Submitted by:

AMPERES
Switch Batteries
REAM

e-waste to e-cook

piloting a scalable, modular power-pack using upcycled lithium-ion technology for affordable & reliable e-cooking in Myanmar

Final Report

February 2020

MECS Modern Energy Cooking Services
Loughborough University
ESMAP Energy Sector Management Assistance Program
UKaid from the British people

e-waste to e-cook:
piloting a scalable, modular power-pack using upcycled lithium-ion technology for affordable & reliable e-cooking

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e-waste / e-cook

" Cooking with electrical appliances can support family to be healthy, easy to use and it's not dirty in the kitchen and no smoke came out to compare with traditional firewood cooking."

--- Ma Aye Mar & Ma Khaing Zin Moe, Pannyo village

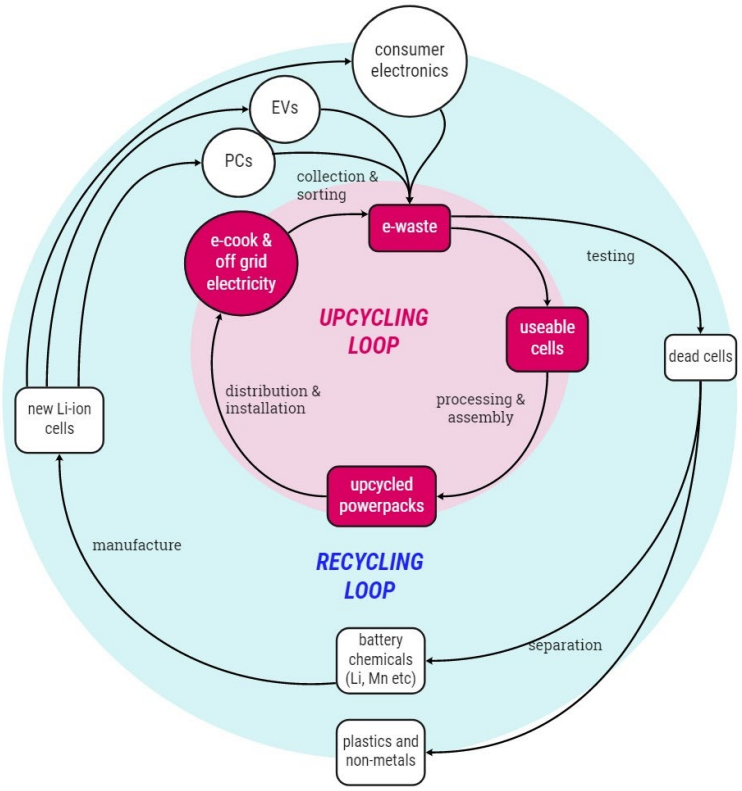
Contents

1 Introduction

1.1 Overview

The e-waste to e-cook project employed an accelerated prototyping methodology to demonstrate the viability of upcycled, locally assembled lithium-ion batteries as an affordable, reliable, clean, portable and dispatchable power source (***Figure 1***). The project aimed to unlock the potential for e-cooking in rural households of Myanmar to improve health and livelihoods of remote communities.

Figure 1 | the Switch powerpack up-cycling loop:



The project is a proof-of-concept for Switch powerpacks and was designed to establish the evidence and business case for creation of a local social enterprise (Switch Myanmar) equipped to take the project to scale and make a significant contribution to rural health and electricity access.

Implementation was scheduled over nine months divided into four phases:

- **Scoping:** scoping and establishment of project and partnerships (Aug – Sept 2019)
- **Prototype**: testing and proof of the technology by assembly of working units (Aug – Nov 2019)
- **Pilot:** testing and proof of the powerpack as a suitable e-cook solution for rural Myanmar by installation of the pilots in rural households and monitoring their performance (Oct 2019 – Feb 2020)
- **Scale:** development of a business case and plan for local manufacture as a thriving business that centres the benefits of the technology, beyond electrification, with local communities (Feb - March 2020).

1.2 Project mission

Switch Myanmar aims to deploy the technologies of the renewable energy transition to maximise the value of dispatchable, portable energy as a catalyst for prosperous rural communities.

Our mission is to create an enterprise in Myanmar, where people develop the local skills to receive, process and distribute batteries. It is expected that some people will specialise in collection of e-waste materials, others in making batteries and supplying them to their locality and surrounds. Some will specialise in developing uses for these batteries in ways that replace manual, combustion fuels and animal labour.

1.3 Objectives of the project

The objectives of the project were to *test*, *prove* and *establish* the enabling conditions for a viable local battery enterprise, including:

- ***Establish the partnerships*** and relationships with Myanmar and international organisations that are needed for Switch Myanmar to be a successful social enterprise.
- ***Prototype upcycled lithium-ion batteries*** and demonstrate that they are affordable, reliable and safe options for e-cooking applications.
- ***Pilot and prove*** that Switch powerpacks are a viable power source for e-cooking in Myanmar.
- ***Establish a business model and plan*** that will enable the Switch powerpacks to go to scale.

1.4 Partnerships

1.4.1 Composition

The project is implemented as a partnership between four core partners in collaboration with an additional Myanmar partner.

- **AMPERES LLC:** working at the interface between engineering, research and technology, AMPERES deploys the agility of an enterprise to solve entrenched development problems of the Greater Mekong region, by leveraging the strength of data, deliberative processes and markets to drive change towards sustainability. AMPERES is based in Ho Chi Minh City (Viet Nam) and Perth (Australia) and have more than 15 years' experience in the Greater Mekong region – and together with their parent company (UEA) have won or been finalists in more than eight distributed PV-Storage awards since 2012.
- **Switch Batteries Pty Ltd:** Switch is a technology company and applied laboratory in Perth, committed to developing customised technological solutions for market niches in the electrification sector. Switch Batteries were part of the team to build Australia's fastest e-motorbike winning back to back championships (2015/16) and is leading the development of affordable home-batteries in Australia. In 2018 Switch developed a cloud monitored battery management system and a 48v, modular, swappable battery. They are currently building Australia's first containerised battery upcycling micro-factory and building off-grid energy solutions for a tiny house initiative in rural Western Australia.
- **Renewable Energy Association (REAM):** REAM is one of the longest-standing renewable energy advocacy and support organisations in

Myanmar, advocating a sustainable energy transition in Myanmar for 30years. They work closely with government to support policy reform and are a trusted partner for communities in locally led community energy and environment projects.

» **Yimon Electronics LLC**: Yimon is a family-owned Myanmar SME designing, importing and building solar projects throughout Myanmar. They have worked extensively with solar irrigation, solar home systems and engineering the productive use of solar by rural communities.

» **Recyglo**: Recyglo is a regional company dedicated to recycling all waste streams in Myanmar. They are an ISO-certified collector and recycler of waste, with a strong partnership network for battery recycling within Myanmar and exploring options for partnership with Japan and Europe.

1.4.2 Roles and responsibilities

The partnership was formed to convene the required expertise needed to prototype, pilot and scale Switch powerpacks as a viable business.

» **Switch Batteries** lead the technology development and training aspects of the project. They led the prototyping phase providing intellectual property and design as well as installation and commissioning during the piloting phase.

» **REAM and Yimon Electronics** lead the community engagement and field aspects of the project. They identified the pilot site, established trust with village leaders and the license to operate with local communities. During the prototyping phase they also sourced equipment and supported with importation of equipment and lead the local assembly of powerpacks. During the piloting phase they selected pilot households, trained families in the safe use of the power packs and managed daily monitoring through the implementation of a cooking diary questionnaire.

» **Recyglo** supported the project to source local e-waste from market and landfill sources throughout Myanmar. They also supported in the assembly and installation of the pilot powerpacks.

» **AMPERES** managed the overall design and implementation of the project and leads in the analysis and formation of the business case for Switch Myanmar, including the formation of the partnership, developing the business model and source of investment.

1.5 Team composition

The project team includes more than a dozen members (***Table 1***).

Table 1 – Team composition

Name	Role	Organisation	Prototype	Pilot	Scale
Tarek Ketelsen	Project Co-lead	AMPERES	X	X	X
Mike O'Hanlon	Project Co-lead	Switch	X	X	
John Sawdon	Scale Lead	AMPERES		X	X
U Than Htay	Pilot Lead	REAM /Yimon	X	X	X
Dipti Vaghela	Project Coordinator	REAM			X
Pat Eastwood	Prototype designer	Switch	X		

Bernard Kong	Prototype technician, installation and training	Switch	X	
Ma Wint Wint Hlaing	Battery assembly, community engagement	REAM	X	X
Ma Thet Myat Phyu	Battery assembly, community engagement	REAM	X	X
Ma Phyu Phyu Winn	Battery assembly, community engagement	REAM	X	X
Ma Ei Thin Zar Moe	Battery assembly, community engagement	REAM	X	X
Ma Aye Mar, MaKhaing Zu, Ma Mar Mar, Ma Myint Myat Thu, Ma Soe Htet Mar, Ma Thida Wai, Ma Nandar Soe	Battery assembling, cooking diaries	Pannyo villagers		X

Figure 2 | Switch and REAM project team members in Pannyo village with local partners involved in villlage battery assembly

2 Methodology

2.1 Developing the concept

The project sought to develop an affordable, reliable, power-source to support remote, isolated rural households' transition to modern cooking services, such as the use of induction hobs, rice cookers and pressure cookers. The concept is designed to respond to a suite of challenges which currently serve as barriers to the deployment of lithium-ion storage technology in cooking practices of those poor, remote households who stand to benefit most from the technology (***Figure 3***).

2.2 Current state of the art technology

At present remote, rural households have limited options or choice for stationary storage. Solar Home Systems, currently experiencing a boom in Myanmar, rely almost exclusively on lead-acid batteries to store day-light PV generation for use in preparation of the evening meal. However, these batteries, while 'state-of-the-industry' are not 'state-of-the-art' and suffer from serious issues:

- ***Poor performance***: lead acid batteries have low C factors, poor discharge capacity and typically struggle with prolonged high load requirements such as e-cooking.
- ***Poor lifetime***: for many countries in Southeast Asia lead-acid batteries need replacement within 18 months of installation saddling poor households with an on-going, significant debt burden.
- ***High maintenance costs***: lead-acid batteries also require maintenance which can be a challenge for rural households and compound longevity issues.
- ***Environmental and health r*isk**: safe storage of lead-acids can be an issue, requiring well-ventilated areas that are also protected from the elements (sun, rain).

Better storage technologies are available but prohibitively expensive in the rural-village context. Many frontier households remain unelectrified and where households do have a solar home system (SHS) costs limit the size of the system which typically means that storage is prioritised for lighting and TV whilst cooking remains reliant on dirty fuelwood.

