# Sodium Ion Battery

## WATTHOUR Private Limited

By Milind Dongre

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# Team Profile

## Dr. Karthik Kaliappan

**Post-Doctoral Fellowship from Western University, London, Canada.**

**Battery Design and Fabrication**

## Dr. Vaibhav Acham

**Ph. D. from CSIR- National Chemical Laboratory, Pune – India and Humboldt University, Berlin – Germany..**

**Catayst Design and Chemical Sythesis**

## Dr. Sachin Jadhav

**Ph. D from IIT-Mumbai.**

**Chemical Process Design and New Material Synthesis**

## Dr. Arjunan

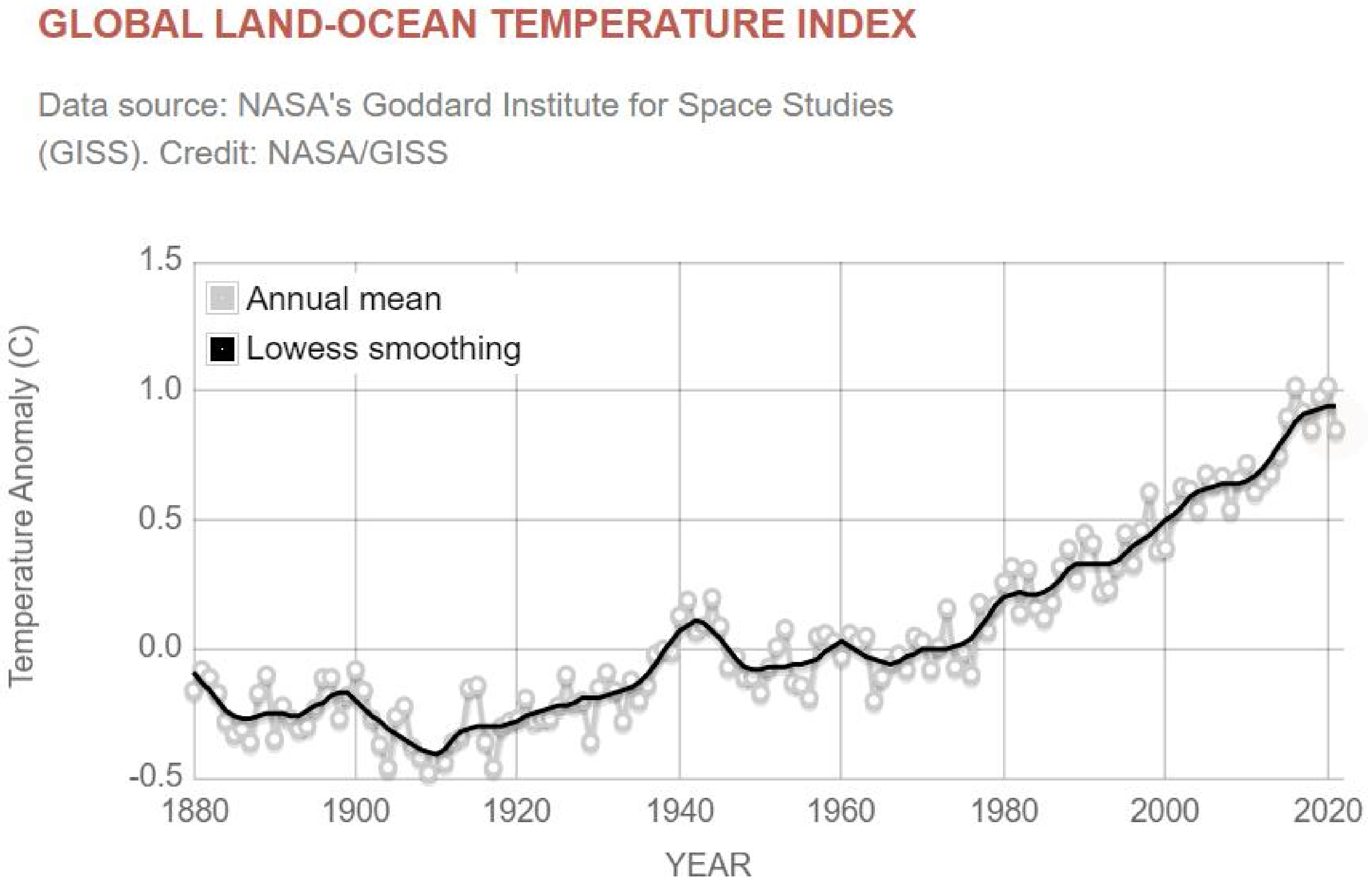
**Ph. D from University of Madras**

**Battery Fabrication and Separator Design**

## Milind Dongre

**B. Tech. IIT-Madras , MBA, IIM-C**

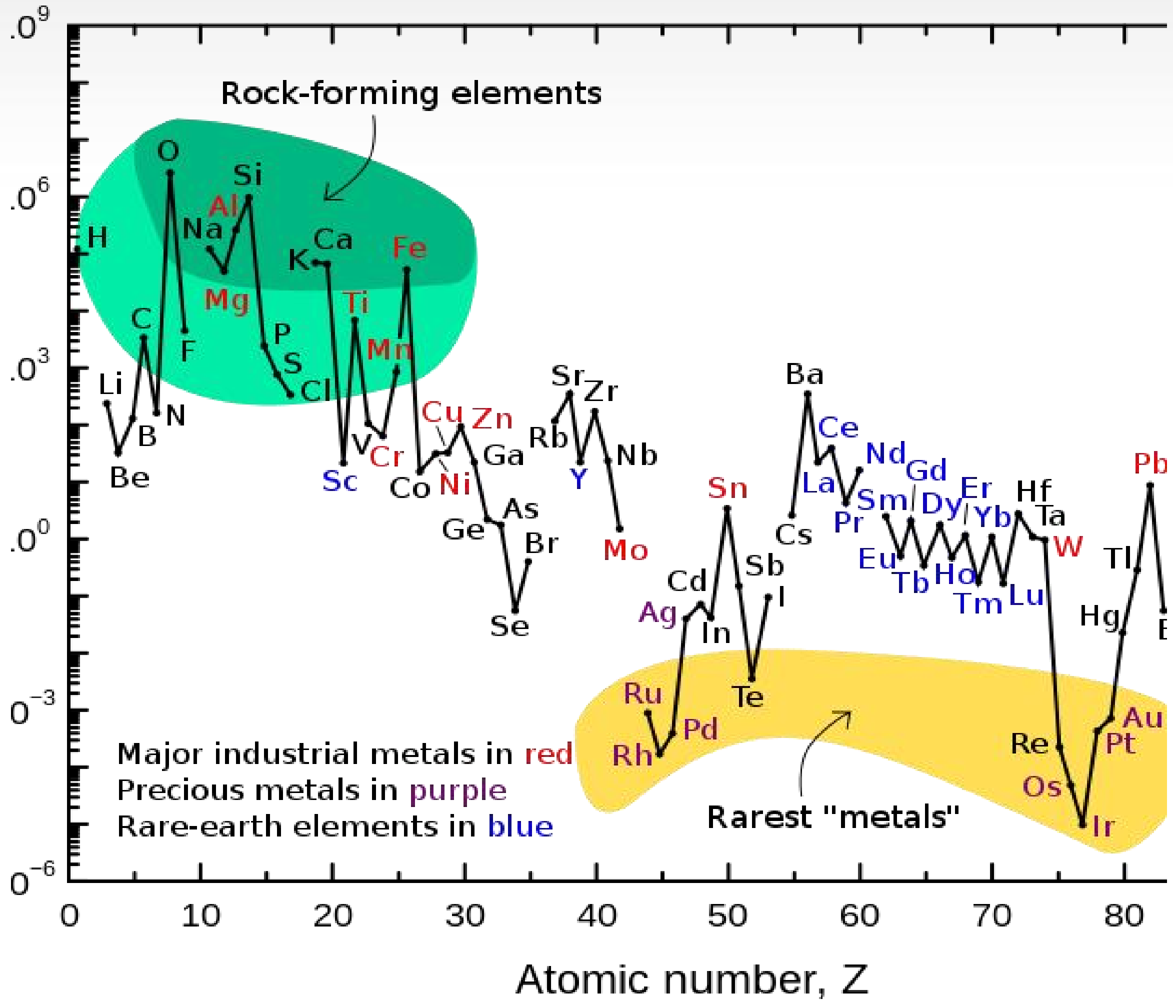
**Marketing, Finance and Product Design**




# Global Temperature Anomaly(Difference between Pre-Industrial Era and Present)

# Sodium Ion Battery(SIB) and its USP

- Using Earth Abundant Materials
- Can Scale Up Quickly
- No Supply Chain Issues
- Lithium , Nickel, Cobalt and even graphite have Geopolitical, supply related and Ecological and Human Rights related Risks.
- No China Dominance
- We will use Hard Carbon + Tin + Sb as Anode in SIB



# Sodium Ion Battery Cost Calculations

- Pricing model given by Argonne National Lab
- Please look at Na+//Gr row for Total Material Cost ($/kWh),
- CAM is Cathode Active Material and with economics of scale the cost will come down

| Battery Cell Energy and Cost Model (CellEst) | | | | Input Variables | Literature Properties | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | | | | |
| Cell Chemistry | Total energy capacity of production facility [GWh] | Number of produced cells [# of cells] | CAM used [t] | CAM material cost [$/kWh] | CAM preparation cost [$/kWh] | Anode cost [$/kWh] | Binder [$/kWh] | Conductive Carbon [$/kWh] | Positive Current Collector [$/kWh] | Negative Current Collector [$/kWh] | Separator [$/kWh] | Electrolyte [$/kWh] | Packaging foil [$/kWh] | Total Material Cost [$/kWh] |
| NCA//Gr Panasonic Use Case | 1 | 1,02,71,439 | 1,520 | 19.78 | 12.94 | 13.42 | 2.52 | 0.72 | 1.44 | 3.93 | 0.47 | 4.83 | 1.49 | 61.55 |
| NCA // Gr | 1 | 1,05,58,008 | 1,563 | 22.92 | 13.30 | 13.45 | 2.57 | 0.74 | 1.48 | 4.04 | 0.48 | 4.85 | 1.53 | 65.37 |
| NMC-111 // Gr | 1 | 1,16,99,787 | 1,874 | 30.24 | 15.85 | 13.71 | 2.90 | 0.84 | 1.79 | 4.87 | 0.58 | 4.95 | 1.70 | 77.42 |
| NMC-442 // Gr | 1 | 1,15,13,684 | 1,814 | 24.48 | 15.58 | 13.67 | 2.83 | 0.82 | 1.73 | 4.72 | 0.56 | 4.93 | 1.67 | 70.99 |
| NMC-532 // Gr | 1 | 1,13,43,852 | 1,758 | 24.64 | 15.09 | 13.62 | 2.78 | 0.80 | 1.68 | 4.57 | 0.54 | 4.91 | 1.65 | 70.28 |
| NMC-622 // Gr | 1 | 1,08,61,561 | 1,655 | 24.06 | 14.14 | 13.54 | 2.67 | 0.77 | 1.58 | 4.31 | 0.51 | 4.88 | 1.58 | 68.03 |
| NMC-811 // Gr | 1 | 1,06,18,010 | 1,563 | 20.97 | 13.35 | 13.46 | 2.57 | 0.74 | 1.49 | 4.07 | 0.48 | 4.85 | 1.54 | 63.53 |
| LMO // Gr | 1 | 1,41,05,875 | 2,356 | 9.77 | 14.89 | 13.19 | 3.33 | 0.98 | 2.44 | 6.63 | 0.79 | 4.78 | 2.05 | 58.84 |
| LMNO // Gr | 1 | 1,14,13,272 | 1,884 | 10.59 | 11.90 | 11.35 | 2.73 | 0.80 | 1.91 | 5.21 | 0.62 | 4.11 | 1.66 | 50.89 |
| LR-NMC // Gr | 1 | 1,00,59,581 | 1,391 | 18.71 | 11.88 | 13.48 | 2.40 | 0.68 | 1.34 | 3.65 | 0.43 | 4.85 | 1.46 | 58.89 |
| Li-S // Gr | 1 | 61,45,050 | 373 | 2.15 | 2.98 | 77.05 | 1.35 | 0.35 | 0.38 | 1.03 | 0.12 | 4.60 | 0.89 | 90.90 |
| Na+ // Gr | 1 | 1,16,51,297 | 1,867 | 0.59 | 14.93 | 12.05 | 2.76 | 0.81 | 1.90 | 5.17 | 0.61 | 4.36 | 1.69 | 44.87 |
| LFP // Gr | 1 | 1,52,40,256 | 2,121 | 7.28 | 21.61 | 15.52 | 3.28 | 0.95 | 2.52 | 6.86 | 0.81 | 5.62 | 2.21 | 66.66 |

