + 5% transport fuel processing and distribution) and large number of jobs
- Recognition: India has low affordability
  - 30 to 40% subsidy on Electric Vehicles in USA, Europe and China: but subsidies in India will be limited (or none at all)
  - EV must make business sense even with this!
- How do we make business sense? Battery contributes to 50% of costs
  - Falling rapidly over last five years
    - Battery-pack with low-cost NMC-Graphite cells under $200 per kWh today
    - but still expensive for the desired range

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

Copying the EV program of USA, China, Europe will take us nowhere

Can India Drive its EV program Innovatively and Differently?

India's Vehicles dominated by two-wheelers

No of Vehicles sold in India in Millions

Category	2011-12	2012-13	2013-14	2014-15	2015-16	2016-17
Passenger Vehicles	2.63	2.67	2.5	2.6	2.79	3.05
Commercial Vehicles	0.81	0.79	0.63	0.61	0.69	0.71
Three Wheelers	0.51	0.54	0.48	0.53	0.54	0.51
Two Wheelers	13.4	13.9	14.8	15.9	16.5	17.6
Grand Total	17.4	17.8	18.4	19.7	20.4	21.9

- Cars no more than 14% of total vehicles
  - About 15% of this (less than 2% of total) costs more than ₹10M ($15,000)
  - World-efforts focused only on this

- Three wheelers have become the main last-mile public transport for 75% Indians
  - Urban as well as Rural (village to town)
  - Rickshaws not included in above table

Percentage of Cars sold in India			
Price Range	2015-16	2016-17	2017-18
Below ₹500,000	2.82	28.85	27.43
₹500K to 1 million	55.49	54.96	56.48
₹1 to 1.5 million	15.29	15.23	14.65
Above ₹1.5 million	1.20	0.96	1.43

EV Policy: India's focus on its 98% vehicles

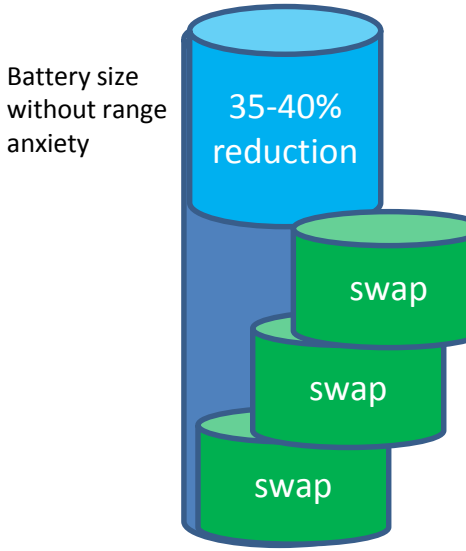
- India's autos different from that in most of the world: small and affordable vehicles
  - Domination of 2-wheelers: 79%
  - Autos including small goods vehicle: 4% (rickshaw not included)
  - Buses and large goods vehicle (including trucks): 3%
  - Economy Cars costing below ₹1 million: 12%
  - Premium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

98%

- 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
  - Will help us build a stronger ecosystem for components and subsystems

An Alternate Approach for Public Transport

- 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
  - Swapped battery can be charged in conditioned environment and in two hours to maximise its life

Approach towards Business Viability

- 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

Private Vehicles: EV Batteries, costs and range-anxiety

- Batteries dominate the cost of an EV
  - Larger battery increase costs (Tesla uses battery for 540 kms)
    - 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
    - Fast Charger with 1C charge: takes about an hour to charge the battery
    - 4C Fast Charger -- 15 to 20 minutes: but reduces battery life for low-cost Graphite-NMC batteries (gets worse as temperature crosses 40°C)
    - Alternatively LTO batteries: Charge Fast even at high temp: but three times costlier

Range-extender Batteries for 4W and 2W

- Suppose EVs have a small low-cost battery with limited range built-in (example 100 km range for e-car or 50 km for e-scooter)
  - Enough to drive within cities for 90% of days
  - Use only night-time Slow Charging: maximising battery life
  - Affordable

- 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), enabling another 100 kms range for a e-car
    - Swap the swappable battery again for still longer range (300 kms or 400 kms)
  - Swapping by Energy Operators

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%), 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