2.3 Design innovation

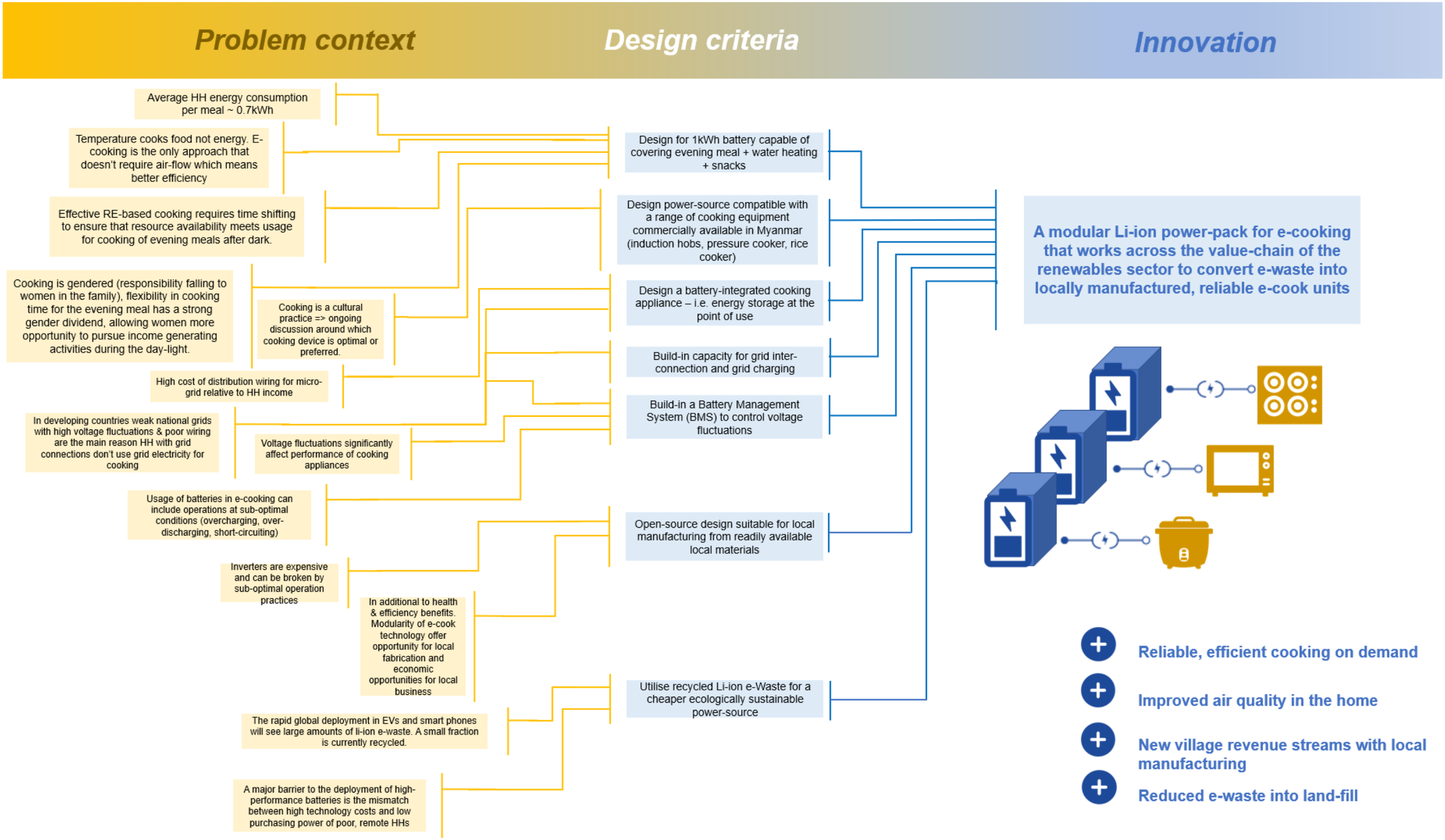
Through mapping out the problem context for e-cooking in Myanmar (**Figure *3***), the design process identified a number of design criteria and the need for two key innovations:

i. **Technological innovation:** an innovative application of e-waste material to provide a higher performance battery at an affordable price point, and

ii. **Process innovation**: an innovative approach to the manufacture of the units to lock a greater proportion of value and benefits within rural communities who need it most.

These two innovations ensure that not only do remote rural households achieve access to a better performing more affordable batteries, but also that a suite of other livelihood benefits are generated and managed by the community for their benefit.

Figure 3 | Ideaiton process and protoype design



2.3.1 Technology: Innovation in second-life use of e-waste

The focus of the innovation is the development of a locally manufactured, standardised, modular and shareable Open Source battery built from upcycled e-waste streams. The project involves standardisation and consolidation of methods developed by a global community focussed on building 'DIY Powerwalls' from '18650' format lithium-ion cells recovered from e-waste. Our project demonstrates that lithium ion cells in a typical urban e-waste stream (EVs consumer electronics, computers) are suitable feedstock for a scalable and sustainable modern energy storage option for low income households. The powerpack enables an ecosystem of end use applications. As well as developing an appropriate tool-and-literature set suitable for micro-manufacturing of batteries.

2.3.2 Process: Innovation in revenue flows and approach to manufacturing

Many industries already take advantage of low-labour costs to move secondary and tertiary industries to the industrial zones of Myanmar. What is novel in our approach is a commitment to decentre the production process from large-scale corporate manufacturing to local community micro manufacturing. By descaling production to the level of the village and enabling community ownership of the enterprise, the project will ensure a much greater proportion of the value-dividend from the production, distribution and sale of powerpacks stays within the village. For Switch Myanmar, production in Myanmar is about grounding value at the local level not corporate efficiency.

Figure 4 | the Switch micro-factory *centres production within the communities who user their products and at a scale that matches the local market size*

2.4 Overview of the approach

2.4.1 Approach to prototyping

The project employs a human-centred approach to design thinking[1] with a workflow structured around four main phases.

[1]"…design thinking is a discipline that uses the designer's sensibility and methods to match people's needs with what is technologically feasible and what a viable business strategy can convert into customer value and market opportunity." (Brown, 2008)

2.4.2 Approach to piloting

See one – do one – teach one.

One of the major risks identified at the project design phase relates to how successfully technical knowledge required for battery assembly can be transferred to non-specialists (villagers, students, non-skilled workers) who are the target workers in the Switch micro factory. Our approach to piloting focusses on this and is based on the concept of "see one – do one – teach one". Each successive prototype was used to transfer know-how in safe assembly to actors without specialist skills in electronic/electrical engineering.

The battery assembly process is suitable for an on-the-job training program, to propagate knowledge rapidly throughout a community. This hypothesis was tested in the Prototype and Pilot phases, where a Switch Intern (no notable background electrical/electronic skills) learnt via this schedule, before leading a solo mission to Myanmar to successfully transfer knowledge in the same way to Pannyo villagers.

2.4.3 Approach to partnerships

Franchise cooperatives

The project aims to establish a model whereby a central organisation owns all brand and process I.P. but only owns a small portion of the Switch Myanmar enterprise. The business model is based on the success of the Bendigo Community Bank model in Australia (Box 1), which requires a 50/50 partnership between the bank and the local community in order to set up branches. Bendigo Bank provides the IP, processes/products, majority capital and regulatory compliance while local communities provide some capital and manage decision making and operations. The model is based on the philosophy that 'the local partner is the managing partner' which gives the stakeholders in charge of operations 'skin in the game' in terms of decision making and shared success.

The partnership intends to adapt this methodology of 'franchise cooperatives' to develop local battery assembly enterprise that is owned jointly by local communities and the partners (AMPERES, Switch). Local owners will lead business operations, distributions and market development, while the partners will support in strategic decision making, IP, training, processes and due diligence.

Under this model AMPERES/Switch provide the enabling ingredients (technology, training, capital etc) that are needed for establishing a local battery upcycling business, while local partners (REAM, Yimon) provide context-specific understanding of the development challenge/market opportunity for the local enterprise and the connections and presence to make the business a success (**Figure *5***). The new joint-venture (JV) will be owned 50% by AMPERES/Switch and 50% by Yimon, REAM and the local community and will operate using local labour. Profits will be allocated according to ownership allowing local communities to decide on how they re-invest their earnings into their communities.

Box 1:

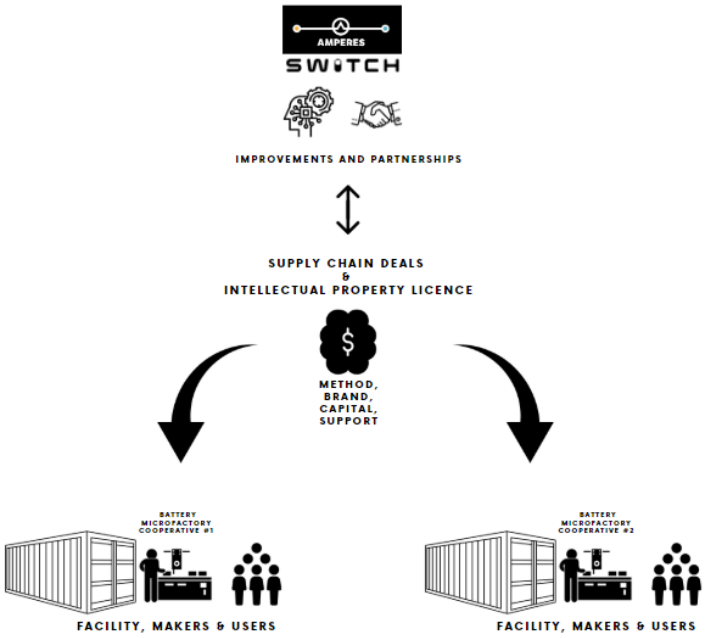
The Bendigo Bank model – a franchise operating as a cooperative

"The centralization of the Australian banking industry that took place in the late 1990s caused the contraction of banking services and significant economic decline across many of the country's small rural communities. The Bendigo Community Bank model—structured as a franchise with certain characteristics of a cooperative — was a response to that troubling trend. Initially inspired by self-organizing impulses originating at the community level, the model has helped recirculate the flow of financial capital into these local economies, and, over time, has had numerous other profoundly salutary consequences." --- (FGRE, 2020)

Bendigo community banks are essentially a franchise model that extends ownership to communities. Communities are required to provide a threshold of investment and then Bendigo Bank establishes a jointly owned entity that benefits from the IP, processes, IT, products, regulatory and compliance, training and banking products provided by Bendigo Bank but managed and run by the community. Revenue is split on a 50/50 basis and most communities recirculate their share of their profits into initiatives and ventures that benefit their local communities, for example, grants to community organisations, re-skilling and employment creation for the community or necessary infrastructure and equipment needed by the community (e.g. a new ambulance etc).