# Sodium, LeadACid and Lithium Ion Batteries Comparison

## Battery comparison

| | Sodium-ion battery | Lithium-ion battery | Lead–acid battery |
|---|---|---|---|
| Cost per kilowatt-hour of capacity | $40–77 (theoretical in 2019)[52] | $137 (average in 2020).[53] | $100–300 |
| Volumetric energy density | 250–375 W·h/L, based on prototypes[55] | 200–683 W·h/L | 80–90 W·h/L |
| Gravimetric energy density (specific energy) | 75–200 W·h/kg, based on prototypes and product announcements | 120–260 W·h/kg (without protective case needed for battery pack in Vehicle) | 35–40 Wh/kg |
| Cycles at 80% depth of discharge[a] | Hundreds to thousands | 3,500 | 900 |
| Safety | Low risk for aqueous batteries, high risk for Na in carbon batteries | High risk[b] | Moderate risk |
| Materials | Earth-abundant | Scarce | Toxic |
| Cycling stability | High (negligible self-discharge) | High (negligible self-discharge) | Moderate (high self-discharge) |
| Direct current round-trip efficiency | up to 92% | 85–95%[60] | 70–90% |
| Temperature range[c] | −20 °C to 60 °C | Acceptable:−20 °C to 60 °C.<br>Optimal: 15 °C to 35 °C | −20 °C to 60 °C |

# Competitors Comparison

| NAME | Specific Capacity in mAh/g or Wh/Kg | Chemistry | Cost in $/kW | Cycle Life | Operating Temp in Celsius | Charging Time in Minutes |
|---|---|---|---|---|---|---|
| Faradion | 155 | $Na_xNi_yMn_zMg_aTi_bO_2$ | 85 | 1200 | -15 to 68 | 20 |
| Natron | 16.5 Wh/kg | Prussian Blue analogue electrodes as Cathode | 65 | 50000 | -20 to 45 | 14 |
| TIAMAT | 140 | $Na_xV_2(PO_4)_2F_3$ | 95 | 2000 | -20 to 68 | 15 |
| CATL | 160 | Prussian White Cathode | 70 | 1500 | -20 to 70 | 15 |
| HiNa | 138 | Na-Fe-Mn-Cu based oxide cathodes | 80 | 3000 | -15 to 60 | 20 |
| Atris | 160 | Iron based Prussian White | 85 | 5000 | -15 to 65 | 25 |
| ***WATTHOUR*** | ***110*** | ***Prussian Blue Analogue Cathode and Porous Hard Carbon Anode*** | ***65*** | ***3000*** | ***-20 to 70*** | ***15*** |
| NORTHVOLT | 160 Wh/Kg | Prussian Blue analogue electrodes | 85 | 2000 | -15 to 65 | 15 |

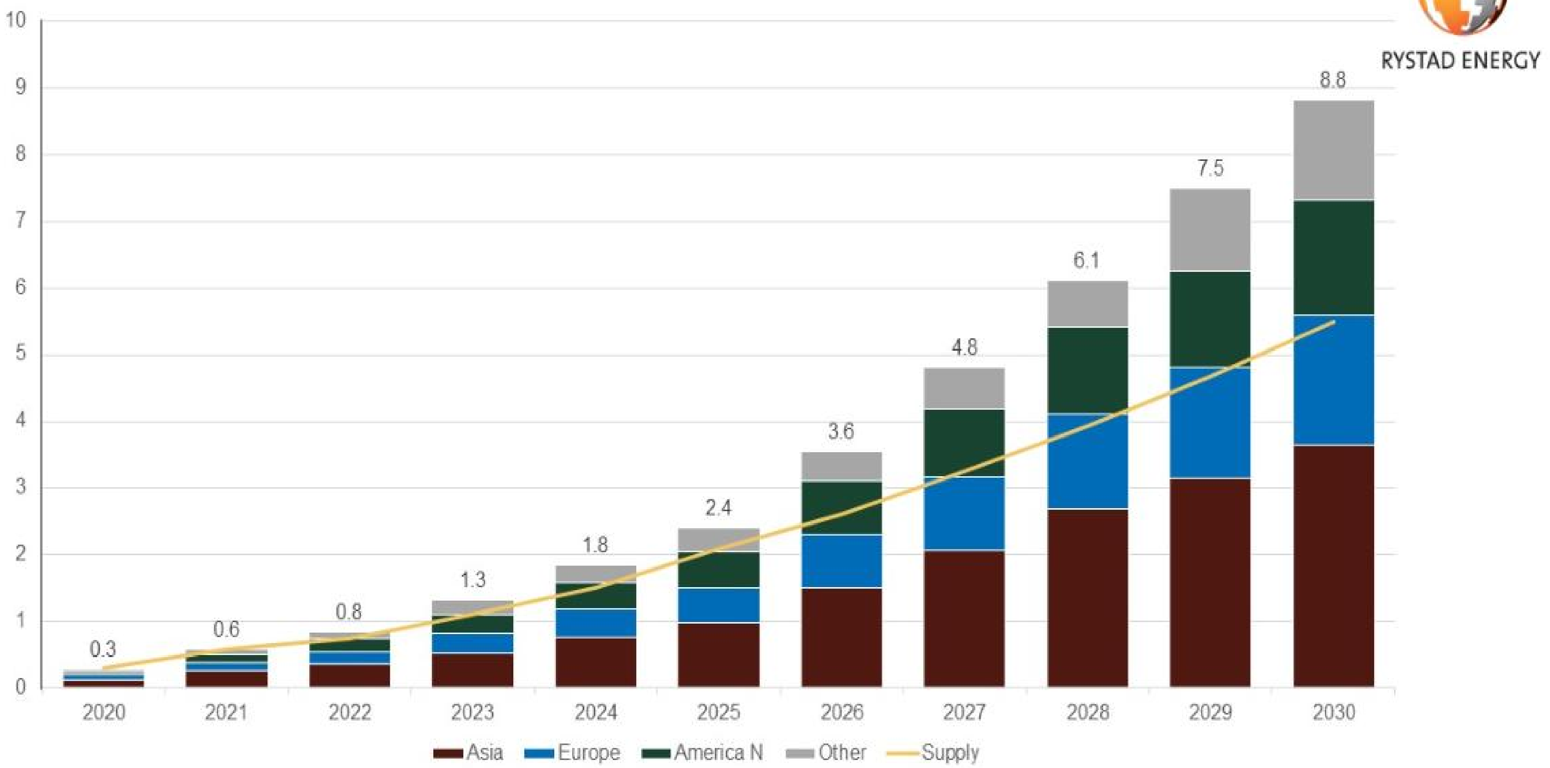
* Tentative Data collected from Various Internet search