Task I: Vehicles and Demand generation

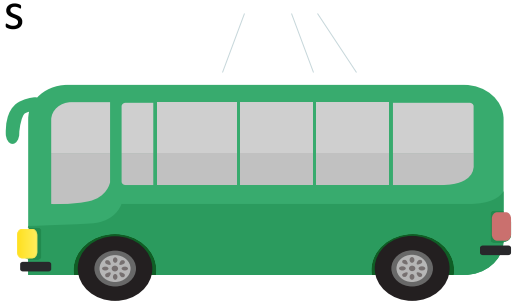
Driven by Industry and Start-ups

- E-rickshaw & e-auto: just started to deployed with battery swapping – will scale
- E-cargo auto: to be developed over next six months with battery swapping
- 2-wheelers with RE battery swap: will launch next month

- 4-wheelers: 100 km range being deployed with fast chargers – volume buying by EESL
  - 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 four months

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



Task II: Charging & swapping Infrastructure

- Develop Low-cost Swapping infrastructure -- Ready to launch and scale
- Chargers at affordable costs
  - Overnight AC chargers: standards defined; product ready and affordable
  - DC Fast chargers under 15 kW (DC-001): standards defined; product ready and affordable -- costs about ₹1.25 lakhs in volumes
  - Fast Chargers with higher powers for larger cars and buses: standards being defined; product to be developed and made affordable over next one year
- Creating charger service industry: to be done this year
- Creating charging and swapping industry (energy operators): done
- Develop communication protocols to get highest performance: good progress

Tasks III: 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% 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

Task II: Industry

- 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

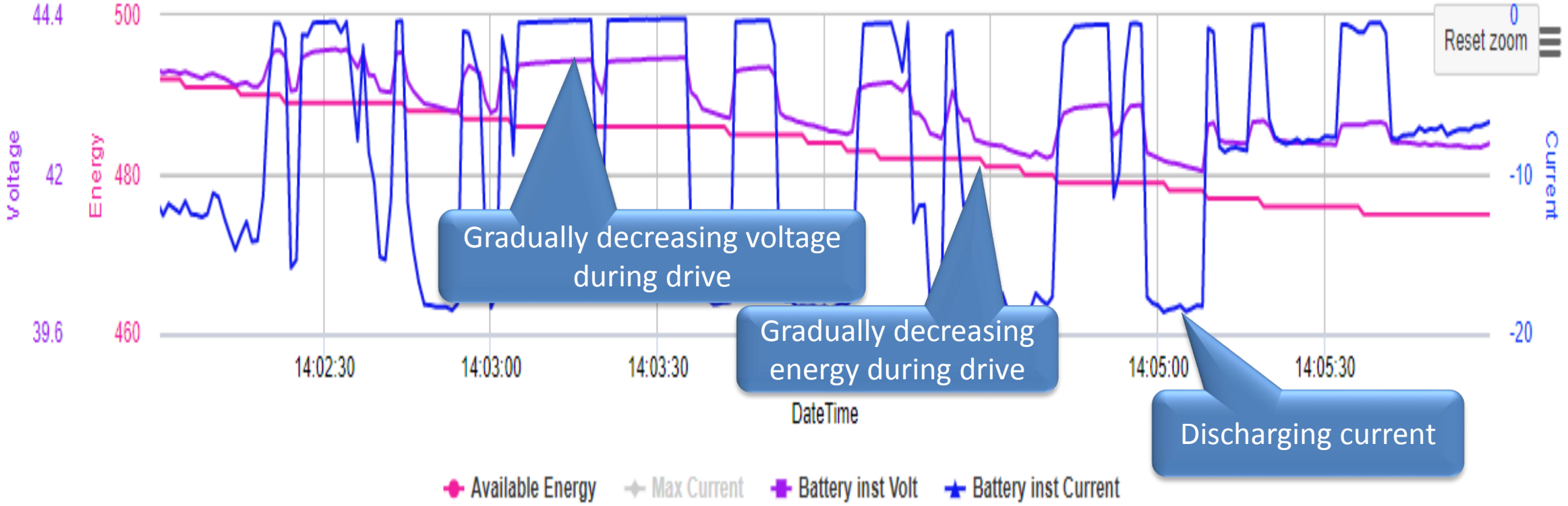
- Developing new Electrical (power-electronics) industries: more needed in developing high-efficiency motors and controllers -- to be done over next two years