"In the beginning Bendigo saw the opportunity with the community bank model to be able to have a presence on the local community level in a way that also offered risk mitigation for the bank. After all, having the community have skin in the game and be responsible for operating expenses enabled Bendigo to expand in a way and at a pace it might not otherwise have been able to. But it was really also about understanding that we could not operate a successful banking business in a community that was not itself viable and sustainable". – Mike Hirst, CEO Bendigo Bank

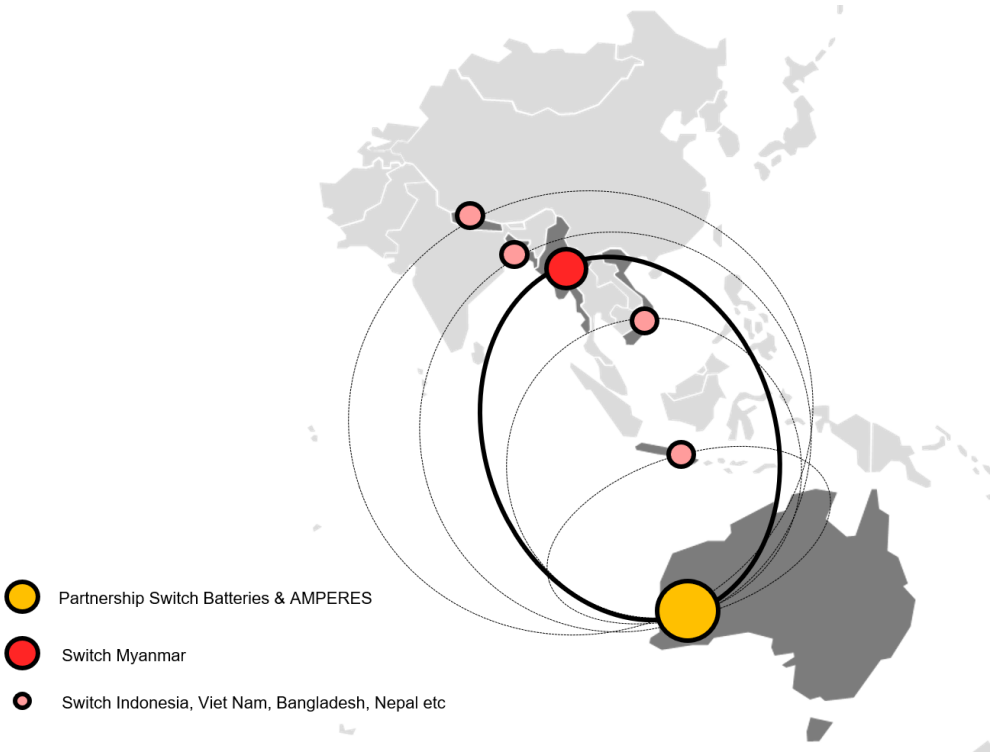
Figure 5 | localising micromanufacturing in the franchise cooperative model



Recognising that the enabling ingredients are similar for a wide variety of local enterprise products and services throughout developing Asia, in the long-term the objective is to establish an open-source ecosystem that exists inside a membrane of related projects. In Myanmar e-cook and home storage powerpacks, in Bangladesh EV sewage collection tricycles, in Viet Nam PV-S cold storage for fisheries etc.

At the core will be an AMPERES/Switch Batteries entity that services each local enterprise with the IP, training, processes and investor security, while each local enterprise advances a sustainable, local solution for a specific electrification market need (***Figure 6***). I.P. improvements developed in one project will flow back to benefit others. Supporting the AMPERES/Switch partnership will be a number of collaborative academic and private sector partnerships that enable the franchise cooperative model by supporting with technology, human resources (for example academic researchers), strategic guidance, market entry and financing.

Figure 6 | The franchise cooperative orbit of the AMPERES/Switch Batteries business model: *a commons of IP will be used to support individual social enterprises establish throughout the indo-pacific, each responding to a highly specialised electrification niche needed in that geographical context.*



2.5 *Project Phases*

2.5.1 Scoping

The first step was to contextualise and test the idea of locally produced, recycled e-cook power-packs in Myanmar. This included discussing the idea with a wide range of stakeholders, formation of partnerships necessary for implementation, scoping of suitable pilot villages and a review of cooking behaviour, technologies and energy usage in rural villages of Myanmar. Formation of the partnership, selection of pilot villages and elements of the methodology were finalised based on this phase.

2.5.2 Prototyping

This phase is designed to prove the feasibility of the powerpacks as a viable 2.5kWh electricity source for use in cooking a typical evening meal for an average rural family in Myanmar. Prototyping includes completion of digital (CAD) design of the module, building and testing of multiple prototype battery power-pack, assembly of the prototype energy system (batter, inverter, PV), testing of useable power and energy, design ideation for modular packing.

Prototyping is an iterative process learning and calibrating design features based on learning from earlier prototypes. Multiple prototype units were built testing, various sizes, configurations, sources of e-waste and stand-alone or with integrated inverters and electronic controls

The technological innovation required to undertake this is modest, given that there is an active global DIY community working on assembling portable powerpacks built from 18650 cells. However, such projects are typically home-garage labours-of-love, developed as one-off units. The Switch powerpacks focussed innovation on:

» *Repeatability*: strengthen the modularity of the assembly process to produce units more tolerant of assembly faults, transport and capable of being reproduced by villagers who are not necessarily battery/electronic nerds.

» *Safety*: recognising that the use of batteries will largely be non-technical village households, effort was also made to strengthen the safety of the power packs, through selection of materials (e.g. fused nickel cell interconnects means that each cell has a fuse and thus the pack is more resilient to individual cell failures and events such as polarity reversal during assembly); as well as through assembly processes (a protocol for testing and sorting cells based on their charge was used to group individual cells into bricks of compatible charge.

2.5.3 Piloting

The piloting phase ground-tested and demonstrated that the prototype technology is a user-useful solution capable of meeting the behavioural and cooking needs of rural households. It included an early survey of cooking behaviour and requirements (‘cooking diaries”), testing and installation of the pilot units. Implementation required a number of stakeholder engagement activities, including a training short-course, a launch/public awareness event in the village, village-led performance monitoring of the power-packs and the facilitation of a village-level review and feedback meeting.

2.5.4 Scaling up

The final substantive phase consolidated the success and learnings from the prototyping and piloting phases into a demonstratable pathway for establishing community-level enterprises capable of micro-manufacturing, distribution and sales for e-cook power-packs. It included an enterprise needs-assessment to understand organizational and operational dimensions of a successful business model. The findings were then used to develop a business prospectus outlining the value proposition, investment needs, technology and skills requirements and the business case for local manufacturing. A launch seminar[2] at the national level will be used to

[2] Timing of the launch seminar has been delayed due to the challenges of organising workshop in Myanmar at present due to Covid-19

launch the prospectus and promote the business model to potential investors as well as policy enablers who can support operationalization of the model.

2.6 Project outputs

The main deliverable of the project was the development of low-cost power-packs built with upcycled lap-top batteries, installed and tested coupled with e-cook solutions (e.g. rice cookers, pressure cooker, induction hob or similar) in rural homes of a target village in Myanmar.

During the project 07 pilot power packs were built, however, because of shipping difficulties the 03 powerpacks that were built in Perth were not able to be installed in Pannyo village. Performance and suitability of the powerpacks as an electricity source was assessed by households utilising the appliance through a daily cooking diary.

The hardware developed will be supported by a final report which includes the business prospectus and analysis of the cooking diaries.

Table 2 | Project milestones and outputs

Timing	Phase	Milestone		
		Hardware /powerpacks	**Event**	**Report**
Aug 2019	Inception			
Sept 2019	Inception/ Prototyping	**v0.1** built in Perth	**Scoping mission** to Yangon	
Oct 2019	Prototyping			
Nov 2019	Prototyping/ Piloting	**v0.2** built in Perth	**Pilot kick-off meeting** with Pannyo village	
Dec 2019	Piloting	**v0.3** built in Yangon **v0.4** built in Perth	**Prototype mission** to Myanmar	
Jan 2020	Piloting	**V0.5** built in Yangon **v0.6, v0.7** built in Pannyo	**Piloting mission** to Pannyo village	
Feb 2020	Piloting / scaling		**Review & evaluation meeting** with target village **Launch seminar** for local manufacturing business plan	**Business prospectus** **Final Report**

In addition to multiple meetings throughout the project, the project culminates in a launch seminar to be held in Yangon. The purpose of the seminar is to promote the business case and model for a local upcycled battery assembly enterprise to potential grant, commercial and venture capital investors.

2.6.1 Prototype units

The prototype units are 2.5kWh powerpacks built to be portable and contained within an electricians Pelican case (***Figure 11***). Each case is waterproof and weighs in the order of 20kg. During prototyping design specs have evolved through the iterative process:

» *Capacity*: increased from 1 – 2.5kWh, reflecting a need to give households flexibility to add on other loads, rather then force cooking to compete with those other lighting and entertainment loads.

» *Inverter*: the inverter was originally housed within prototype v0.1 but was subsequently removed to provide more storage space, as well as allow for easier coupling to existing solar home systems and easier replacement of inverters that fail.

2.6.2 Training manual

Based on the piloting philosophy of “SEE ONE – DO ONE – TRAIN ONE” a training manual was developed to transfer the capacity to build, test and troubleshoot the assembly of powerpacks to non-technical specialists. The battery field manual will be adapted to a more visual / less wordy style - in the vein of a Lego technic instruction manual (***Figure 7***).

A draft of the assembly manual is attached (Annex 4).

Figure 7 - the Switch powerpacks manual will adopt a highly visual LEGO techincs layout to allow technicians of all levels participate in the assembly process

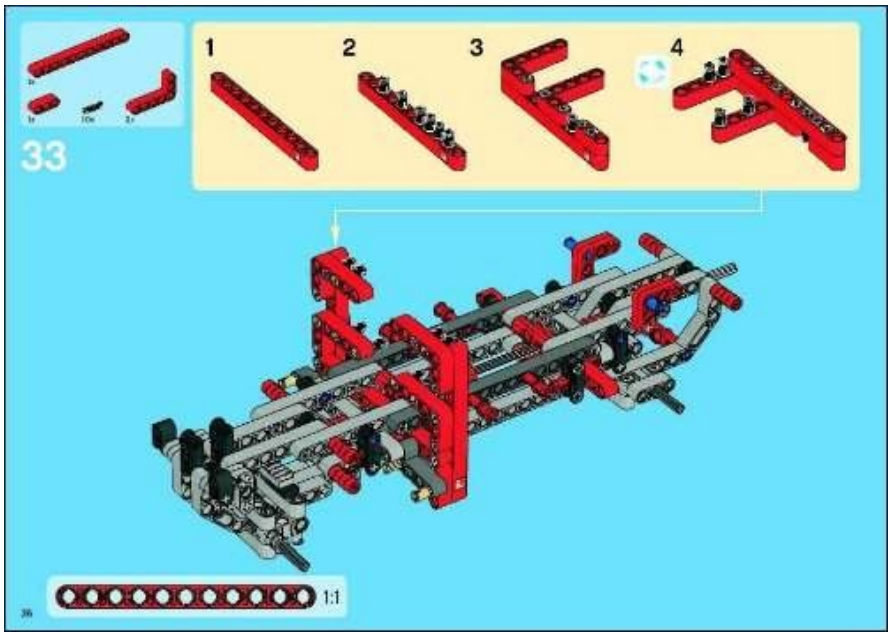


Figure 8 | the Switch powerpack prototype (2.5kWh): (TOP) cell configuration within the power pack; (BOTTOM) assembled powerpack in water-proof electricians box charging on the Pannyo solar system

2.6.3 Business prospectus

The business prospectus draws on the findings of the pilot to describe the value proposition and business model for scaling out the e-waste project as a viable local business.

