Battery technology energising off-grid power solutions in East Africa

Better understanding of the global battery market enables M-KOPA to achieve product innovation, enhance customer experience, and sustain commercial growth

Summary

M-KOPA has made clean, safe electricity to more than 600,000 homes in East Africa with its solar home systems (SHS). Batteries lie at the core of these SHS, and have the greatest impact on customer satisfaction. This paper summarises research that M-KOPA Labs undertook[1] to ensure that batteries acquired by M-KOPA support the long-life and reliability of the SHS in customers' homes.

The battery is one of the most expensive and technically complex components in a SHS, however commoditised nature of the battery market means that the complexities of battery technologies can be overlooked by SHS providers. In practice, the impact of battery performance on customer experience, and willingness to repay, makes it a critical business consideration, as well as one of safety.

M-KOPA considers it important to understand how to deliver positive customer experience by: ensuring stable battery performance under variable sunlight and temperature conditions; mitigating against charging and discharging irregularities; and ensuring long-life of the batteries. Through the research undertaken by M-KOPA Labs (the research and development business unit of M-KOPA), M-KOPA has developed deeper expertise in these key areas. Working with academics and industry partners, M-KOPA has advanced its knowledge of battery efficacy and management to enable it to make informed decisions relating to:

- which battery chemistries to use;
- which suppliers to buy from and at what price;
- which manufacturing processes and tests it should require from its suppliers;
- how to manage the charging, shipping and storage of batteries;
- how to monitor and manage a vast fleet of batteries in customers' houses; and
- when and how to replace and dispose of batteries safely and responsibly.

This paper summarises some of the key learnings from this research and identifies the next areas of research that M-KOPA Labs is embarking upon.

1 With support from the Adolf H. Lundin Charitable Foundation.

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The battery is the heart of customer's solar home system

M-KOPA's customers are predominantly low-income families living in rural areas of Africa with no access to the electricity grid. For less than the daily cost of dirty kerosene (for lighting and cooking), customers can buy a SHS that provides reliable electricity, and cease using toxic alternatives. M-KOPA's core SHS offer is an 8W photovoltaic (PV) panel combined with a battery, up to four LED lights, rechargeable LED torch, phone charger and a radio. Customers can also upgrade to a 20W system with a digital TV and purchase additional products, including smartphones and refrigerators. Many customers also use their solar systems to boost incomes by keeping businesses open later or offering movie screenings to neighbours, for example.

The right battery, properly managed, enables M-KOPA to provide its customers with affordable, high quality SHS. M-KOPA's SHS is only as good as the battery within, and reliable batteries form a critical element of M-KOPA's two-year device warranty.

M-KOPA found the effective life of batteries in its early products was strongly affected by environmental conditions, customer usage patterns, and, of course the quality of the batteries themselves. This resulted in high costs to M-KOPA to replace defective batteries under warranty, and to customers who had to travel to service centres for replacements to be provided.

Therefore, M-KOPA has strong incentives to source high quality batteries and improve the management of batteries in its SHS. This has resulted in M-KOPA recruiting a battery technology specialist, embarking upon the research discussed in this paper, and implementing a number of improved battery sourcing and management activities. The following sections summarise some of the key learnings that have informed M-KOPA's actions in these respects.

Box 1:

M-KOPA story

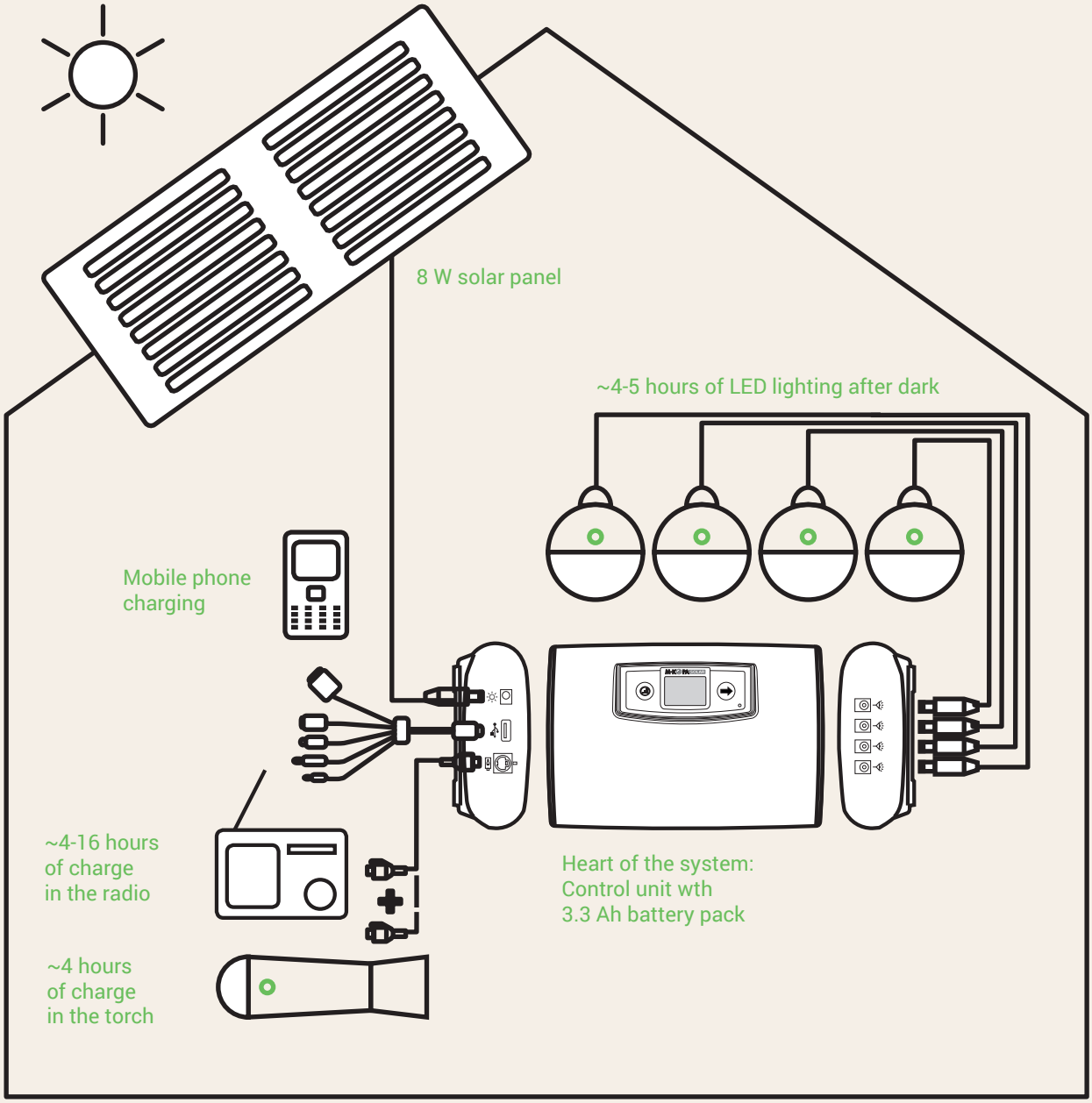
In 2012, M-KOPA set out to address the huge demand for affordable off-grid energy by pioneering pay-as-you-go solar energy services. The simple system provides low-income households with clean energy to power their lights and phones for less than they previously spent on kerosene for lamps and batteries for torches.

Using widely-available mobile money services, customers pay an initial US$35 deposit and then make daily payments of 50 cents for roughly a year. After completing the full payment, they own the SHS, with multiple lights, phone charging facility and a radio. They also have established creditworthiness with M-KOPA and can purchase a suite of other life-enhancing products, such as clean cookstoves, TV, and smartphones on credit.

M-KOPA has now connected 600,000 homes in Kenya, Tanzania, Uganda to affordable solar power, adding 500 new homes every day. The impact has been huge, both for individual families and the environment. Together, M-KOPA's customers enjoy 75 million hours of kerosene-free lighting each month and have saved more than 700,000 tonnes of CO2.

Figure 1: The battery plays a key role in the solar system

M-KOPA's core offer is an 8W PV panel combined with a battery, up to four LED lights, rechargeable LED torch, phone charger and a radio. Customers can also upgrade to a 20W system with a digital TV and purchase additional products, including smart phones and refrigerators.



The battery supply market is diverse in quality and in price

Recognising the fast pace of change in the battery supply market, M-KOPA commissioned an extensive study to identify new suppliers of high-quality, yet affordable batteries. The study also considered a range of battery chemistries to investigate alternatives that may exist to M-KOPA's currently preferred chemistry. The study provided a detailed understanding of the supply-side market and uncovered a wide range of additional factors that will affect M-KOPA's selection of battery manufacturing partners in the future.