Vehicles on Drive

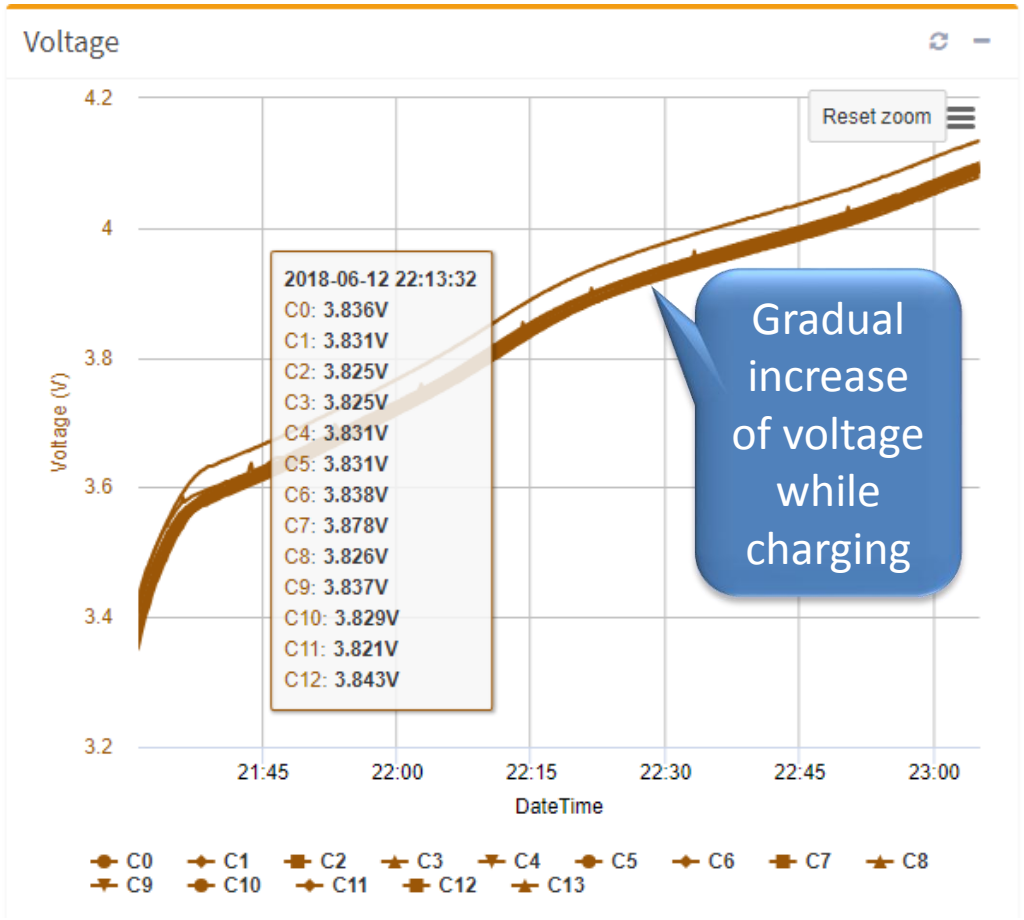
Pilot of LS Battery swapping at IITM Campus