The business prospectus includes:

- Insight into key market features, including a description of the competitive landscape and third part forecasts with drivers for growth.
- Description of the business model and value proposition.
- Explanation of the strategy, strategic objectives and milestones, describing how the company will engage with competitors, identify and segment customers and respond to the actual market environment.
- Identification of the key risk factors specific to the company and explain how it plans to mitigate them.
- Outline the governance and ownership structure, including the track record of selected key managers as well as the top management compensation and how it is aligned with long-term value creation.
- Analysis of strategic, structural and management issues facing the business.
- Summary of historical financial performance.
- Overview of performance summarised from output 1 and preferably pictured through a couple of financial and non-financial key performance indicators (KPIs) as well as environmental and community impact indicators.
- Overall indication of management's view on market trends as well as the related forecasts.
- Marketing and operations plan.
- Financing required and financial management plan

2.6.4 Launch seminar

A seminar the national level will be used to launch the prospectus and promote the business model to potential investors[3] as well as policy enablers who can support operationalization of the model.

2.7 Project Geography

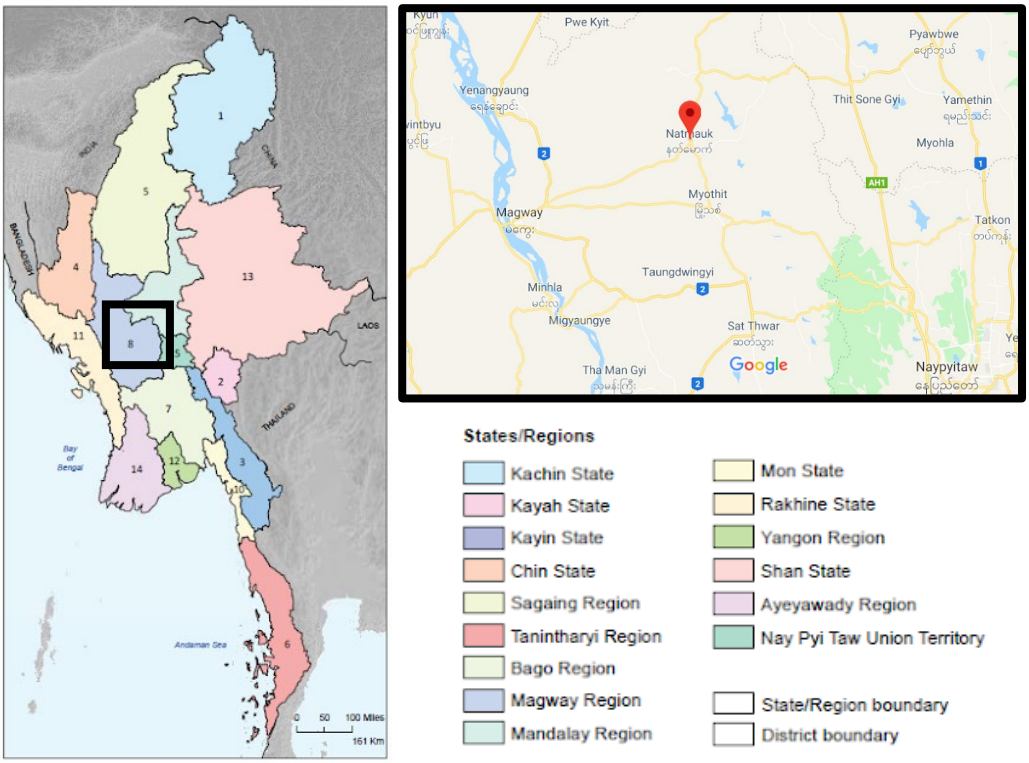
2.7.1 Pilot site selection

During the scoping mission a number of potential pilot sites were explored with stakeholders, including Kayin, Southern and Eastern Shan State, the Central Dry Zone, the Ayeyarwady Delta, Kachin and Chin State. The scoping confirmed that there are multiple highly suitable options, reflecting the high potential for scaling out in Myanmar. Natmauk township in Magwe Division (***Figure 12***) was selected as the pilot site for the project. Natmauk is located approximately 1-hour drive south-east from the

[3] For example, international development partners and international/domestic private sector CSR programs.

domestic airport at Bagan, includes 74 village tracts[4] and a population of 212,500 people[5].

Figure 9 | location of project pilot site



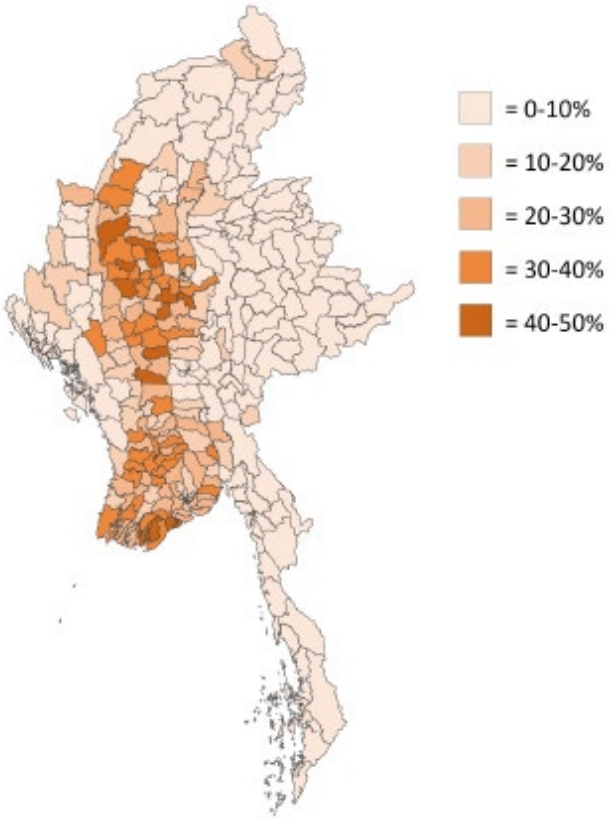
Natmauk township was selected for the following reasons:

- **Unreliable electricity:** Grid electricity has arrived to many of the villages in the township, but it is unreliable with many households experiencing frequent and long-duration blackouts. This is confirmed anecdotally by organisations working there (REAM, Mercy Corps) and is also reflected in the township having amongst the highest national percentage of households that utilise batteries for home-lighting (***Figure 10***).
- **Familiarity with battery technology:** As above, 30 – 40% of households in the township have experience using battery technology for lighting purposes. Whilst the incumbent technology is likely lead-acid, familiarity will be important for both adoption and safe operation.
- **Ease-of-access:** The township is easily accessible from regional airport hubs making access quick and economical.
- **Precedence:** the MECS program has implemented a previous e-cook trial project in parts of this township. This means that the "cooking diaries" which were completed as part of this program can provide useful socio-economic information for the project.
- **Relative peace and stability:** the township is predominately ethnic bahma and has historically not been a site of armed conflict, which makes it safer for the project team, and easier in terms of permissions and authorisations to access.

[4] In Myanmar a village tract is an administrative unit comprising a cluster of several villages.
[5] Population estimate is based on 2018 extrapolation of 2015 WorldPop data base from (Rasaenen et al, in publication)

Within Natmauk, Pannyo village was selected as the pilot site, primarily because of an existing relationship.

Figure 10 | National census information on batteries as the household lighting source



2.7.2 Pannyo village profile

Pannyo village is a small agricultural village located in the Central Dry zone of Myanmar, in the East of the Magway region, in Nat Mauk township. The village has a population of 1,281 living in 270 households. Like much of the Dry Zone, most households in the village are involved in agricultural production with around 1,740 ha farmed by village households for various crops such a rice, sesame, sunflowers, peanuts, millet, gram and tomatoes. Animal husbandry is also an important livelihood activity with sheep, goats, cattle, pigs and poultry being reared in the village, there is also some aquaculture in the village with two fishponds. The village supports a number of small services and trading businesses including, greengrocers, a tailor, a carpenter, a motorcycle repair shop, different hire businesses for tractors, trucks, pumps and generators, and milling (rice and oil seeds).

With an average village household income of less than US$ 2 per person per day, poverty remains a problem in the village. In particular, approximately a third of households have no agricultural land and rely on raising animals and casual agricultural labour for their livelihoods.

The village has a poor access to utilities. The road connection to the centre of the township is poor and it is not connected to the electricity grid. Households meet energy needs through the use of wood and occasionally charcoal for cooking and heating water, most households also have small battery-solar systems (10Wp) to provide some lighting. A few more affluent household have larger systems (100-250 Wp) that are used for lighting and to power TVs, and two households in the village

have diesel generators. Other productive energy needs, for water pumping, milling grains and seeds, sewing, welding and trimming cattle's feet are met mainly though diesel engines.

Figure 11 | Snapshot of Pannyo village: *located within Myanmar's central dry zone, Pannyo is a typcia agricultural village dealing with a range of access problems: electricity, water, transportation.*

3 Implementation

3.1 *The work conducted*

SCOPING

The objective of the scoping phase (August – September 2019) was to finalise the design, approach and implementation arrangements for the project. It includes formation of partnerships, a scoping mission to identify pilot villages, a review of cooking and energy demand for rural Myanmar, and finalization of the workplan. A scoping mission was organized to Yangon in 15 - 20 September to advance the inception phase and included meetings with a dozen actors / organisations (Annex 1).

Figure 12 | Scoping consultations in Yangon

PROTOTYPING

The partnership has built 07 prototype units. The assembly process is summarised in Figure 12. The first three prototypes were built to test and improve the design. The final 04 versions were built to demonstrate the SEE ONE- DO ONE – TEACH ONE methodology and assess the ease with which assembly can be transferred to technicians of varying levels of expertise, including university students, solar electricians to office workers and rural villagers.

Figure 13 | Overview of the powerpack assembly process

v 0.1 (Perth)

A 1kWh ‘all-in-one’ battery was built in Perth. The battery included an MPPT solar input and an inverter. The battery was unable to be shipped to Myanmar in a viable timeframe, so an alternate approach was taken.

Figure 14 | Powerpack v0.1

v 0.2 (Perth)

A process for rapidly harvesting and processing cells sourced from e-waste laptop batteries was developed. A simplified battery comprising cells, connections and BMS was designed, using readily available 18650 pack building hardware (cell holders & fused nickel) with the battery made from 14 identical 3.7v(nominal) submodules (each comprising 20 cells in parallel). The hypothesis was that breaking the battery down into submodules breaks the assembly process down into clearly visible steps, allowing for QC checks to be placed at the submodule level before a full voltage pack is assembled.

Battery 0.2 is a 2.5kWh unit.

v 0.3 (Yangon)

Switch lead Mike O'Hanlon undertook a field trip to Myanmar in December '19. E-waste was sourced by (project partner) Recyglo and a workstation was established first in their co-working office and then relocated to REAM HQ. Battery v0.3 was a copy of battery 0.2 Due to time frame constraints that limited how many cells could be harvested, battery 0.3 was built with 1.5kWh of storage. REAM staff observed and assisted with part of the assembly tasks. Switch + REAM travelled to Pan Nyo village and the battery was installed with a 2kW inverter and a 1kW solar charger.