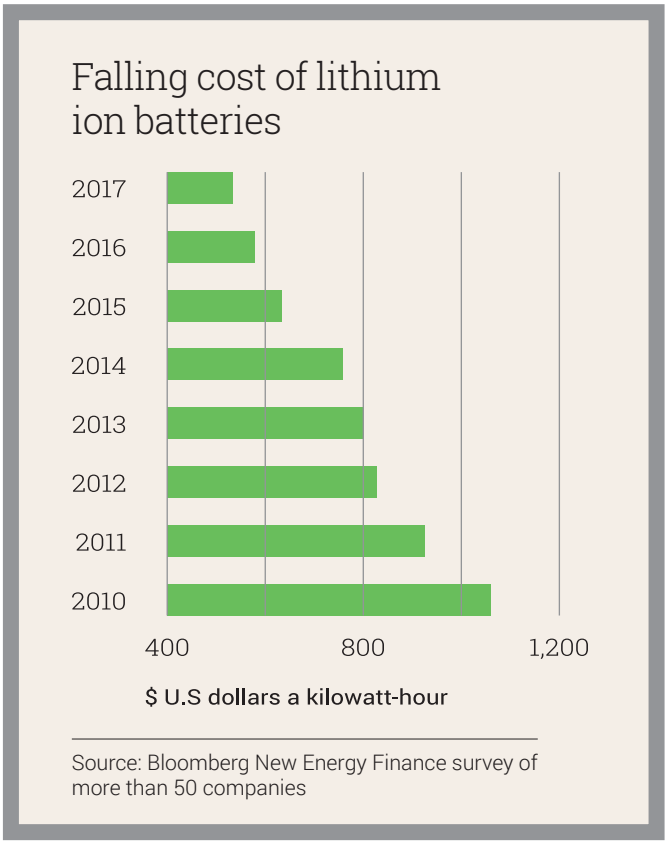
The supply side of the battery market is evolving, quickly

M-KOPA currently integrates lithium iron phosphate (LFP) batteries into its SHS. This selection was based on cost-effectiveness, portability, safety, and suitability for use in warmer climates. However, given the R&D investments in other battery chemistries, and the scale of investment in battery manufacturing, M-KOPA wanted to validate its choice of battery chemistry.

M-KOPA examined several other existing and emerging battery chemistries – including lithium nickel manganese cobalt oxide (NMC), lithium manganese oxide (LMO), lithium titanium oxide (LTO), lithium sulphur and metal air. Although these have significant opportunity to provide alternative and potentially lower cost alternatives, the effective time to market (at scale) is prohibitive. M-KOPA's priority is on the supply of batteries within the next five years, and further developments in production, cost, quality, and safety are required before these alternative options become commercially attractive.[2]

Battery economics are improving

The range and scale of lithium-based battery systems have significantly increased over recent years. This is driven in part by the battery needs of several markets: improved performance in personal electronic devices, renewables integrations, and electric vehicles. As a result, manufacturers have made considerable investments in their own operations to meet the rising demand for batteries and address specific industry needs.



This recent upsurge in volumes has also led to falling costs, a trend that is expected to continue with further supply chain efficiencies and manufacturing investment. Bloomberg New Energy Finance (BNEF) predicts the average price of lithium ion batteries might fall to approximately $100 per kilowatt-hour by 2025 (from $209 in 2017). They credit this decline to the rise in demand and the economies of scale achieved through increased production capacity.

2 It typically takes twenty years for an emerging chemistry or battery type to reach commercial penetration from lab bench prototyping.

The battery supply market is diverse in quality and in price

In addition to falling manufacturing costs, there are also growing opportunities throughout the value chain. Companies across industries, most notably electric vehicle manufacturers, are grappling with large stocks of used, yet still valuable batteries that must be recycled or discarded at a high cost to them. As a result, an interesting, nearer-term supply route alternative is the use of second-life battery packs from electric vehicles (EV).

This raises a case for extending the lifetime of batteries by reusing them in second life applications. The idea is simple: once batteries have reached end of life for one application, they can be reconfigured to meet the performance requirements for another purpose, increasing the supply of lower-cost batteries, maximising lifetime value, and deferring e-waste.

For example, batteries are discarded from EVs, when they lose 20-30% of their useable initial capacity in accordance with industry standards. There is an opportunity to repurpose them for a second-life application in SHS, creating a new revenue stream for EV manufacturers and extending the battery's lifetime value. M-KOPA is working with industry and academic partners to explore how M-KOPA may tap into the circular economy for batteries and source dependable, high-quality packs from the growing EV supply chain at a competitive cost.

Investing in expertise and competencies

By investing in its in-house expertise, and conducting external research, M-KOPA has sought to move from being a price-taker, to quality-setter when negotiating with its battery supply partners. It has also been able to define and set standards for factors such as battery quality and management requirements, sourcing audits, and data analytics. In this section we summarise some of the key advantages of this approach.

