Aceleron Pilot – Lessons Learnt

Authored by

Dr. Paul Jennings
Joseph Mungai
Fousseno Sylla

Dr. Amrit Chandan

UKaid from the British people

Shell Foundation

Executive Summary

Aceleron has undertaken two projects with Shell Foundation partner BBOXX, to investigate the viability of replacing lead-acid batteries currently in use with Aceleron’s advanced Li-ion offering.

The BBOXX pilot has demonstrated the ability for Aceleron to successfully build and deploy advanced Li-ion batteries that are fit for purpose and have a number of advantages over their lead-acid counterparts. Further, with both projects we have demonstrated an ability to utilise and upskilling a local workforce with popup builds in country.

Special thanks to the BBOXX team for support this pilot and to Shell Foundation and DFID for funding this work.

Contents

Introduction

Background

With grant funding from Shell Foundation, Aceleron aimed to complete a pilot over the course of 12 months to address the following:

- Lab and field test the suitability of the repurposed battery technology for off-grid applications, with existing SF partner - BBOXX (household energy).
- Produce approximately 125 lithium-ion based "drop-in replacements" for the associated field trials in East Africa – replacing the lead acid batteries currently being used by BBOXX their respective products.
- Achieve a commercially attractive price point vs SF partner current Lead-Acid battery prices (ensuring sufficient unit economics to enable scale - post-pilot).
- Investigate the availability of a sustainable feed stock of local waste lithium-ion battery supply in East Africa – suitable for 2nd life application. Though for the purposes of the pilots, batteries will initially be sourced/shipped directly from the UK.
- Measure the impact that access to more affordable, efficient energy storage can have on the price point and lifetime of off-gird energy applications.

Summary Statistics

As of 14th December 2018 the following data has been collated.

Units Built	220 packs
Units Deployed	111 packs

The following data is compiled for the units deployed through the BBOXX pilot:

Uptime Total	6.63 years	Measured active hours summed
Carbon Offset	45 KgCO2e	Total energy CO_2 from coal power
Energy Total	128.44 kWh	Measured energy stored summed
Cycles Average	0.36 per day	Total number of cycles / active time (days)
Data Total	1,955,570 rows	Total number of data rows pulled from BBOXX API
People Impacted	500	5 (Kenya household size) 100 deployed units

Learning Outcomes

The expected learning and insights associated with this project sought to explore the following research questions – each mapping to one of main the project objectives:

I. To what extent could Aceleron achieve satisfactory performance metrics of their innovative repurposed lithium ion battery pack vs current lead acid batteries used by SF partners - both in lab and field testing?

II. What could be learned about the price point and unit economics that need to be reached in order to make 2nd life batteries a commercially attractive option at scale - both for Aceleron, and their targeted B2B customers?

III. To what extent was it possible to establish a circular economy related to energy storage - centred around the local collection, supply, testing, deployment and ongoing servicing of 2nd life lithium-ion batteries in a developing market?

IV. To what degree could the use of 2nd life lithium-ion batteries packs reduce the LCOE of the use cases for the pilot, and can a clear path/roadmap be established to apply this more broadly within the sector e.g. OGU's?

BBOXX

the solar revolution

ACELERON

BBOXX Pilot

Background

Aceleron and BBOXX deployed 100 Li-ion batteries in Kenya. This project was aimed at helping BBOXX transition away from their typical lead-acid battery packs, to more advanced Li-ion packs.

As part of the trial, Aceleron has accessed the BBOXX API to analyse telemetry data being collected. The level of data collected from these packs would not be possible with the lead-acid alternatives. While the Aceleron advanced Li-ion battery gives information on both the pack and cell group level, a lead-acid battery gives information only on the pack level. The additional data available for the Li-ion batteries gives us additional metrics with which to build our forecasting models that will improve accuracy compared to lead-acid.

Outcomes

The trial looked to assess the ability of Aceleron to replace BBOXX lead-acid batteries. As part of this trial, we looked to collect and analyse data giving high resolution insight into how the packs were running in their required application.

Ultimately Aceleron aimed to give BBOXX the ability to understand when assets would need recalling. This utilised intelligent algorithms to accurately predict failure points, dependent on past usage and allow for a consistent energy supply for customers.