Figure 15 - power pack v0.3

v 0.4 (Perth)

Battery v0.4 was built in Perth as a copy of v 0.2 and as a test of the 'see one – do one – teach one' methodology. Using this approach, knowledge on how to assemble the battery was transferred to an engineering student who currently interning at Switch Batteries and who would use the experience for the final year thesis. Once the intern proved capable of building the powerpack

v 0.5, v0.6, 0.7 (Yangon and Pannyo)

The next three powerpacks were built in Myanmar. v0.5 was built in Yangon by the Switch Intern, teaching REAM staff in the assembly process. E waste was sourced via Recyglo again, with both laptop and e-bike batteries used as feedstock. Battery 0.5 was built in Yangon in a similar manner to battery 0.3.

v0.6 was built by REAM staff who taught local villagers in the process. Finally v0.7 was built by local villagers with no technical background with support from REAM staff and the Switch intern.

Figure 16 | Powerpack v0.6 and v0.7

see one...

do one...

teach one...

PILOTING

Powerpacks assembled in Myanmar were installed in pilot households, with each household trained in the safe operation of the units and guided to develop cooking diaries (annex 2). A 'Battery Assembly Field Manual' was developed as a checklist quality-control each step. This manual was used as a reference document for both teaching and for QA during each step of the manufacturing process.

SCALING

A business prospectus (ch 5) was developed, describing the business case for scaling the pilot into a local social enterprise. A launch seminar for the prospectus is planned but will occur subsequent to the completion of the MECs project due to travel restrictions associated with the global co-vid19 outbreak.

4 Practical applications

4.1 *Findings from the piloting and prototyping*

Findings from the project are summarised in ***Table 1***.

Table 3 | Findings from the e-waste to e-cook pilot

Topic	**SWOT**			
	Strengths *What has worked well, why did it work*	**Weaknesses** *What were the big challenges faced and where and why did we encounter an obstacle*	**Opportunities** *Are there any factors that could help the e-waste to e-cook project to continue and grow in scale to a national initiative?*	**Risks** *Are there any factors that could pose a risk or hinder the e-waste to e-cook project to continue and grow in scale to a national initiative?*
Upcycled battery technology	• Upcycled battery technology can reduce the need for production of new batteries subsequently creating more e-waste. • By upcycling the batteries which are working with Solar Photovoltaic charging system, that is the best way to use in remote village. • Creating a Power Pack by using Waste battery can be a way to reduce e-Waste problem. • It is an updated study which reflects the prominent changes in the battery storage technology for RE application. • The battery assembly tasks undertaken demonstrate that the skills required to build a battery can be taught rapidly and that specialist tools can be easily brought into the country.	• Proper knowledge upon Lithium-Ion battery technology and energy storage for e-Cook is required. • There is insufficient information on the lifetime and performance of the waste battery. • Warranty term of the system is unknown. • To get to scale the project needs an inventory of spare equipment and balance of system equipment on stand by and ready for deployment to avoid delays. • System design is important and requires on-site specialist to make sure best system Model is design • Need to improve data and information systems both input data from the village and output from the operating powerpack. • The high currents typical of an e-cooking application mean that the e-cooking battery pack must have extra thermal management	• This technology can help the people from off-grid area with no proper access electricity for cooking. • Rural people can use modern and clean technology for cooking to reduce their fuel cost and environmental issues. • Rural people are widely using solar systems for lighting therefore they are already familiar with battery and solar system. • Raising the awareness of upcycled battery technology will make public discover alternative ways of using renewable energy for their daily life. • As Waste Electronics and Electrical Equipment (WEEE) are rapid emerging contemporary global concerns, Myanmar has a chance to participate in research and daily domestic consumption with other nations.	• The cost of the solar panels to charge battery packs is high. • Danger of electrical shock, it can cause fire-hazard by using improper system components and bad practices in using. • Government policy favours in emergency such activity for public awareness and market promotion.

		considerations if it is expected to demonstrate longevity[6].		
Sourcing e-waste in Myanmar	• Old laptops and Electric Bicycles are common in Myanmar so that the availability of used old Lithium Ion Batteries are available. • There is a strong need for affordable, useful alternative options for Lithium-Ion battery storage technology in Myanmar, because of the rapid deployment of solar home systems and mini-grids. • It is also a green practice for clean and hygienic answer for people.	• Waste battery utilised in this technology is difficult to collect and still requires establishment of collection streams. • Electronic waste management practice is not common in Myanmar. • Lack of knowledge in e-Waste by people as well as Government.	• Market of old lithium-ion battery will emerge if people know how to upcycle the old Li-Ion battery effectively. • Damage of e-Waste pollution would be cleared by an effective Reuse technology.	• Almost all people throw waste Li-ion battery at dump site without knowing its danger and usefulness. • Have the importance of knowledge not only to get rid of e-waste but also to notice, classify, and control in a formal systematic "garbage throw and store" supervised by the State e-waste either hazardous/ toxic or non-hazardous. (May be workshops, pamphlet/etc. in Project budget its introduce along with the usefulness of e-waste to app. • To notice e-Waste in environmental hazardous issue by proper knowledge in good e-Waste management practice including recycle or upcycle activities.

[6] A refined version of the 20p submodule is in development that includes a liquid cooling system that will change the long term performance of the battery without adversely affecting its cost or time to manufacture.

The process of assembling the battery packs	• The process of assembling the battery pack is not so complex and complicated, many rural people can assemble if they get well trained. • It does not involve heavy loaded components and harmful work as well. • The simple, picture-based manual makes the assembly process accessible to people with a wide range of backgrounds and skills.	• Myanmar has a different level of safety standards relative to the developed world • It needs intensive care to check the temperature of individual battery cells while charging and the whole battery pack. At present this process is highly subjective based on the conscientiousness of the worker. • Some tools and parts that have to use in assembling battery packs are not available at present in Myanmar. • In some steps, IT technology involves therefore the individual who assembles the power packs must have basic IT skills. • All are manual so personal skill is required.	• The process can be demonstrated and taught, so it can be easily delivered. (doing with learning process) • If this technology can transfer to the rural people, their living standard will be higher than now. • New business opportunities will appear in Myanmar. • New market of specific type of Lithium-Ion Battery for e-Cook can emerge in future.	• The reliance on human labour opens the process to mistakes and errors. A shift from prototyping to production needs to develop robust processes to account for this risk. • Availability of Hand- Phone for IT application including assembled Battery-station.
The process of engaging and involving Pannyo villagers in the assembly process	• There is very strong interest from villagers to participate and learn. • Almost all the villagers, especially young women are keen and participated in assembly process. • Village community realize our research actively as their own community development function, which signifies a lot of buy-in at the household level. • High levels of satisfaction amongst villagers involved in the project.	• The participants are mostly young women and not familiar in techniques of the assembly process such as soldering. • They have less computer skills to access the website for calculating the capacity and grouping for packing battery cells. • Implementation period of the project meant that village assembly team did not have sufficient time to consolidate and absorb training fully.	• Development of a mobile app for this calculating and Battery assembling process, will make the process more convenient for rural local people. • From this participation, they've learned about this technology that they can use for lighting and cooking at their home with electricity. • Village Group-work together on Renewable Energy based e-Cook activity will enhance them to support their community development.	• The assembly process requires electricity for the use of power tools, and this is not always or not reliably available in villages. • Although they are interested and involved in this process, they still need more training and more practical work to become proficient. • Knowledge transfer needs to be disseminated more widely in the household so that family members can fill in for the primary worker if he/she is not available. • Imitative funding for trial or demo-project. • There is a need for budget support system for Local business entrepreneur especially from village community.

Suitability of power-packs to e-cooking (2.5kWh)	• Created good system package for further propagation. • This power pack is suitable for cooking as well as lighting. • Get-easy and portable packs. • Advantage of this Turn-key system package.	• It has not enough power for cooking 3 meals daily. If they use lighting at night, they cannot cook in the morning time. • There is a need to offer larger modules capable of meeting cooking, lighting and other household needs. Suggested a power pack at least 5kWh; it will be enough to cook the whole 3 meals. • Clear system design for specific application. • Low levels of capital in the community	• Significant time savings in avoided for fuel collection • Protect from the danger of smoke that cause health issue. • Now DC rice cookers are available in market to set with this system. Such DC cookers can eliminate the inverter and less power consumption to get more storage power. • Users will become more and more experience in cooking utensils and cooking practice.	• Firewood is most available, less cost and easy for villagers at the moment and that habit has to be changed by strong demonstration and mobilization wakens by initiative project. • Creation of the new market will take time to achieve and it essentially need Government encouragement and development aid.
Suitability of larger power packs to household electricity or village mini grids.	• Myanmar has potential to commence with Trial or Demo Project to scale up. • Technology is available for practice. • Energy storage is one of the essential components in most RE application so there is widespread need for the powerpack.	• Undeveloped supply chains for balance of system components • There is a problem of market for this approach, especially availability of system components. • It needs proper budget for implementation. • Myanmar's e-waste volume is growing quickly as the country develops, but the assembly of larger powerpacks raises the importance of well-developed supply chains. • Needed capacity and skill for all stakeholders, technically as well as management is challenging.	• The larger power pack can do village mini-grid system especially for household application. • Larger power packs for village mini grids, will improve the rural electrification program by dropping significantly electricity costs. • System design with good modelling in demand and supply management will make mature the usage of Lithium-ion Battery Pack.	• The larger power pack needs the more recycled battery. • Due to the use of recycled waste battery, it is not sure to tell its life time and performance. • No specific regulation for e-Waste management. • No priority regulation to enhance RE and Storage System application. • Improper by managed products of local Lithium-Ion Battery packages will create e-Waste pollution.
Reliability of the power packs	• Because of BMS system with Bluetooth technology, the conditions of power pack and individual battery packs can be checked anytime. It is a leap-frogging step for development. • It can prevent the danger of explosion and fire because of its cut-out function. • Educational activities in advance will achieve good results where the power packs assembling and utilizing for the benefit of the community.	• Firewood fuel is still needed when power pack is not enough power to cook for the daily meal. • For ordinary rural people are not familiar with smartphone technology, it is not easy to check the power pack condition. • Village community need to realize more knowledge on power packs and its sustainable reliability. • Capacity of Battery Pack still needs to redesign to suit with community usage.	• Adjustment of cooking habit and electric power consumption for Battery-Pack will improve the system. • Turn-key support of complete system-package with good services for utilization will push forward the project achievement.	• Incomplete trial or demo function will not get interest by community as whole without suitable package and service for usage and also follow-up propagator found commercial action. • All system components and necessary spare-parts or breakdown-components must be available.
Villager interest and acceptance of the power pack technology	• The villagers are highly interested this power packs technology that they haven't seen before.	• It is a problem that they are not familiar with electric cooking appliances because this is their first experience of using electricity for cooking.	• Pannyo village has strong potential to be a demonstration project for a pilot micro factory.	• Powerpack capacity must be sized to meet community needs. At present they are too small and this could