# Global Demand & Supply Forecast

- Global Supply will be close to 5.5 Tera Wh by 2030
- There are 300 Major Manufacturing Facilities globally
- Global Demand by 2030 is expected to be close to 8.8 Tera Wh
- Electric Vehicles and Renewable Energy sector driven demand
- There may be supply short fall by 3.3 TWh by 2030.

**Global battery supply and demand by region***

Terawatt-hours (TWh)




*Includes demand from transportation and energy sectors.
**Source: Rystad Energy BatteryCube, Rystad Energy research and analysis**

# Indian Demand for Battery

- India has almost 300 Million Fossil Fule based vehicles at present
- The Electric Vehicle Batteries Market is expected to reach a value of $175.11 billion by 2028, at a CAGR of 26% during the forecast period 2022-2028
- Total Indian Demand may be around 2560 GWh by 2030 as we have largest market of Electric Two Wheelers and affordable Cars
- Currently In India there is almost no Manufacturing plant for Lithium or Sodium Ion Batteries
- I have met Central Govt Minister Mr. R K Singh and requested his team to speed up VGF Scheme Roll Out
- Indian Govt encouraging all companies to produce energy saving devices
- Renewable Energy firm requested us to make 500 MWh asap, very pressing demand
- **Indian Scenario is very attractive as there is very low Supply and potentially Huge Demand in coming decade**

*Source Niti Ayog

**EV (considering 30% penetration by 2030)**

| Transportation sector | Energy storage per vehicle | Energy storage requirement (GWh) |
|---|---|---|
| 2 wheelers: 200 million | 1–2.7 kWh | 200–540 |
| 4 wheelers: 40 million | 10–20 kWh | 400–800 |
| Buses: 3 million | 100–324 kWh | 300–970 |
| Energy storage demand for EVs in 2030 (GWh) | 900–2300 | |
| Energy storage demand in grid sector by 2030 (GWh) | 260 | |

# Meeting with Honorable Power Minister


We met with Honorable Power and MNRE Minister Shri R K Singh. We insisted to help us and speed up VGF Scheme processes.

His team is good and they want us to create plug and play product and this will benefit Renewable Energy and EV Firms a lot.

# Potential Clients

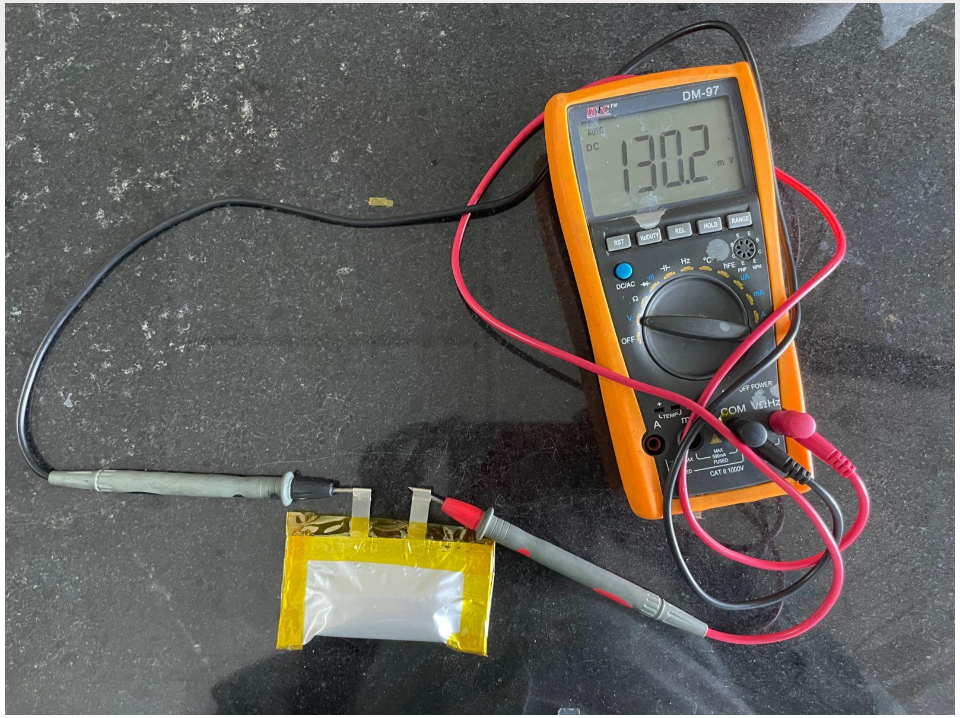
- Solar, Wind, Waves Farms (Renewable Energy Firms)
- EV Manufacturers
- Hydel Power Plants
- Genset Manufacturers
- Defense
- Railways
- Drones