Prototyping

For the prototype phase, Aceleron was able to deliver a couple of iterations of the battery to the BBOXX offices in London. There was a collaborative atmosphere that developed during this period. This was particularly beneficial during troubleshooting, with a particularly noteworthy time during development of the BBOXX control algorithm. A version of the algorithm ultimately discharged the cells too far, damaging the pack. Due to the serviceable nature of Aceleron's design, we were able to visit the BBOXX offices, fix the pack and discuss progress in under an hour.

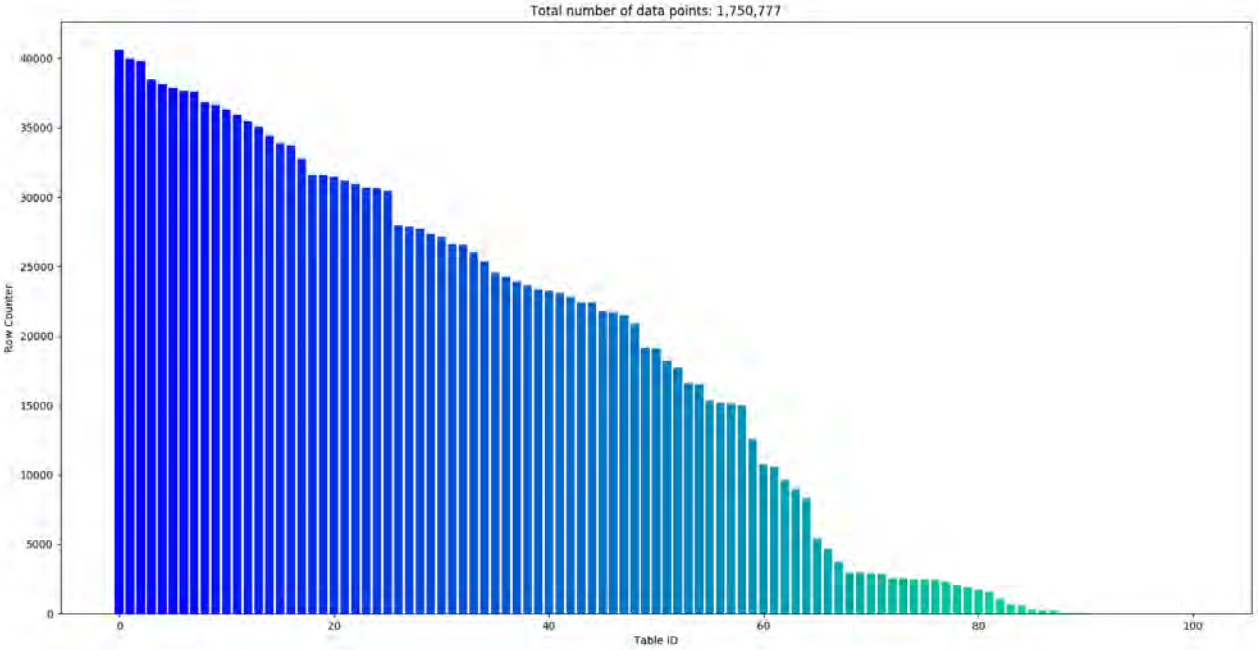
Results

Of the 100 batteries that were built on-location in Kenya, 9 suffered from some BMS problems. The remainder were dispatched into the field and have generally been running without issue. Recently a number of the packs had to be returned to the BBOXX distribution centre for repair. We are currently awaiting confirmation on the exact cause of a capacity issue, however, it currently appears as though the batteries are performing as should be expected and the issue lay with the BBOXX SHS unit.

All data collected from the battery packs is made available to Aceleron through the BBOXX API. This has allowed us to gain a detailed understanding of how the packs are performing in the field.