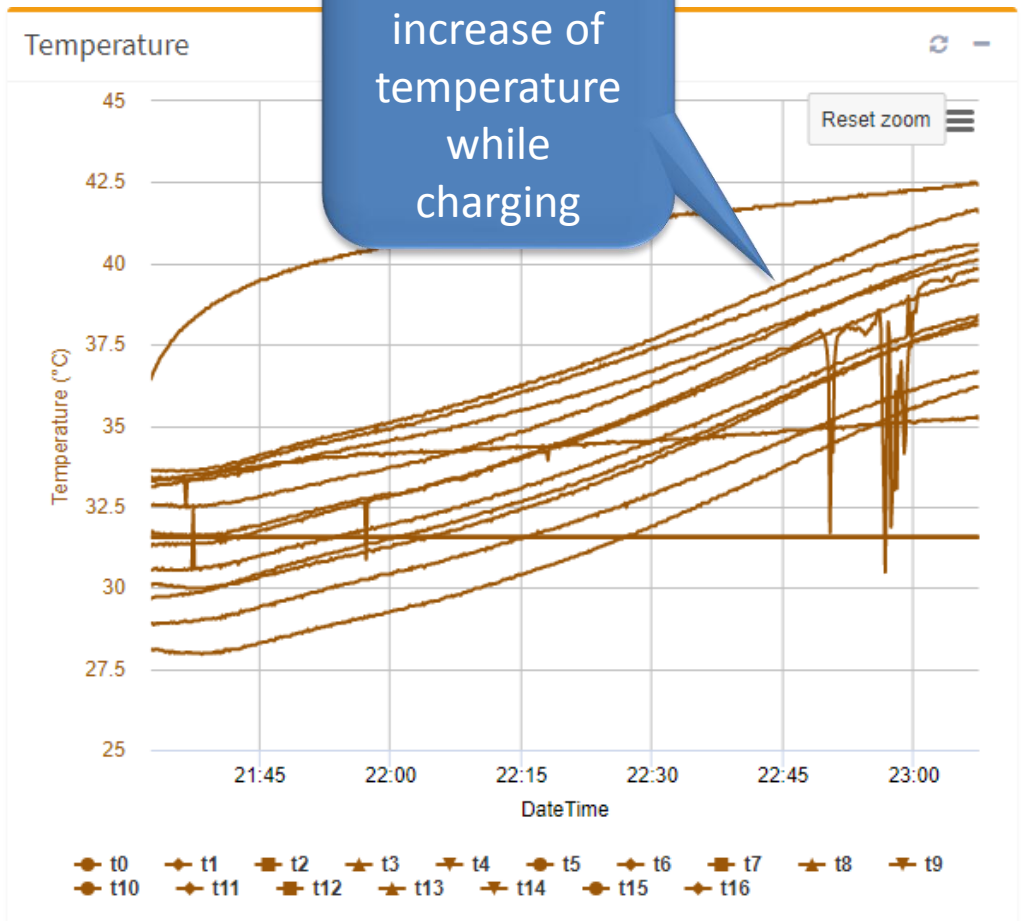
Test vehicle with school kids, residents and staff in IITM campus