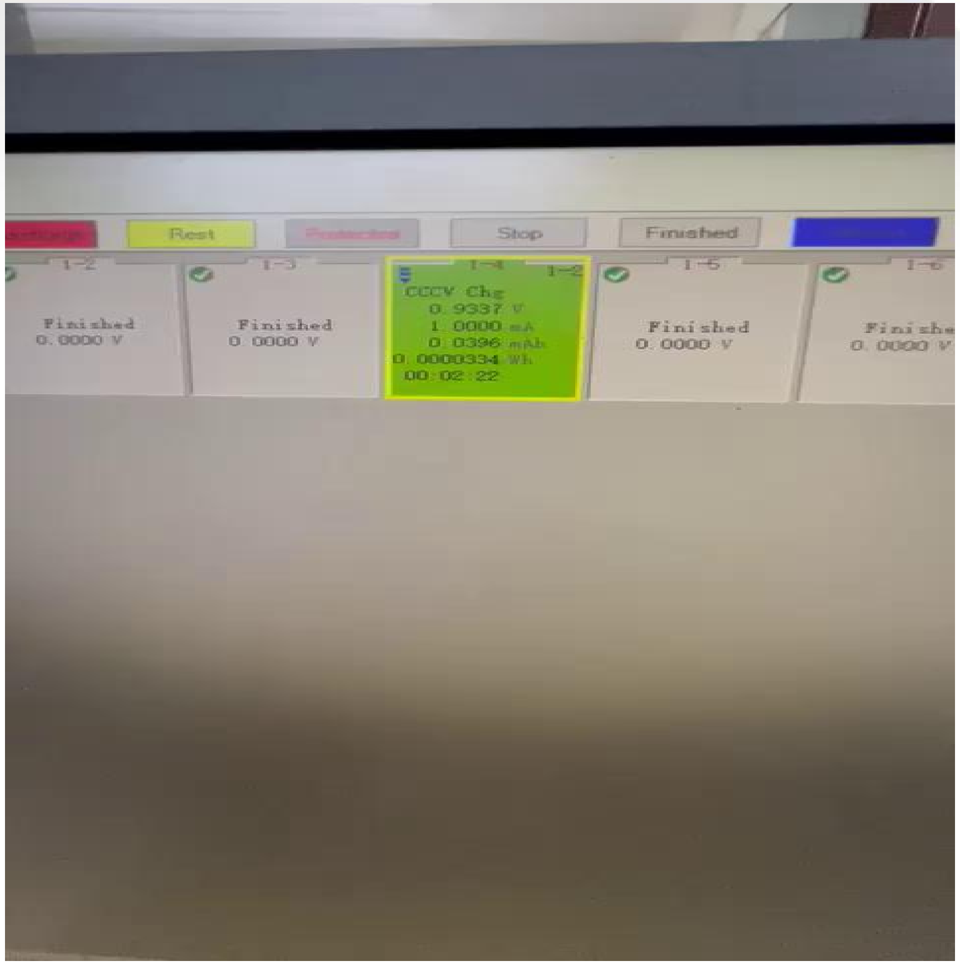
* Prelim talks held and clients are very keen as they have a pressing requirement for this product. Discussed with a big client (Renewable Energy Firms) who wanted us to make 500 MWh storage Capacity. Demand is huge and very urgent one.

# Product Roadmap

| YEAR | TARGET |
|---|---|
| 2023 | Create a commercially viable prototype Battery- Achieved |
| 2024-25 | Commercial Production |
| 2025-26 | Enhance the capacity to 160 mAh/g |
| 2026-28 | Develop certain combination of Quasi State Separator and Electrolytes to achieve high Ion Conductivity and enhance capacity close to 500 mAh/g. |
| 2027-29 | Develop room temperature Sodium-Sulphur , Lithium Air or similar very high Capacity, close to 1100 mAh/g Sodium Ion batteries |