	• Both young /and women have keen interest on the technology with instruction to learn and use practically.	• Characteristic of villager in off-grid areas has not much knowledge in using electricity.	• Providing required knowledge on this new field can overcome their unfamiliar worry in e-cook. • Various types of energy-efficient cooking utensils are more available in Myanmar market.	impact interest in the long term. • SPV charging system is probably important to work Lithium-Battery power package and it need to perfect in enough charging also.
Suitability of Pannyo as the location for battery assembly	• It's suitable place to explore this battery assembly but not recommended for battery power pack manufacturing. • Necessary spirit for community development by villager is seemed to be very positive.	• Pan Nyo Village is a far place from the main road. • No easy accessibility by good road. • Such remote community has less knowledge about advance Technology and facilitation.	• The Village community has good livelihood for their simple living. • Especially gender, i.e., Youth "Young ladies" of educated in some extent of Basic Education High School level and they have ability to propagate their learning to others in e-Cook application. • System package assembly is not proper to practice there but assembled Battery-power pack application practice there is fix on a trial or demo activity.	• The cost will be so high for Battery assembling in Pan Nyo Village because of bad road and communication. • Infrastructure and Transportation is really poor. • Monitoring & Evaluation function in project operation & maintenance will poor due to poor manageable status by project provider.
Training process	• This technology introduced by training will get good achievement due to proper timing of requirement. • Usage of battery pack will create a new market. • Trainee of Young women are willing to learn and able to understand the processes for their practical application. • Training booklet and manual for usage can be production in this new e-waste to e-cook project. • Master of Trainers for TOT should be developed.	• No master of Trainers for ToT at the moment. • Budget constraint for all necessary Teaching Aids. • No proper Training Manuals and Training's Booklet are not ready.	• This project has high potential for National Clean and Efficient Cook Stove Program. • ToT program will enhance country RE, Environment and Electrification programme. • People can build the power packs systematically by themselves for community development. • More business opportunities can be developed based on the technology. • Based on upcycled battery technology, new electric appliances and battery systems could be developed which meet the locally requirements. • Myanmar can become good practitioner in Future Global e-Cook Development.	• Trainers need to take time for more practical works as long term training process. • Expenditure for Training Process and Training Facility and Teaching Aids. • Master Trainer's availability. • Strategic plan to arrange ToT Program.

4.2 *Comments and pilot household feedback*

One month after installing the pilot packs, the project team returned to review the cooking diaries and interview villagers on the experience of cooking with the Switch power packs. Feedback from pilot households is summarised in ***Table 4***.

Table 4 | General comments and feedback from pilot households

Participant Name	Experience and Feedback
Ma Aye Mar & Ma Khaing Zin Moe	Cooking with e-cook power pack saves more time than cooking with firewood fuel. The problem that we faced is we could not completely cook with electric cooking appliances in cloudy days. We love cooking with electric appliances because it easy to use, more clean and save man power to collect firewood. By recording daily cooking diary, we've known: how many amount of energy we used for cooking; how long for each meal take; and cooking with electrical appliances can support fairly to be healthy, easy to use and it's not dirty in kitchen and no smoke came out to compare with traditional firewood cooking.
Ma Mar Mar	Cooking with solar battery is hard to use at first because this is very first experience for us. But later, we can use it very well, it is so useful. By using electric stove, it saves more time, can do another work while cooking and also it is easy to use for cooking. Many smokes come out from Firewood stove. Cooking with firewood stove takes a long time and we cannot do another work while cooking. So we prefer electric stove for cooking. Recording the cooking diary, we know how many amount of energy using in daily cooking and getting more knowledge about cooking.
Ma Myint Myat Thu	Electric cooking appliance is easy to use and no smoke coming out from there. We can use other different kinds of cooking utensils to test further. But the e-cook power pack has not enough power for the daily meals for the whole family. By recording cooking diary daily, we've known fuel cost of our daily meal, and we can manage time.
Ma Soe Htet Mar	We worry about the smoke that comes out from firewood stove; it can affect our health problem. We've got the new knowledge and known how many amount of fuel that we used by recording daily Cooking Diary.
Ma Thida Wai	By recording daily cooking diary, we've known: how many amount of firewood fuel we used for cooking; how long for each meal; and how much does it cost.
Ma Nandar Soe	Daily cooking diary recording practice makes aware about fuel consumption by difficult food items. We can calculate the cooking cost of our family daily, monthly and yearly to analyse our budget.

4.3 Cooking diaries

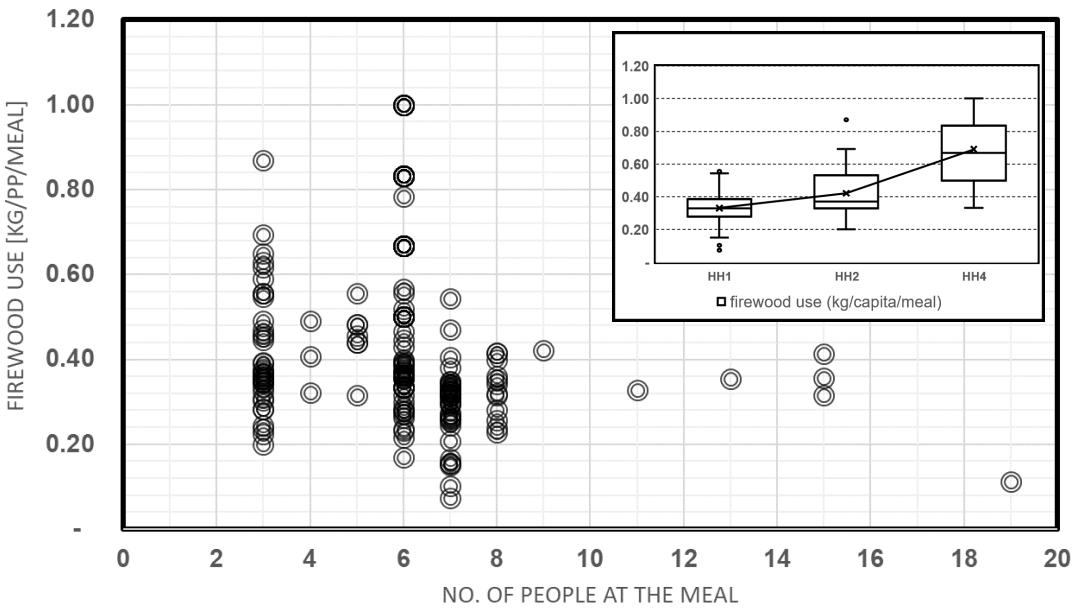
Cooking diaries noted the cooking activities of four households over a month. Three households were provided with Switch powerpacks and one household acted as a control and continued to rely on fuelwood. In total the Pannyo surveys monitoring fuelwood consumption and powerpack usage for 321 meals cooked using the two technologies in the four households.

4.3.1 Fuelwood consumption per meal

191 meals were cooked with fuel wood by the pilot households. These meals varied significantly in terms of the type of food cooked and the number of people fed (3-19people per meal). On average 0.45kg of fuel wood was used per person per meal, but the fuelwood consumption varied significantly (0.11 – 1.0 kg/capita/meal).

In general per capita fuel wood consumption decreased with larger households, while cooking behaviour also has a big impact on fuelwood consumption as reflected in a large variation in consumption between pilot households (***Figure 17***).

Figure 17 | Fuel wood consumption in pilot households: (MAIN) *Amount of fuelwood (kg) per meal based on number of people joining the meal:* **(INSERT)** *variability in fuel consumption per meal between pilot households.*



4.3.2 Performance of power packs

Overall, households responded positively to the use of powerpacks for cooking. They noted that the use of powerpacks for cooking:

- saved time actually spent on cooking,
- saved time and money otherwise spent on the collection or purchase of firewood; and
- was much cleaner than using fuelwood.

There were some concerns regarding the capacity of powerpacks to provide for all household cooking needs , this is likely because the powerpacks were also servicing other household energy demands at the same time, and cooking multiple meals in one day. Adjusting cooking approaches to the use of powerpacks also took some

time. Even households without powerpacks reported that the cooking diaries made them more aware to the cost of using fuelwood.

Voltage measurements were taken for a total of 130 e-cooked meals across the four pilot households. For each meal, starting cell voltages ranged from 3.1 to 4.2V and experienced an average 5% reduction in cell voltage (23% max). In all trials the BMS safety management system ensured that cell voltage did not drop below 2.7V/cell demonstrating the success of the safety feature.

4.4 *Opportunities and applications*

4.4.1 *In Pannyo Village and other grid-frontier agricultural communities*

The project piloted the use of Switch power packs for e-cooking applications. Within Pannyo village all 270 households currently utilise fuelwood for cooking services[7] – presenting a potential to scale out e-cooking throughout the village. Importantly most households already have small solar-home systems (10Wp) and a few more affluent households have larger systems (100 – 200Wp), which means there is a familiarity with the technology that can enable powerpacks to take on a wider cross-section of household loads in addition to e-cooking.

Figure 18 | Breakdown SMEs and productive uses of electricity in Panny Village

Beyond the household, a survey of the community identified 63 small village enterprises that partially or fully utilise electricity for the provision of their goods and services (***Figure 17***). These include power provisioning SMES (diesel generator and pump hiring services), agricultural processing SMEs (rice & oil crushing and aquaculture ponds), transport SMEs (truck & tractor hiring services), and village trade

[7] Surveys indicated that charcoal is also available in the village but it is rarely used because of its high fuel price.

SMEs (sewing, grocery, carpenters, vehicle repair and welding shops). The Switch powerpack technology due to its modular, portable nature is capable of displacing diesel as the energy source for all of these applications, though some like the transport SMEs require more complicated electrification conversions.

4.4.2 In Myanmar

The project demonstrated the viability of upcycled power packs as a clean energy source enabling households to switch from fuel wood to electric cooking. The capacity of the powerpack was oversized (2.5kWh) compared to energy needed to cook the evening meal (1kWh), in order to avoid some competition between cooking use and other households uses (lighting, entertainment etc). Both within the project and in the literature, there is evidence that when electricity availability is limited, cooking tends to be deprioritised compared to other uses and so some buffer capacity was added to reduce this competition.

However, the modular nature of the powerpacks, would allow larger units to be built allowing the powerpacks to scale up as a clean, affordable power source for:

- cooking (2.5kWh),
- solar home systems (5-10kWh) and
- village micro-grids (100kWh).

The recommendation from pilot households is that 5kWh minimum is needed to account for all domestic household loads.

4.4.3 Rest of the world

The modular, portable and affordable nature of the powerpacks mean that they are a versatile electricity source for a wide range of niche applications. Since the completion of the prototypes, there has been expressed interest in three additional applications (***Figure 17***).

Faecal Sludge Management, Bangladesh[8]

In Bangladesh, the absence of universal sewage services means that many urban and rural areas rely on Faecal Sludge Management (FSM) services to ensure safe emptying, transport and treatment of faecal sludge matter. However, efficient FSM is only possible with a sufficient fleet of vacutugs[9]. Operation and maintenance cost are a major cost driver and have to be covered by the revenue. Particularly in slum areas vacutug can often not reach the pits and manual emptiers are providing the emptying service. Powering pit latrine and septic tank emptying devices by electricity stored in recycled batteries can not only increase the efficiency of the FSM emptying and transportation sector but also transform it into a carbon neutral operation, bringing down operation and maintenance cost considerably while addressing the e-waste challenge. However, recycling batteries will not only bring down fuel and O&M cost for the FSM sector but also generate new income opportunities for communities and by providing cheap reliable batteries open up a whole new horizon of applications.