Battery pack energy, voltage and current during driving

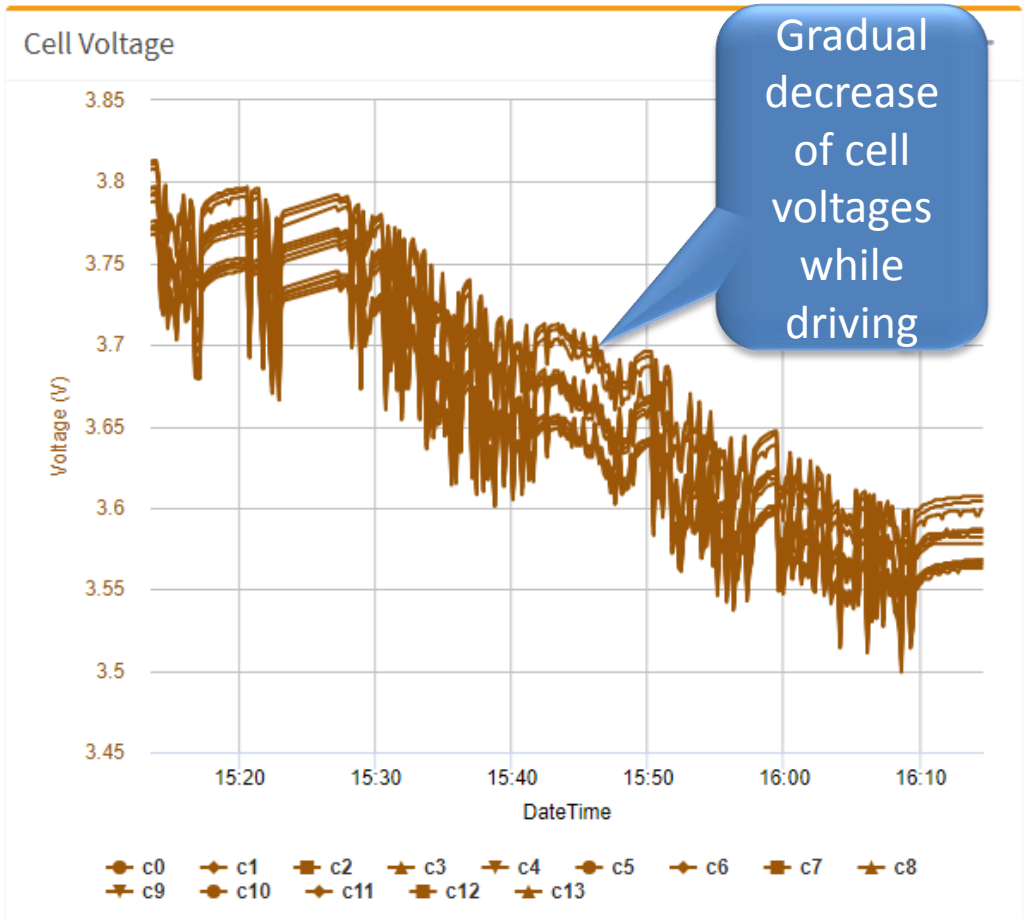


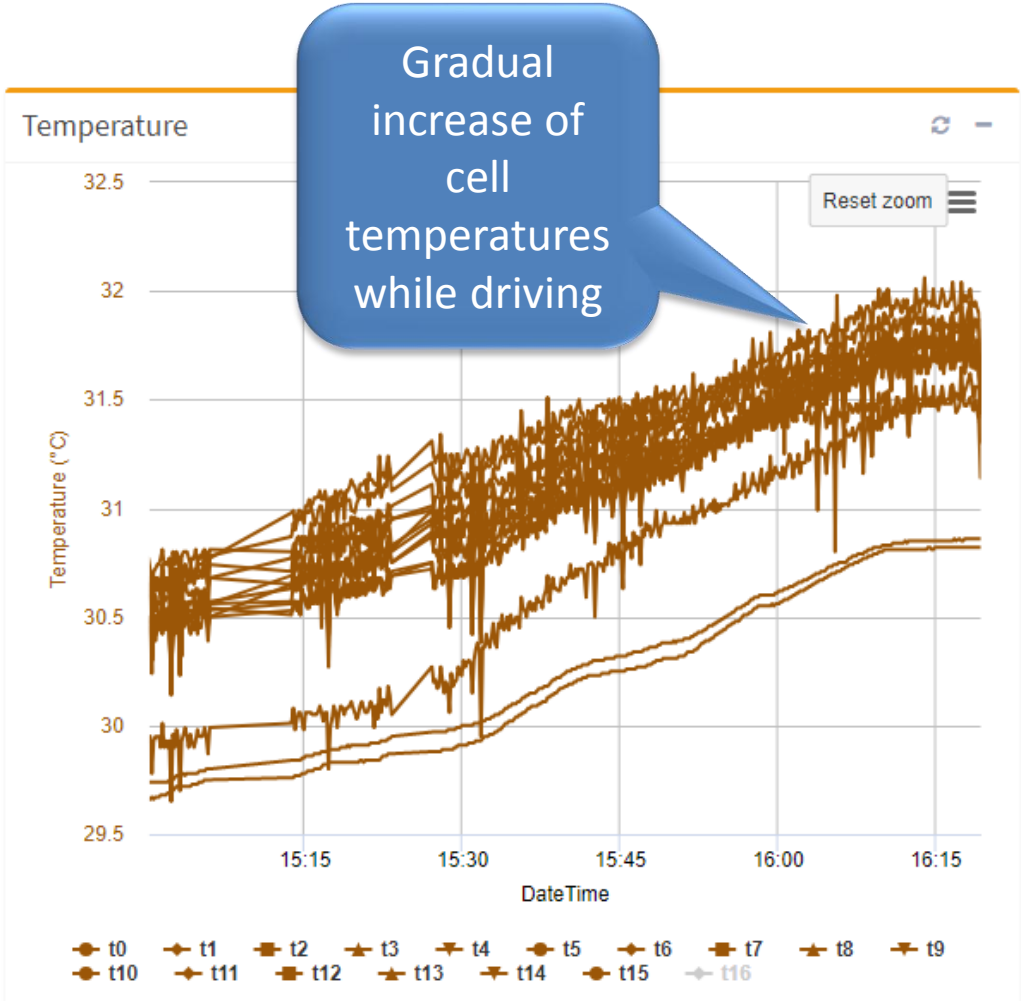
Individual Cell Voltage and Temperature while charging