# Demo of Our Sodium Ion Batteries



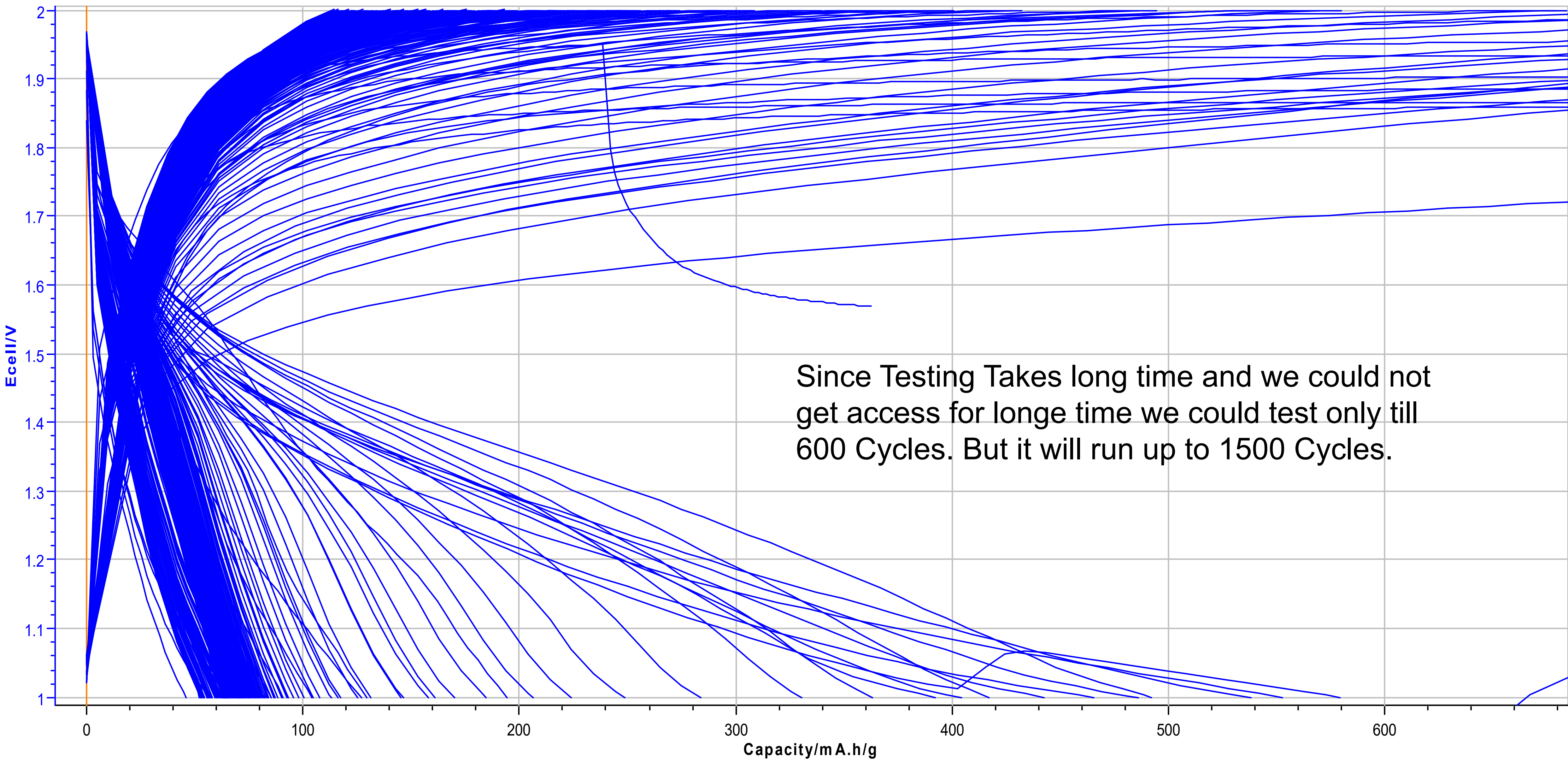




**Voltage Before Charging the Battery in 130.2 Milli Volts**

**We can provide Old Test Data**

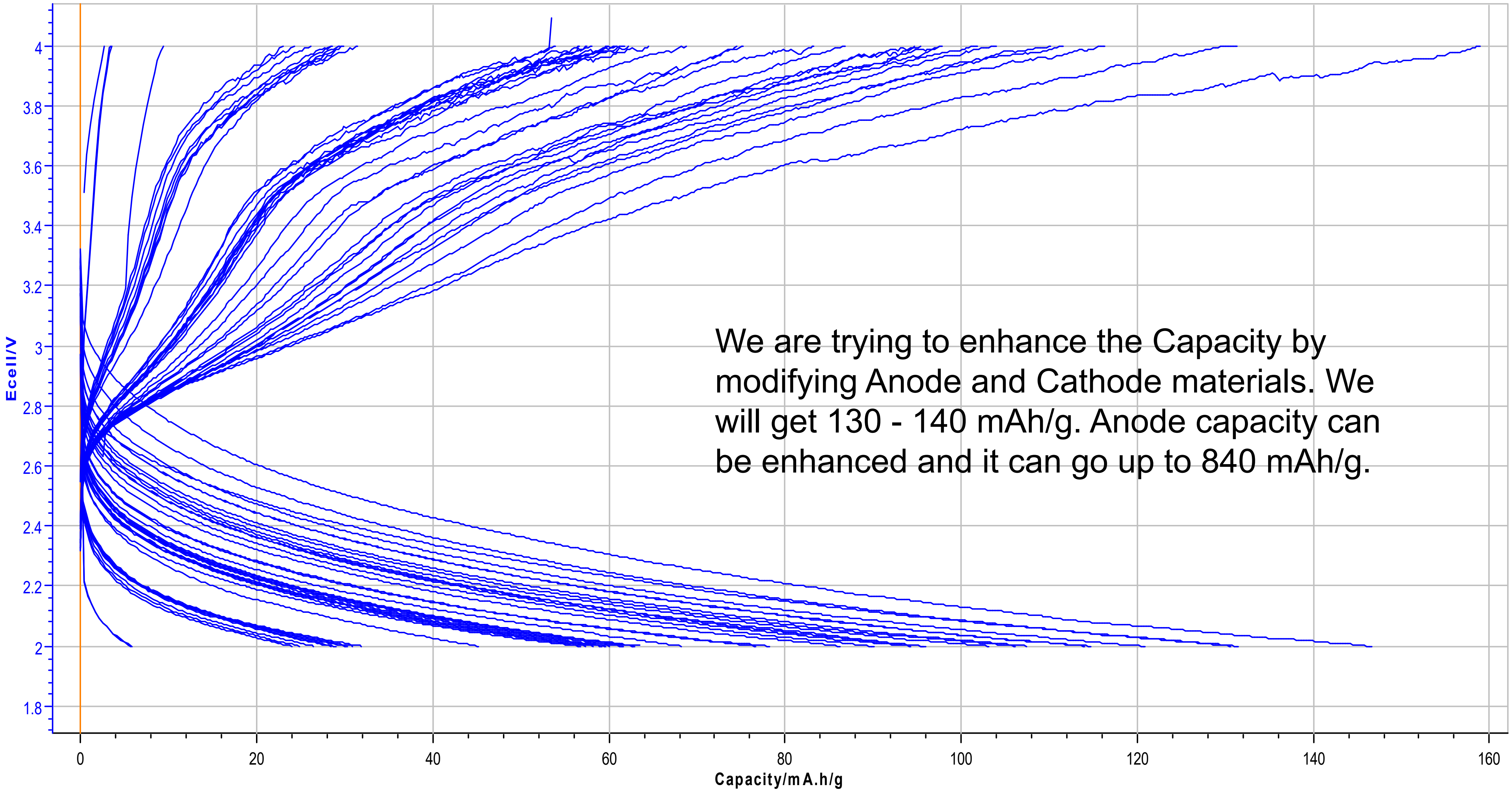
This is a Video while Charging. The Battery Voltage is Close to 0.93 Volts. It proves that Battery gains Voltages and Charges Successfully. Youtube Link **https://www.youtube.com/shorts/gFBD3mPkHac**