Collaborative supplier relationships unlock new possibilities

Panasonic, Samsung, CATL and other Asian giants produce high-performing lithium ion cells and packs in large volumes. However, M-KOPA still does not have the comparative purchasing power to acquire batteries from these top-tier suppliers at a price that ensures SHS affordability. Rather, M-KOPA sources from lesser known suppliers. This tier of battery manufacturers can appear rather homogenous, with little difference in price or quality. In fact, quality (performance and longevity) varies considerably.

Our research demonstrates that, through careful audit measures, it is possible to select manufacturers who have higher production standards, more quality assurance, and sound testing procedures in place. Selecting suppliers based not only on cost, but also safety and quality (only manufacturers with the appropriate ISO certifications) is essential.

When proposing these more rigorous selection criteria, M-KOPA has found an unexpected willingness amongst battery manufacturers to be active partners. This means M-KOPA can now work closely with battery suppliers to implement quality control processes at each stage of the manufacturing process. This helps ensure good quality cells, which in turn improves the overall quality of the battery packs (and, ultimately the SHS).

Just as battery manufacturers have tight quality assessment protocols and audits in place for the electric vehicle market, M-KOPA wants to raise the bar for battery manufacturers who supply off-grid solar applications. Arguably, quality standards are even more important where these relate to power supplies in customers' homes – requiring longevity, reliability and safety.

We believe that, over time, pressure from M-KOPA and other SHS providers will incentivise battery manufacturers to apply comparable standards of production to those offered to the EV market.

Knowledge transfer from industry, and academia to end-users

Academia and battery manufacturers are working on the next generation of battery chemistries to improve energy density, lifetime, safety, and more. M-KOPA's collaboration with both academia and industry partners is intended to ensure that the benefits of this knowledge will be realised through supply chain optimisation, as well as educating end-users on best battery practices.

Best practices for battery shipping, storage, and disposal are also common within academia and industrial scale battery users, but have not yet pervaded battery buyers in sub-Saharan Africa and elsewhere. Without quality control checks along the supply chain, SHS can expect higher maintenance costs and disappointed customers. For example, keeping fully-charged batteries in stock for too long can degrade batteries before they ever reach a customer's home, potentially requiring a replacement if the lights go off too soon. Therefore, close collaboration and communication between M-KOPA, its academic partners, and its battery suppliers is fundamental to extracting the full value of battery technologies and to ensuring quality standards that will benefit its customers.

Box 2:

M-KOPA partners with UK academia and industry bring innovation to East Africa

M-KOPA Labs, the research and development business unit of M-KOPA Solar, works with funding and implementation partners to identify new value-add products and services and bring them to market-readiness. It also informs the market on the impact of technology, energy access, and consumer finance in sub-Saharan Africa. M-KOPA Labs is currently undertaking two major battery projects, supported by Innovate UK, with strategic partners in industry and academia.

The first is a partnership involving Microsoft Research and the Department of Engineering Science at Oxford University. The project will analyse M-KOPA customers' user patterns to develop better diagnosis and prediction techniques, such as state-of-health and remaining useful life algorithms, for batteries in the M-KOPA fleet. A better understanding of customer behaviour will enable M-KOPA to optimise the lifetime of its devices in the current fleet, so customers are never without light for more years to come. This is increasingly valuable as we supply larger appliances, such as refrigerators. As battery size increases, so too will the criticality of a smart, remote monitoring system.

The second project is in partnership with Denchi Power and the Dyson Design School of Engineering at Imperial College London. The study will test the feasibility of re-purposing lithium ion batteries from the EV industry for solar home systems. Batteries discarded from EVs are still valuable for other, less demanding applications, such as M-KOPA's solar home systems.

Developing new capabilities in Africa

M-KOPA's research initially focused on an improved understanding of the battery supply market, but it eventually led to a far wider initiative to improve all aspects of battery management. M-KOPA's concentration on additional research and process improvements will lead to better products and enhanced customer experience.

In 2017, the UK's National Physical Laboratory (NPL) highlighted five key challenges to the widespread commercialisation of high energy density batteries in the UK[3]:

1. Quality control.
2. Diagnostic techniques: developing state-of-health algorithms.
3. Predictive models: combining data analytics and fundamental battery chemistry.
4. End-of-life thresholds.
5. Establishing standards.

This is interesting because the same challenges exist in M-KOPA's markets in Africa, and M-KOPA is focusing on all five areas in its research. M-KOPA is particularly focused on applying scientific research principles to battery selection, and better battery management to ensure that M-KOPA's SHS better serve customers in remote areas of East Africa.