Cell voltage and temperature monitoring during driving





Performance Comparison

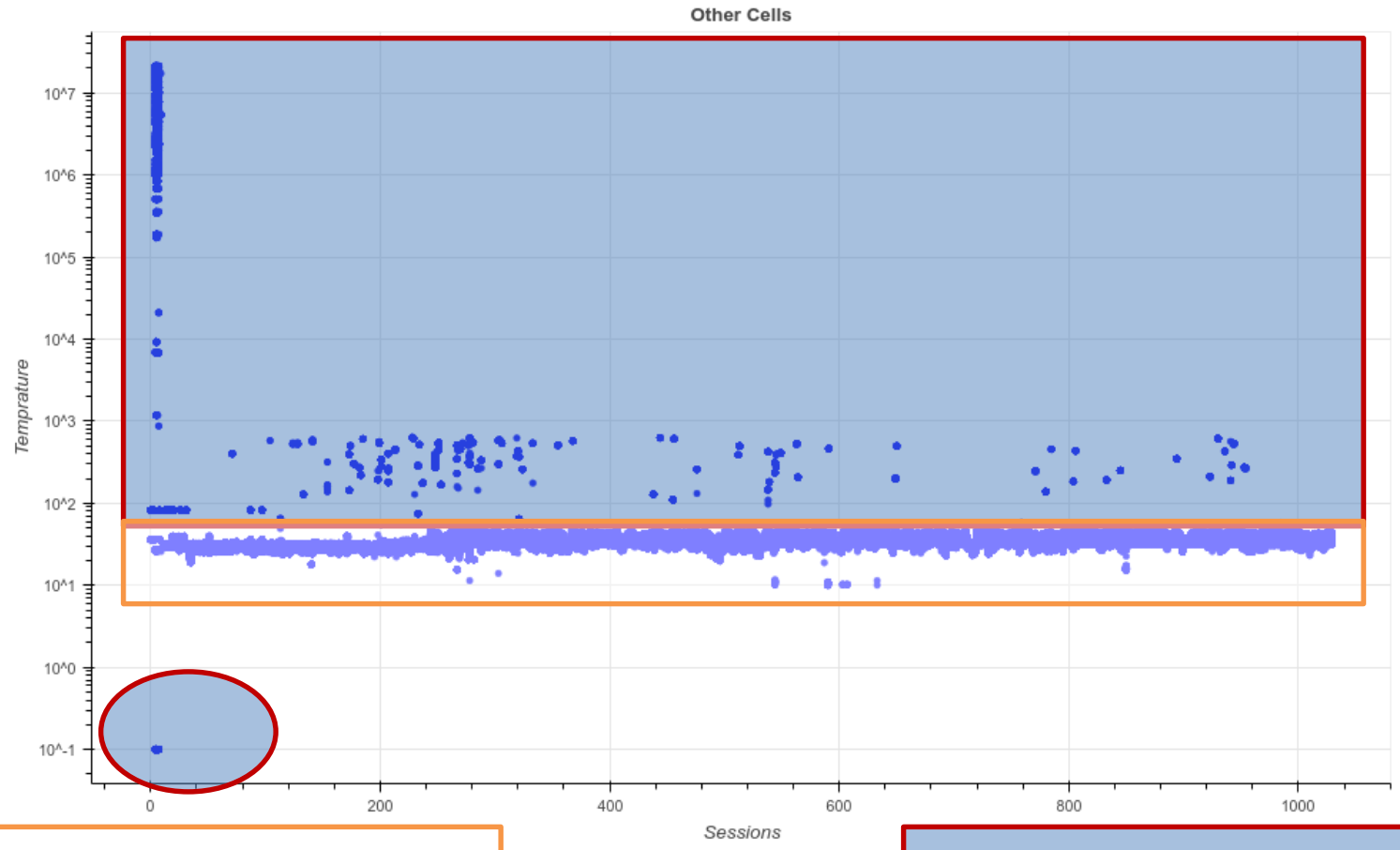
S.No	Make and Model	Wh/Km	Distance travelled (Kms)
1	Make 1, Model A	44	36
3	Make 1, Model C	38	27
4	Make 2, Model A	42	43
5	Make 2, Model B	37	51
6	Make 3	39	46
7	Make 4	58	31
8	Make 5	41	46

Sample Dated: 14th June, 2018

S.No	Vehicle Make	Total Rides	Avg. Wh/Km
1	Make 1/C	164	40.36
2	Make 2	331	44.15
3	Make 3	324	44.28
4	Make 4	419	46.29
5	Make 5	82	52.18
	All	1320	45.45

Cumulative of 4 Months

Charging – All Cell temperatures for all sessions (~ 6 Million data points)



Normal operating range – 25 to 50 deg.C

Wrong values - to be analyzed

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
  - like fuel-cells, distributed motors, batteries withstanding higher temperatures, motors without permanent magnets, heavy trucks

To Conclude

- More needs to be worked out
- 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
    - With attempts to preserve India's GDP and grow jobs
- Can we do it by 2030: Certainly

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