# Cycle Life of Sodium Ion Batteries -- Old Test Data



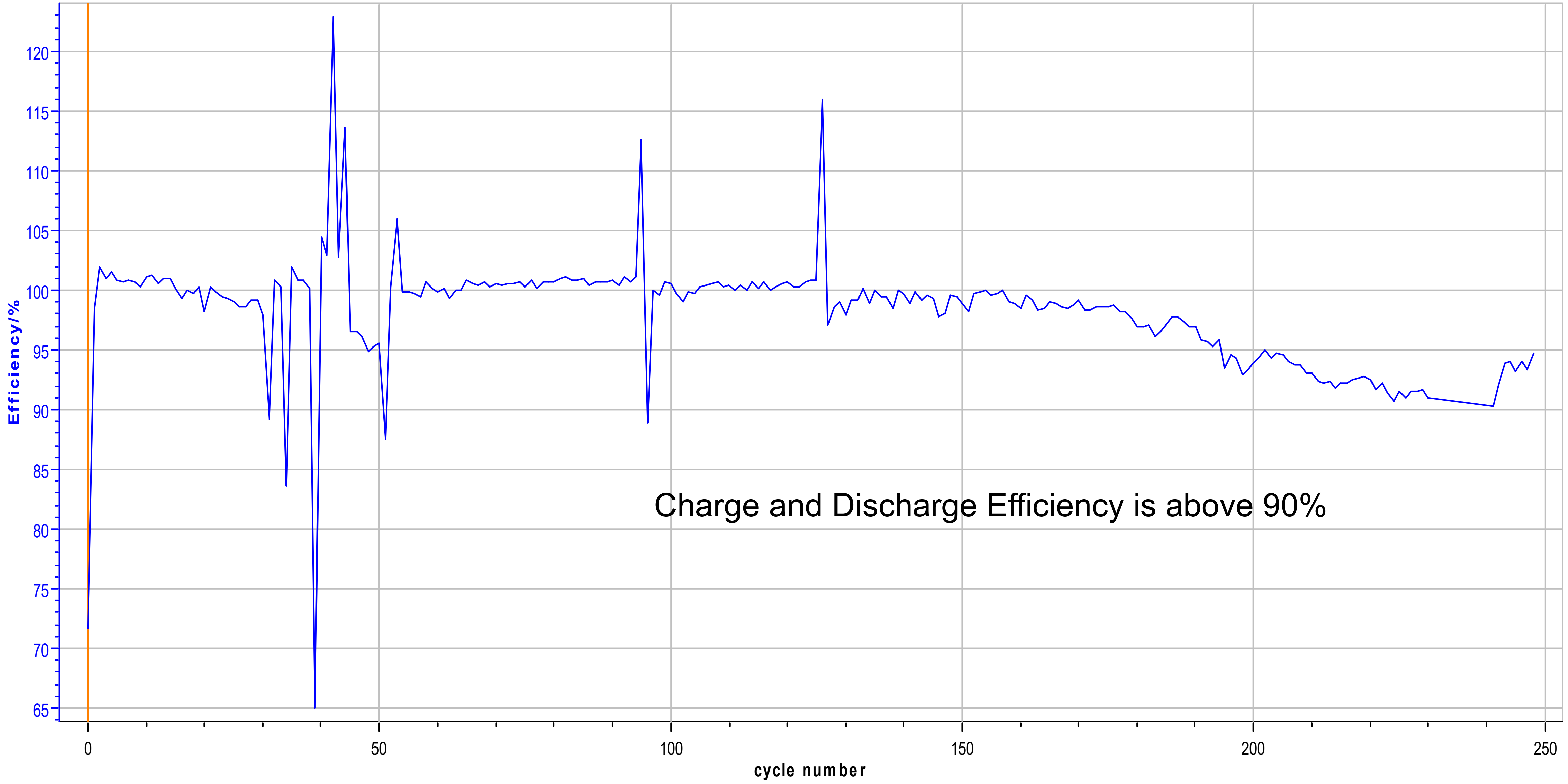

Since Testing Takes long time and we could not get access for longe time we could test only till 600 Cycles. But it will run up to 1500 Cycles.