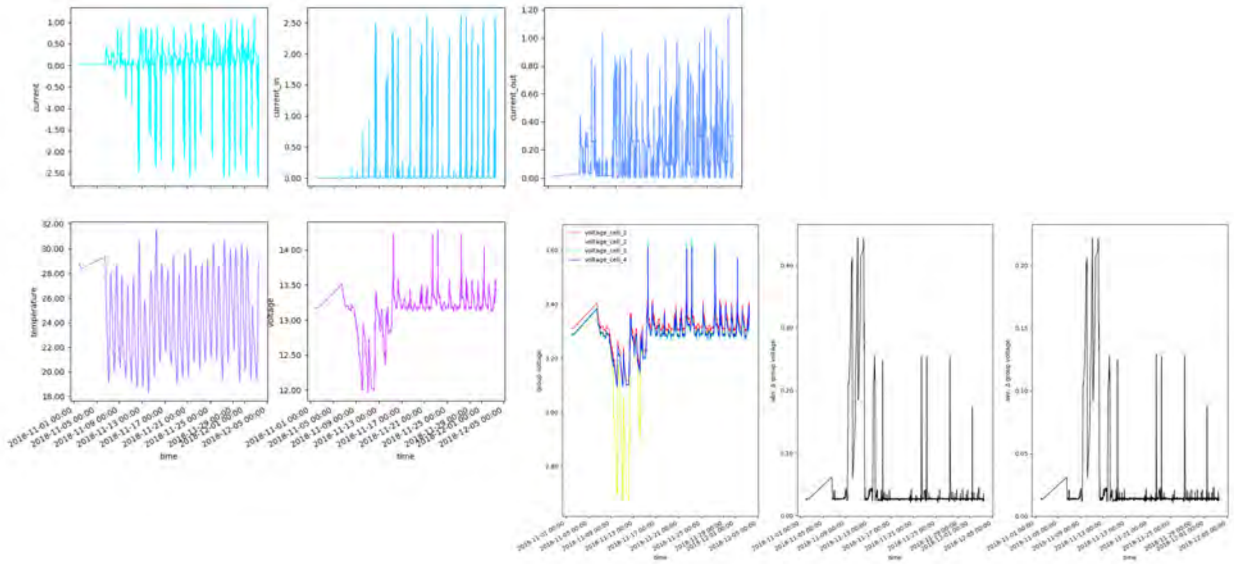
Database Analysis

Through the BBOXX API we are able to pull data collected from the field and store it in a local database to perform analysis. To date, we have access to almost two million data points, though from the graph it is possible to see that packs are not generating data with uniformity. Each bar represents a separate pack, so for some we see that ~40,000 data points have been collected, for others we see very little (or none). When the BBOXX SHS unit is running without issue, data is collected every minute of active operation.



Time Series Data

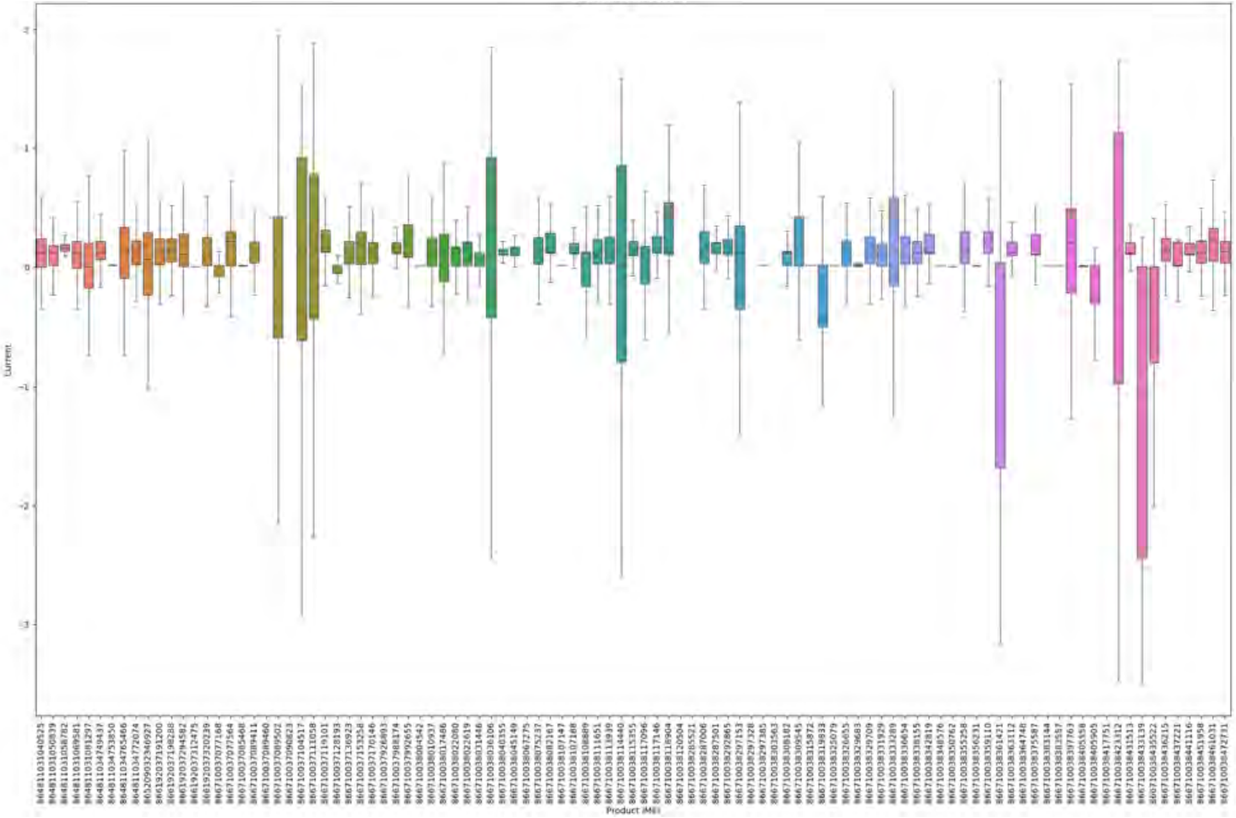
With the time series data being collected, we are tracking trends and monitoring for unexpected behaviour that could suggest failure points. Metrics being tracked through the BBOXX API are typically current, voltage and temperature.