Quality control, diagnostic techniques, and predictive models at the centre of the customer experience

Management systems for small battery packs are in the early stage of development. M-KOPA's cloud-based platform MKOPAnet already allows M-KOPA to remotely monitor each customer's device and tackle problems remotely. It also collects data on battery use and performance for each solar device in customers' homes. The huge volume of data collected (roughly 14.5 million data points per day), together with feedback from M-KOPA's Customer Care team, is analysed to improve battery management, maximise SHS life, and monitor the safety of batteries.

The next step in this process is the development of tools that will predict when customers' devices are likely to suffer a battery failure in the future and to pre-empt replacement – ensuring customers are never without a source of power.

The benefit of M-KOPA's model (SHS connected to a cloud based platform) is that M-KOPA can utilise machine learning and big-data analytics to develop and deploy tools that will monitor hundreds of thousands of devices without the need for intervention by the customer.

Embarking on a pathway to larger power solutions

Development of remote monitoring and management capabilities will become increasingly important. Not just to support customers who have M-KOPA's current SHS in their homes, but also to ensure reliable operation of the next generation of larger power devices.

M-KOPA is developing new products to meet customer wants and needs beyond lighting, phone charging, and TV. These new products will provide more utility in the household and support small enterprise income generation. They require sourcing and testing more powerful, higher capacity batteries, whilst maintaining a strong focus on affordability. One bad cell in an aggregated pack can weaken the performance of the entire system, making smarter battery management systems a necessity specially for larger battery packs.

3 National Physical laboratory. Energy transition: Measurement needs within the battery industry report.

Managing end-of-life batteries responsibly

M-KOPA takes steps to ensure battery quality and safety before they enter customers' homes, it also seeks to ensure safe and responsible disposal once batteries reach end of life. Globally there is a limited supply of facilities to recycle or dispose of lithium ion batteries. M-KOPA conducted an extensive search and partnered with a Kenya-based e-waste disposal company that complies with international environmental requirements for battery disposal.

As the number of SHS increases in sub-Saharan Africa, there will be a growing need for local recycling and disposal facilities for lithium ion batteries. This represents an investment opportunity to support the nascent recycling industry which can create local jobs and support the longer sustainability of the off-grid energy market.

Proper battery storage is one of the best practices M-KOPA implements to ensure high-quality products for customers

Case study

Larger batteries enable solar-powered refrigeration

Thanks to battery storage, many families can access refrigeration technology for the first time.

The use of a solar-powered refrigerator in a typical off-grid household yields many benefits[4]:

- *15% daily saving of cash through grocery bulk buying, on average*
- *41% cash saving through reduced cooking, on average*
- *26% reduction in time spent shopping and traveling to market on a weekly basis*
- *42% less food waste*

The battery plays a critical role, safeguarding food contents from spoiling by ensuring the refrigerator stays powered even on cloudy days. M-KOPA's remote monitoring capabilities for the battery enable M-KOPA to more accurately troubleshoot customer enquiries in real-time without requiring a visit to a distant service centre.

4 M-KOPA's internal research evaluation.

Moving from insight to innovation

The research summarised in this paper, supported by the Adolf H. Charitable Lundin Foundation, enabled M-KOPA to jump forward in its competencies and capabilities relating to battery sourcing, shipment, storage, management, and disposal. M-KOPA is now well equipped in the following areas.

- Auditing and collaborating with manufacturers committed to quality and consistency of batteries.
- Communicating and collaborating with academia and experts to adopt and implement best practices to optimise the lifetime of batteries in M-KOPA devices.
- Forming new partnerships, undertaking data analytics, and developing (cloud-based) tools to offer a new level of service to customers.
- Incorporating larger lithium ion batteries, diagnostics, and control systems into its new products – so customers can have more power, and do more with power.

M-KOPA is committed to leading the SHS industry with impactful battery innovation. The company's business model is based upon a long-term relationship with customers, and the battery lies at the heart of this proposition. Poor-quality, cheap batteries would lead to customer dissatisfaction and poor reputation, as well as material safety concerns. Therefore, M-KOPA places great emphasis on the sourcing and management of its batteries, even across a customer base that has already exceeded 600,000.

M-KOPA will continue to advance its understanding in the battery space to bring affordable, high-quality solar solutions to off-grid customers, and deliver still better customer experience. Throughout this journey M-KOPA will continue to share its findings to contribute wider industry knowledge for the fast-growing off-grid energy sector.