# Capacity of Sodium Ion Batteries -- Old Test Data



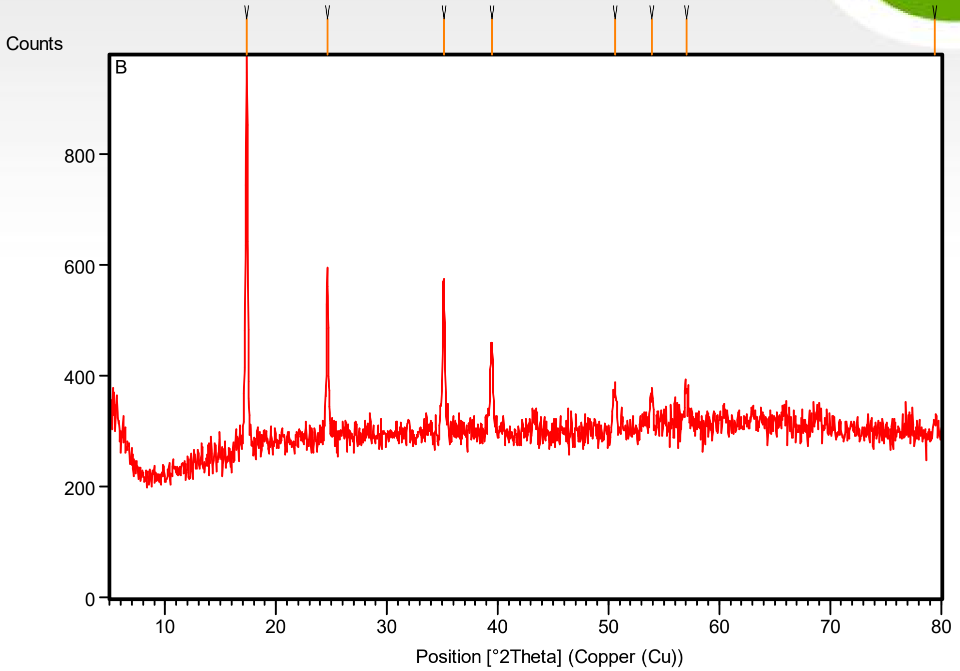

We are trying to enhance the Capacity by modifying Anode and Cathode materials. We will get 130 - 140 mAh/g. Anode capacity can be enhanced and it can go up to 840 mAh/g.

# Efficiency of Sodium Ion battery- Old Data



# In House Synthesized Prussian Blue Cathode Material

In House Synthesized Prussian Blue Cathode Material




| Pos. [° 2Th.] | Height [cts] | FWHM Left [° 2Th.] | d-spacing [Å] | Rel. Int. [%] |
|---|---|---|---|---|
| 17.3511 | 727.41 | 0.1574 | 5.11100 | 100.00 |
| 24.6414 | 313.51 | 0.1574 | 3.61291 | 43.10 |
| 35.1266 | 276.09 | 0.1968 | 2.55481 | 37.96 |
| 39.4932 | 161.84 | 0.2755 | 2.28182 | 22.25 |
| 50.5735 | 79.21 | 0.3936 | 1.80484 | 10.89 |
| 53.8846 | 66.04 | 0.2362 | 1.70150 | 9.08 |
| 57.0565 | 60.65 | 0.2362 | 1.61422 | 8.34 |
| 79.4616 | 21.34 | 0.4723 | 1.20613 | 2.93 |

Peak List Data and Graph

# Grant / Investment and its Usages

- We have NDA signed with IIT-Mumbai and can use Pilot Line

- Grant / Investment will be used to make Commercial Grade, plug and play Prototype as most of required materials can be synthesized in house

- We have already synthesized some Cathodes like Prussian Blue, NVP, NNM and Separators and Anode as Hard Carbon.

- We are trying to synthesize New and hgh Capacity Anode material and soon we will have some samples

- Other required materials are of low cost and are available easily

- We have experienced Fabriation Team to fabricate and to test these Batteries

- We have contacted Pilot Line or Mini Plant Machine Suppliers and they can provide machines and install that in less time.

# Immediate Investment Required for Protoype

- We have made NDA with IIT-Mumbai for Pilot Line Usage.
- This is a paid services and we need to pay 350000 INR + Taxes for 5 days usages.
- We can make and test 100 batteries per day in Pilot Line at IIT-Mumbai
- In-House Lab can synthesize Cathode , Anode, Separators, Electrolytes etc.
- This reduces cost for our Batteries even further and speeds up the process
- We need around 2 Crore INR or around 250000 USD to make Prototype.

# Investment for Pilot Line Cost

- Daily Productivity: 800-1000 pieces/8Hours/Day
- 18650 **Cylindrical Cell** and Capacity: 2.3 Volts, 1.2 Ah
- Cost of machines for Cylindrical Cell Pilot Line : 0.7 Millions USD
- Operating Cost for Cylindrical Cell Pilot LIne : 0.55 Millions USD
- Total Cost for Cylindrical Cell : 1.25 Millions USD

- Daily Productivity: 800-1000 pieces/8Hours/Day
- **Pouch Cell** Size L*W*H:70*35*5 mm and Capacity: 2.3 Volts, 1.2 Ah
- Cost of machines for Pouch Cell Pilot Line : 0.8 Millions USD
- Operating Cost for Pouch Cell Pilot LIne : 0.45 Millions USD
- Total Cost for Pouch Cell : 1.25 Millions USD

*Best Estimates numbers based of given Quotations

# Investment Needed and Its Usages for 1GWh Plant

| Investment Costs | | SIB |
|---|---|---|
| Capital equipment cost including installation, mil$ | | 27.5 |
| Building, Land and Utilities | | |
| Area, m2 | | 10800 |
| Cost, $/m2 | | 700 |
| Building investment, mil$ | | 7.5 |
| | | |
| Launch Costs (Marketing, Admin, R&D , Salaries, Legal, Insurance, Miscellaneous) , mil$ | | 7.60 |
| Working capital (30% of annual variable costs), mil$ | | 24.90 |
| Total investment, mil$ | | 67.5 |

*** We have used Bat-pac-V2 by Argonne National Lab Model to get above numbers for Indian Conditions. These are best Estimates given Quotations of Manufacturing Machine Suppliers.**

# Boeing Company Bootcamp Participation Certificate

Certificate of Participation

This is to certify that Mr. *Milind Dongre*

of Team *Watthour Pvt Ltd*

was selected for the 2023 **Regional Cohort** of the

***Boeing University Innovation Leadership Development***

Program and successfully completed Regional Level workshops

held from 18th December to 20th December at

**SINE IIT Bombay**

IIT Bombay

SINE

Business Incubator

**We participated in a Bootcamp by Boeing Company. There was significant interest in our work in this program.**

# Questions & Answers

Thanks You