We track balancing between cell groups that gives an indication of pack health. In this example, cell groups were initially fairly unbalanced after the build. But BMS was able to re-balance through normal usage of the pack. One of the BMS functions is to balance the voltage of the cell groups. Without this balancing, a group could age faster than others resulting in a limit to the available energy of the pack. This would ultimately reduce pack efficiency.

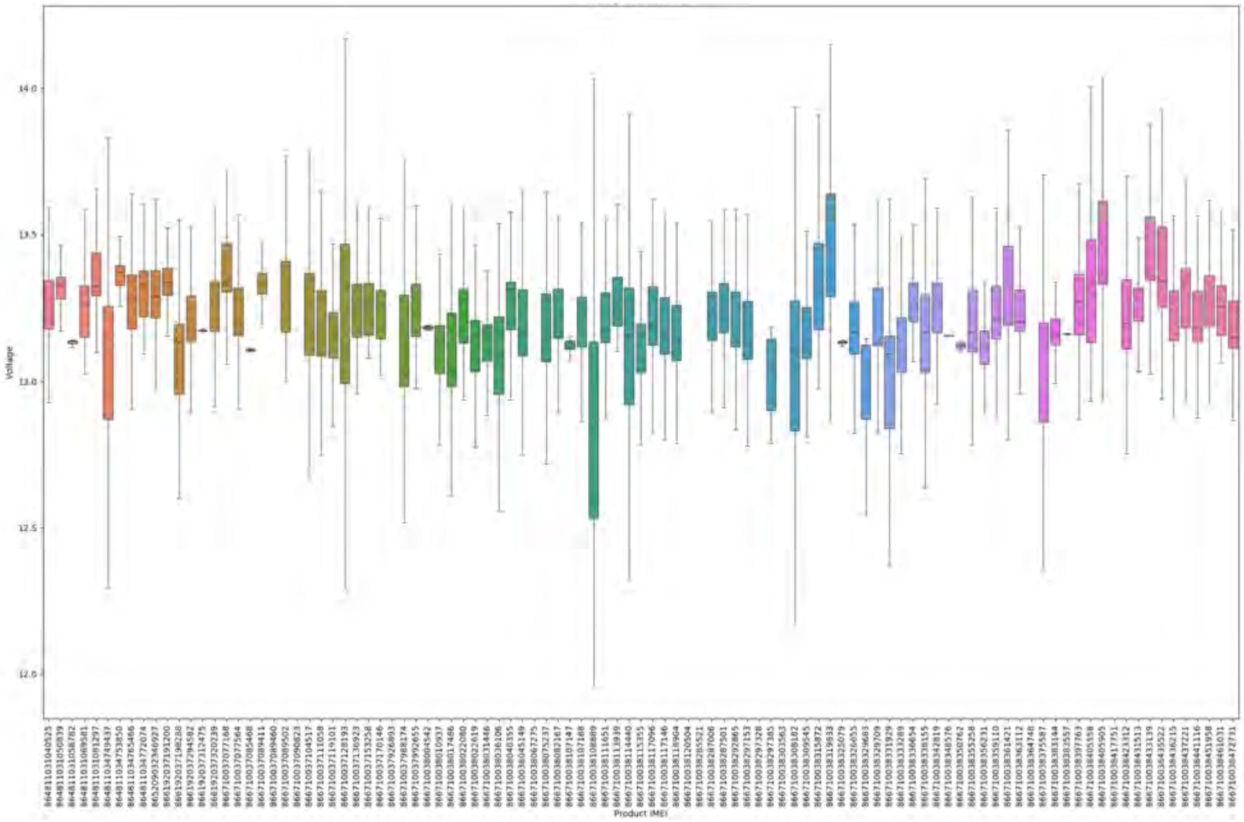