Squid fishing, Viet Nam ++

In central Viet Nam, squid fishing remains a key livelihood activity for many coastal communities. Squid fishing requires the use of halogen lights throughout the night to

[8] The concept for the e-waste Vacutug was developed in partnership with SNV
[9] The Vacutug is a portable machine used to extract fecal sludge from septic tanks and pit latrines and transport them to a sewage disposal site.

attract squid to the nets; and with boats staying out at sea for two weeks at one time, this represents a large electricity load. At present squid fishers utilise the power from their diesel boat engines to run these lights – an expensive, unhealthy and polluting practice. Converting the lights to higher efficiency LEDS and powering them with a rechargeable Switch powerpack would greatly improve the economics of squid fishing as well as provide additional health and environmental benefits.

Fisheries cold storage, Myanmar, Indonesia ++

In many coastal communities fisheries are central to local livelihoods and form the dominant source of income. However, the perishability of fish catch means that a large percentage of the catch is spoilt before it goes to market. Middle-men who buy the product and sell on to other markets utilise this perishability to drive down the selling price for fishers who have limited opportunity to wait decide when to sell. The Switch powerpacks coupled with solar could support fishers by providing an affordable continuous cold storage facilities. This will reduce losses and leverage bargaining power in the market.

Figure 19 | other niche applications for Switch powerpacks: *(LEFT) the Vacutug; (MIDDLE) Squid fishing boat; (RIGHT) community cold-storage for fish*

dispatchable electricty for the village...

...by the village

" Cooking with solar battery is hard to use at first because this is a very first experience for us. But later we can use it very well, it is so useful. By using electric cooking stove, it saves more time, can do another work while cooking and also it is easy to use for cooking."

--- Ma Mar Mar, Pannyo village

5 Business plan

The full business plan is available on request (Annex 5). The main features of the market, entry-points and value-proposition are summarised below.

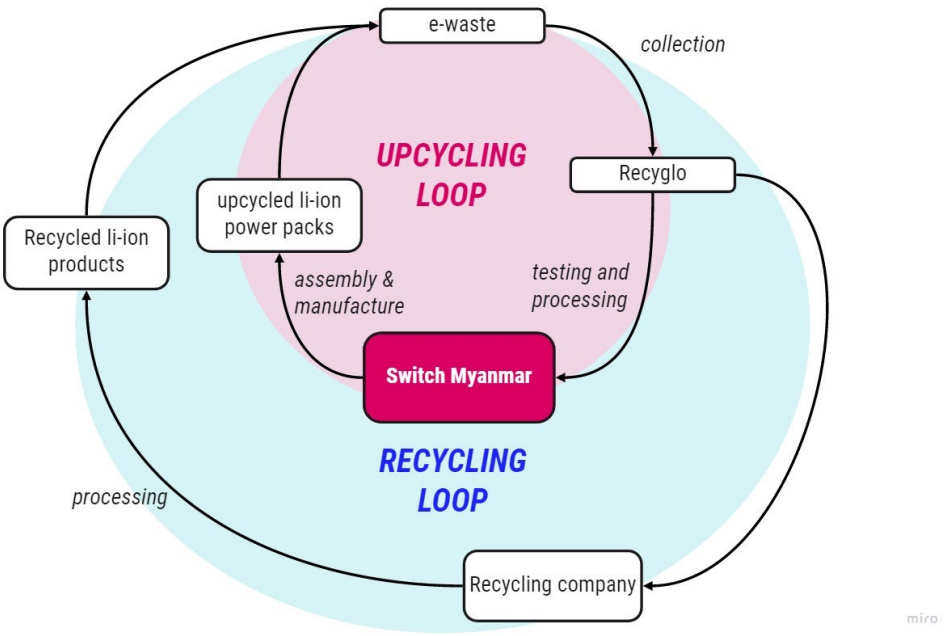
5.1 *Overview*

Switch Myanmar employs an accelerated prototyping methodology to demonstrate the viability of upcycled, locally assembled lithium-ion batteries as an affordable, reliable, clean, portable and dispatchable power source, Based locally, the social enterprise aims to unlock the potential of affordable electricity for off-grid and weak-grid households in Myanmar to improve health and livelihoods of communities.

Through upcycling and reusing lithium ion batteries Switch Myanmar addresses a number of interconnected issues in Myanmar:

- Household energy access
- Health issues related to indoor pollution caused by use of biomass-based stoves
- Enabling more efficient use and economic of renewables
- Value addition in rural communities (both through energy provision and the development of local level powerpack assembly and support)
- Reuse of viable components of e-waste

Figure 20 | Switch Myanmar



5.2 *The market*

The demand for rechargeable batteries for domestic power supply in Myanmar is significant, both in rural areas unserved by the national grid and in areas with grid access suffering frequent power outages. Demand is set to grow based on two industry trends:

- Government of Myanmar, with substantial international financing, is aggressively expanding deployment of solar home systems (SHS) and mini grids. More than half a million additional households will be connected to these technologies with subsidised systems in the next few years.
- In grid-connected areas, rapid rates of economic growth and grid expansion will see demand continue to outstrip supply, resulting in more frequent and longer duration power outages.

5.2.1 Grid connected areas

Myanmar has the lowest rate of electricity consumption and electrification in South East Asia, with around two thirds of households (6.5 million) without a grid connection,[10] many of these households are in remote rural communities and far from current grid infrastructure which is focussed on urban areas. For households lucky enough to have grid connections or in areas served by mini-grids, electricity provision can be unreliable with frequent outages and voltage fluctuations even in the large urban centres of Yangon and Mandalay.

Ambitious government plans aim for universal electricity access in Myanmar by 2030 predominantly through development of a centralised national grid. Government plans, with support from international development partners, aim to connect 3.75 million additional households to the national grid by end of 2021[11].

Despite the laudable objectives, based on other country experience it is unlikely that these plans are feasible.[12] It is likely that many households will remain without a grid connection for the foreseeable future. Given recent technological innovations in the provision of decentralised electricity production and distribution, it is unclear if the centralised grid-based approaches will provide the best solution to energy provision, especially in areas away from large load centres in the future.[13]

Given Myanmar's low starting point in terms of electricity access, much of the effort and investment is focussed on achieving universal access. This is an important goal but it masks a longer term structural problem Myanmar's grid is facing, and which will worsen as number of connections increase – namely the reliability of power. Myanmar's energy demand (due to economic growth and expanding connections) is increasing much faster than the expansion of generation capacity in the national grid. The power outages that have become a persistent and crippling feature throughout the country will worsen over time as increase in demand is projected to continue outstripping capacity upgrade. In this context, households, SMEs and civic services will continue to face regular power outages with significant social and economic impact. In affluent urban areas, many households and businesses rely on diesel generators as their power supply during outages which can last a few minutes to a few hours.

5.2.2 Off-grid areas

Myanmar has seen the development of a vibrant market for off-grid electricity provision, including diesel generators, solar home systems, and mini-grids utilising a range of generation technologies including biogas, small hydropower, diesel and increasingly, solar and solar diesel hybrid systems. It is estimated that in 2019 there were 25,000 villages with off-grid solutions providing electricity to 2.5 million households. Of these, 190 villages were served by solar mini-grids[14] and further

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[10] Roland Berger, 2019, Smart Power Myanmar.
[11] World bank. 2015. National Electrification Program (NEP), Project Administration Document.
[12] Ibid.
[13] Ibid.
[14] Defined as serving more than 70% of households.

7,927 villages were partially served by solar mini-grids or used off-grid household solar PV systems. Estimates that there are 140,000 households in Myanmar with stand-alone solar PV systems.[15] Conservative projections suggest that demand for off-grid electricity in Myanmar will grow by 3.5% per year between 2020 and 2030.[16] Household and mini-grid based solar PV technologies are likely to compose an increasing share of off-grid provision. Under the NEP program, the Government aims to about 500,000 households with SHS and mini-grid systems by 2021.

5.2.3 Switch Myanmar market entry points

It is against this background that Switch powerpacks have identified three important market segments ideally suited to the product.

Entry point 1: Distribution of power packs to Myanmar's growing Solar Home System and mini-grid sector

Solar PV systems, for households and mini-grids rely on batteries to store energy for use when solar radiation levels are low during the day or for use at night. Typically, these systems rely on lead-acid batteries because they constitute the lowest investment cost for the technologies available in Myanmar.

Based on lithium ion battery technology, Switch powerpacks perform better and are more cost effective than lead acid batteries for the role in support of solar PV systems (see section 3); and are cheaper than new lithium-ion batteries making a high-quality product more affordable. It is this large and growing market segment for battery storage in solar PV systems that Switch powerpacks are ideally suited.

In the short term, the market for bulk provision of powerpacks to solar systems providers will be an important market. At present, there are a number of companies operating in Myanmar which provide batteries as part of solar PV systems (Table 1), and dozens of local and foreign companies providing mini-grid and roof-top solar solutions to households and villages.

Both SHS and mini-grid developers are actively targeting subsidy schemes that Government of Myanmar is providing with financing support from the World Bank and the IFC which aim to connect more than half a million households by 2030 – representing a sizeable market in need of affordable and reliable storage technology.

Table 5 – Main household solar system providers in Myanmar

Provider	Activities	website
Solar Home	SolarHome installs integrated solar energy and appliance units in customers' homes and offers affordable "rent-to-own" plans of energy service subscription.	http://solar-home.asia/en/
ovSolar	Focuses on the design, production and global marketing of photovoltaic lighting products including home solar systems.	http://ovsolar.com/index.php?m=Page&a=index&id=56
Greenlight Planet	Greenlight Planet designs, distributes, and finances solar home energy, including home systems. Offers affordable finance for systems through 'pay-as-you-go' model.	https://www.greenlightplanet.com/sun-king-greenlight-planet/

[15] Ref.
[16] Roland Berger, 2019, Smart Power Myanmar.

d.light	d.light provides distributed solar energy solutions for households and small businesses.	https://www.dlight.com

Entry point 2: Distribution of power packs direct to households

The secondary and tertiary entry points for the Switch power packs represent sales direct to households and energy users. These entry points are differentiated by the type of household and the service provided by the electricity.

Entry point 2A: Distribution of power packs direct to off-grid households

Secondly, the longer-term opportunity is in the provision of powerpacks directly to end-users and localised production within communities. Switch Myanmar would first target existing SHS households familiar with PV-storage technology, offering a higher performance replacement power pack which can be swapped directly for the incumbent technology. Larger size modules will also offer existing SHS households the potential to utilise the power packs for productive uses, for example taking the power pack to the fields to power agricultural equipment.