Current Distribution

Distribution of measured current shows batteries working as should be expected. The battery pack has been designed to allow charge and discharge current up to 15A. Batteries are working safely and well below the limit.



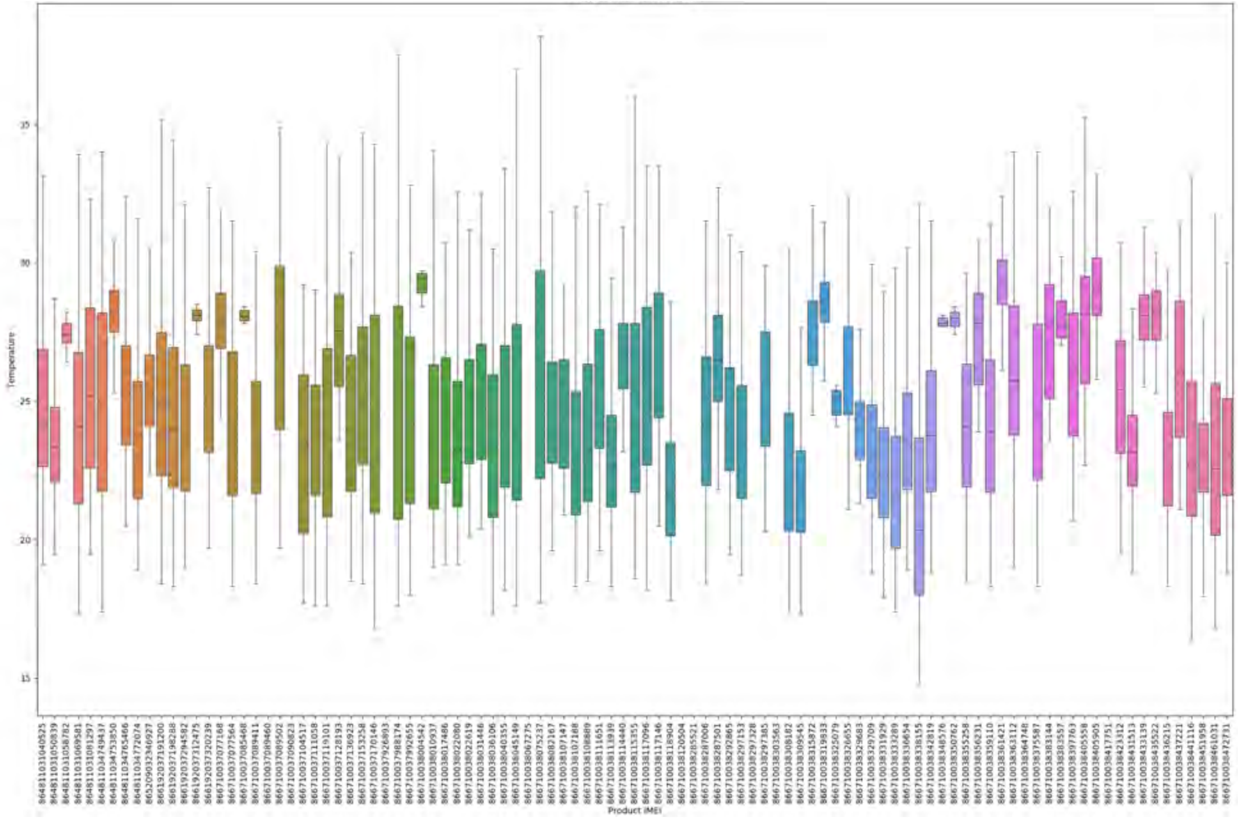
Voltage Distribution

Distribution of measured voltage again shows batteries working as should be expected. BBOXX algorithm has been designed to allow the battery to operate at a voltage window between 11V-14.5V.



Temperature Distribution

Distribution of measured temperatures remain between safe limits, unlikely to damage the pack. To get the best efficiency a battery should operates between 5 to 45°C. From the graph these limits are respected.



Dashboard Prototype

As part of the trial, Aceleron has prototyped a dashboard interface, served internally currently. This allows design engineers to spot long-term trends and potentially modify designs based on this feedback. There are plans in the mid to long term to commercialise this platform to allow for battery monitoring and performance insight.

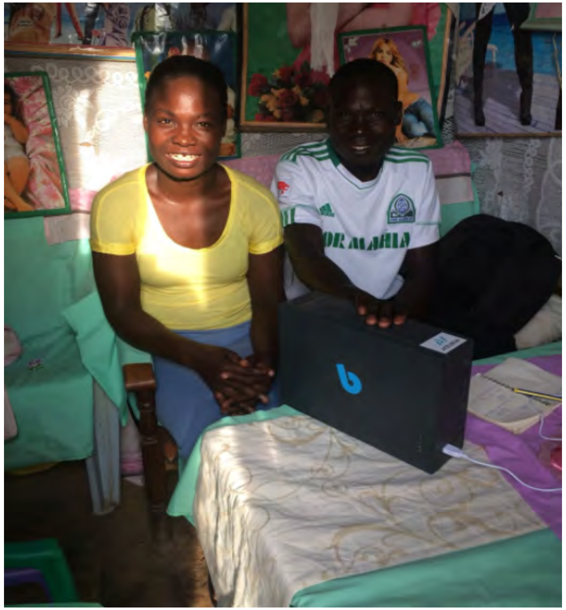
Anecdotal Evidence

"I like the system because it is light and makes work easier at the same time, it is safe with respect to positioning-it can be placed lying with its broad side, a thing that makes it stable and reduces chances of falling off at customer's premises."

- BBOXX Kenya Technician

"I have been able to enjoy the battery energy from 6.40pm to 11pm daily. In fact, I like the light battery because my husband had the heavy one, and it was never stable until he decided to return it, but this one has been so good. I like it much more. All my lights are on without a blink, having charged my two phones and my torch. Sometimes I charge two phones for my neighbor too. Am grateful for BBOXX."

- Emily Otieno Ndolo



Emily and her husband

Conclusion

The trial in Kenya has been successful from the hardware perspective, the packs were deployed and the majority are running consistently well to date with benefits such as significant weight reduction for the end user.

Telemetry data from the deployed packs are being collated and analysed. This is giving Aceleron ongoing insight into how the packs are being used and is already giving indication on how to optimise for the BBOXX use case.

To date, only a months worth of data has been collected. With this we can pull some daily trends. As the project progresses, it will be possible to understand monthly trends as well.

Due to the positive nature of the pilot, BBOXX are now placing a purchase order for between 1,000-2,000 advance Li-ion batteries from Aceleron.

Summary Responses to Research Questions

Outcome I.

I. To what extent can Aceleron achieve satisfactory performance metrics of their innovative repurposed lithium ion battery pack vs current lead acid batteries used by SF partners - both in lab and field testing?

Initially Aceleron has focused on engaging customers with first-life cells. The decision to initially pilot first-life instead of second was predominantly due to the speed at which the trial aimed to be completed. Reliability of supply for 2nd life cells in country was questionable and the regulatory hurdles required for the import of 2nd life cells would have been significant. However, utilising new cells has allowed us to build a particularly productive relationship with BBOXX. As we gather data on the packs that have been to deployed to the field, we are able to see that the packs are running as should be expected, further we will also learn usage profiles over time.

At the very least, they are providing comparable performance to the previous lead-acid packs but with additional advantages of being significantly lighter, which is a very important implication for the end user, typically carrying the unit a long way from the distribution facility. The packs are also easily repairable, with the training that has been undertaken so far, this is already seeing rewards. Finally, as we gain an understanding of what each pack has been through in 1st life, we can start writing the algorithms that can be used to classify returned cells for repurposing. Therefore, we have now broadened our focus to include serviceable battery packs as opposed to purely repurposed packs.

Outcome II.

II. What can be learned about the price point and unit economics that need to be reached in order to make 2nd life batteries a commercially attractive option at scale - both for Aceleron, and their targeted B2B customers?

Aceleron has learned that BBOXX purchase lead-acid batteries from Chinese suppliers for around a very small amount per unit. The upfront cost of an advanced Li-ion battery from Aceleron is higher, though the total cost of ownership is lower. This is due to the ability to maintain the pack replacing components as needed. Further, we have worked to develop a new (cheaper) range that can provide the advantages of Li-ion to particularly price sensitive markets, such as East Africa. As part of this development, the use of second-life cells will significantly reduce the cost of the pack, but we have further reduced the number of components within the platform and performed other cost-reducing activities to aid meeting this price point. The data collected from the BBOXX pilot has given clear indication of where we can successfully utilise repurposed cells within the use-cases coved.

Outcome III.

III. To what extent is it possible to establish a circular economy related to energy storage - centred around the local collection, supply, testing, deployment and ongoing servicing of 2nd life lithium-ion batteries in a developing market?

Training has been undertaken to ensure a local workforce is capable of performing cell testing on used cells at the WEEE Centre in Kenya. The project involved a repurposing scheme for the waste batteries contained in the Total/d.light defective solar lamps collected and sorted by the WEEE center, an electrical waste management company. This looked to class cells sent for recycling, where suitable cells were then retained for repurposing. This has resulted in classification of over 5,000 cells, current work is looking to utilise unsupervised machine learning to optimise cell grouping for building packs. Further, Aceleron is currently in talks with Lumos Group for a similar testing project on the west coast.

Being able to track battery usage over time has allowed us to start forecasting points at which the pack will have degraded beyond the point for which it is still a viable solution to the given application. At this point we can see how the data can be used to feed into optimising hardware placement within a circular economy.

Outcome IV.

IV. To what degree can the use of 2nd life lithium-ion batteries packs reduce the LCOE of the use cases for the pilot, and can a clear path/roadmap be established to apply this more broadly within the sector e.g. OGU's?

Whilst second-life cells have not be placed into the field, we have seen a clear advantage to the use of our serviceable design in storage as a service model. Data from the current units is enabling us to better understand lifetime costs and usage profiles in different applications. This is culminating in a service model based on the feedback and desires of the pilot partners that will reduce the upfront cost of the battery pack, opening up the market and ultimately enable Aceleron to profit from a subscription based model whereby we can ultimately optimise hardware placement within a localised circular economy.

Operational Lessons Learned

Lessons	Outcomes
Ability to transport battery packs through customs quickly can be dependent on the certification and paperwork being correct.	A possible way around shipping of batteries is to build the batteries in country. Aceleron now favours pop-up builds during any pilot phase.
It is really important to align expectations of the battery system and the end user requirements.	Aceleron has developed a detailed “tech pack” for the business development team to utilise while engaging on new projects to ensure needs are well understood.
Data and the ability to remotely monitor the batteries will be of vital importance to the success of the batteries in conditions such as SSA.	With availability of data from the BBOXX pilot, Aceleron has been able to prototype data workflows as well as start learning how the batteries are used.
Tampering of the batteries needs to be carefully considered as the batteries are serviceable and therefore easy to reverse engineer. Innovative ways to protect the IP needs to be developed.	New designs are being developed to make adding tampering more difficult and importantly more obvious when it has occurred so as to avoid Aceleron being responsible for damage as a result of tampering.
All teams members ought to be trained from the on-set including field technicians to successfully address concerns arising from the field regarding the battery features e.g. weight, positioning.	Aceleron has established protocol for both building and testing aspects of a project. When initialising projects in new regions, these can be followed to ensure safety at all times.
Stocking of batteries for replacement is key. Customers don’t appreciate getting a replacement of a different battery type with different chemistry.	From the pilots, we were able to gather some statistics on likely failure of components/packs. This gives an understanding of tolerances that should be accounted for.
Use of unique accessories to assemble the battery packs will significantly reduce the customer curiosity to open up the battery.	Design work is being undertaken to reduce the likelihood of a customer opening the pack.
Energy limiting of batteries affect the performance of the battery.	It appears to be common practice in some areas to limit the performance of the battery in order to prolong life. Aceleron is considering whether implementing these run parameters would impact the service model.