Entry point 2B: Distribution of power packs direct to weak-grid households

There is a third market amongst on-grid users, at 2.5-10 kWhs Switch powerpacks have the potential to provide back-up for critical loads, and general household and commercial use in the event of power outages for on-grid and mini-grid users, and represent a cost effective alternative to small generator sets, especially for income constrained households. Consumers in this market will tend to be less income constrained than rural households and easier to reach given their location within larger population centres.

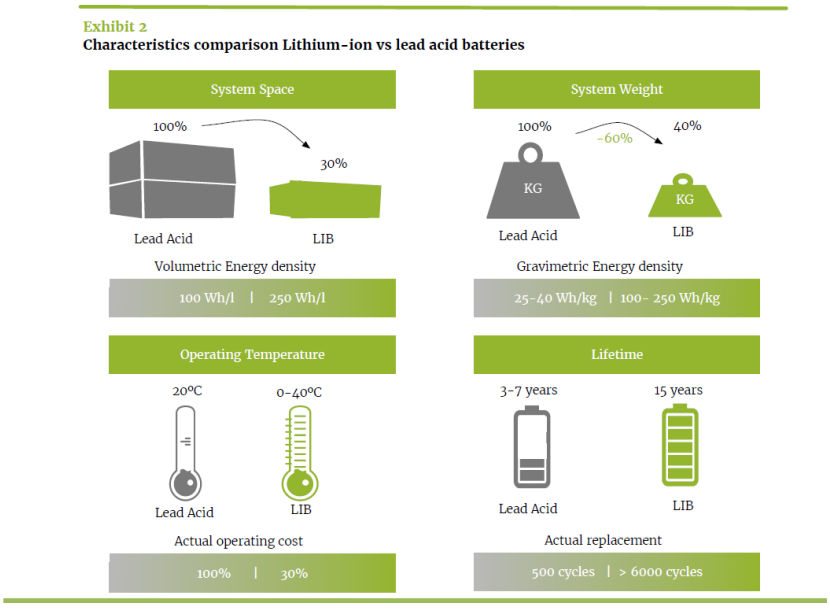
Whilst charging of the power packs for (1) and (2A) would likely be PV systems, it is likely that ,many customers under (2B) would charge their power packs direct from the grid.

5.3 The innovation

The value proposition of the Switch powerpacks is based on the project's resolution of four key barriers currently facing the household sector:

- **Performance:** lithium-ion batteries are the best-performance technology for short/medium term stationary storage (<6 hours). At present, the market for stationary electricity storage for solar home systems or similar uses in Myanmar and other developing countries is dominated by lead acid batteries. But lithium-ion batteries have much better performance characteristics for these applications, including greater efficiency, deep-charge capability, longevity and lower operational costs, as well as posing lower environmental health risks (***Figure 21***). Switch power packs effectively make the best technology available to users.

Figure 21 | Comparison of Lithium-ion VS lead-acdid battery technologies *(Source: Reid et al, 2018)*



- **Affordability**: Despite the better performance of Lithium ion batteries, lead-acid battery technologies have dominated the domestic electricity storage for off-grid applications due to lower up-front costs. Lithium ion batteries have lower storage costs overall[17], as a result of their better performance characteristics, but higher up-front costs which have typically been prohibitive for general domestic use in remote rural areas. While the costs of lithium ion batteries have fallen[18] dramatically, price declines seen for the EV sector have not been matched for stationary applications.[19] Through the reuse of reconditioned lithium ion cells, and the assembly and testing taking place in Myanmar, Switch powerpacks are able to offer the advantages of lithium ion batteries at an affordable price.

Table 6 – technology comparison[20]

	LEAD-ACID AGM	GENERIC LITHIUM-ION
Installed capacity	100 KWh	50 KWh
Usable capacity	50 KWh	50 KWh
Lifespan	500 cycles at 50% DoD (Depth of Discharge)	3000 cycles at 100% DoD
Number of installations	6 (1 + 5 replacements)	1

[17] For example, Anuphappharadorn, S., Sukchai, S., Sirisamphanwong, C. and Ketjoy, N. 2014. Comparison the economic analysis of the battery between lithium-ion and lead-acid in PV stand-alone application. Energy Procedia 56 (2014) 352 – 358

[18] BNEF, 2018, 2019. BNEF's annual battery price survey cites a learning rate of 17-18%.

[19] Ref (BNEF article)

[20] Source of generic information on Lead-acid and lithium-ion technology is from: Source: Power Tech. 2020. https://www.powertechsystems.eu/home/tech-corner/lithium-ion-vs-lead-acid-cost-analysis/

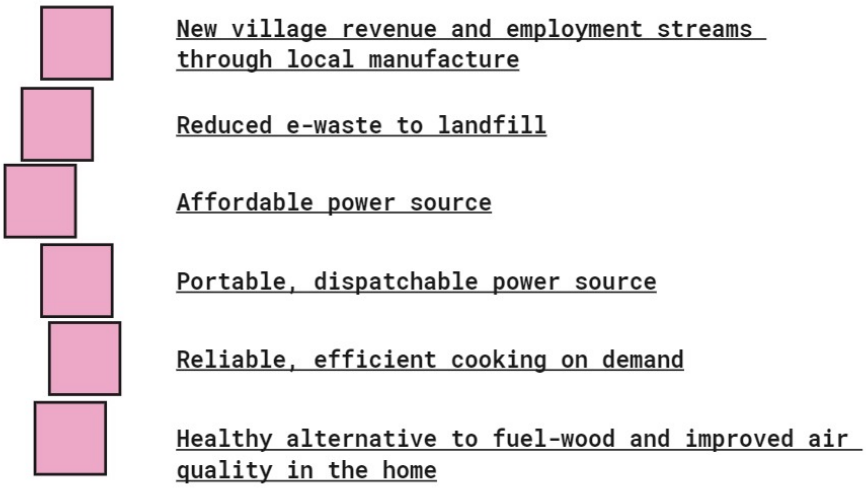
Battery cost	60 000€ (100€/KWh x 100 x 6)	25 000€ (500€/KWh x 50 x 1)
Installation cost	12 000 € (2000 € per install x 6)	2000 € (one shot install)

- **Circularity:** the global renewable energy transition has a nascent waste management problem. By 2030 there will be in the order of 1,000 GWh of accumulated storage retired form EVs with currently no proven value streams for second life applications[21]. In Myanmar, there are a growing number of illegal e-waste dumps supplied by large volumes of waste transported over the Chinese border and laptops and other e-waste generated in Yangon. The Switch powerpacks pioneer a second-life value stream for domestic and regional e-waste.
- **Developing value-added in rural communities**: there is strong evidence that access to electricity is a positive enabler of rural development and improved livelihoods in rural communities.[22] However, the other benefits associated with the renewables value-chain are typically not captured within the community. Through the localisation of Switch powerpack assembly, distribution and sales, a greater share of the value created will be kept in the community, creating paid employment and the development of skills in the local workforce.

5.4 *The value proposition*

Switch powerpacks leverage the environmental and market advantage of upcycled lithium ion batteries to provide affordable, reliable and portable electricity to off-grid and weak-grid communities of Myanmar (***Figure 19***).

Figure 22 | The Switch powerpacks value proposition



[21] Reid et al. 2016.
[22] Roland Berger, 2019, Smart Power.

Annex 1 | Scoping phase consultations

RENEWABLE ENERGY ASSOCIATION OF MYANMAR (REAM)

REAM is a registered association advocating for renewable energy policy reform and implementing sustainable community energy projects, including solar irrigation projects in the central dry zone.

Salient points of the discussion:

- REAM worked with a former MECS project to pilot DC batteries for e-cooking. That project developed cooking diaries which were completed by each household for two weeks before introduction of the battery and two weeks after. The pilots were focussed on Yangon, Ayeyarwady Delta, and Natmauk township in the Central Dry Zone.

- Central Dry Zone in general and Natmauk township specifically is a good location for e-cook batteries, because:

    - Grid electricity has issues of reliability, especially low voltage. In Natmauk township utilising grid electricity requires residents to wake up very early.
    - Many households still use fuelwood for cooking, yet this long standing dependency has resulted in deforestation which is make fuel wood incredibly scarce.
    - While reliable electricity is a problem, this is not a significantly poor township which means households do have disposable income for purchasing e-cook appliances.
    - REAM board member U Htan Htay is from this area and has a workshop.
    - All the REAM-installed solar irrigation projects are not utilising all the solar energy generated, which means there is potential to charge the power packs with existing solar cells.

- REAM has established the Solar Energy Group within the Union of Myanmar Federation of Chambers of Commerce (UMFCC), which is an important stakeholder for the scaling phase.

SAVE THE NATURAL RESOURCES (SANR)

SANR works on environmental projects in Southern Shan state, especially with the Danu ethnic minority. At the policy level SANR advocates for alternative energy promotion and work closely with the Shan National League for Democracy (SNLD). At the field-level they are active in Yarngan district.

All activities in Yarngan are closely related to forest protection and watershed management as the community have strong cultural and livelihood connections with the forest. SANR identified 3-4 villages that are very receptive to micro-hydro or solar projects however they are in areas under control of the ethnic armed forces which make access difficult.

Conclusion from the discussions is that there is a lot of interest and potential for e-cook power packs to integrate into the alternative energy programs of SANR in Shan State, but that the logistics of working in these areas may not suit the time frame of the MECS gran.

SANR has a workshop and training event in late November 2019, with HIVOS support. It was agreed that this would be an opportunity to share and promote the e-

waste to e-cook project as a first step to working with SANR and SANR-supported communities. During the scaling phase, more concrete steps to scale out to Shan state could then be explored.

MERCY CORPS

Mercy Corps runs the largest clean cook-stove campaign in Myanmar. Their campaign subsidizes important cook-stove technology to offer consumers a USD34 stove for USD 8. The campaign also supports environmental awareness raising and strengthening of entrepreneurs who sell the clean-cook stove technology. They have a target to reach 100,000 households and currently have reached 31,000 households. The Mercy Corps program selected areas with: high fuel wood reliance, and significant deforestation issues.

Based on their experience, Mercy Corps staff offered the following guidance:

- **Gender dynamics** is an important factor for success of clean cooking programs. One of the reasons Mercy Corps avoided e-cook solutions, was that their community research revealed that gendered-household power dyanmics would see the stored electricity being used by men to watch football matches, leaving women to cook with old dirty fuel-stove technologies.
- **Focus on fringe grid not off-grid communities:** Those areas with unreliable electricity access may be most interested in e-cook batteries as they have a familiarity with electricity which MC research reveals as one of the largest barriers to e-cook adoption. These areas may also have a higher 'willingness to pay' even if their e-cook power packs are only used for backup power.
- **Connect with local recycling companies:** two organisatoins work with recycling in Myanmar. Recycgo offers recycling services to Yangon based companies, and "Building Markets" works with a network of SMEs engaged in recycling.

Conclusions for e-waste to e-cook:

» Consider pilot sites in fringe grid areas where electricity is available but unreliable.
» Connect with Recycgo and Building Markets to assess potential local waste-streams for scaling up phase.

RESPONSIBLE BUSINESS FUND (RBF)

RBF is an enterprise investment fund established by DANIDA in 2017. The goal of the RBF is to allow Myanmar to grow its economy whilst leap-frogging the carbon-intensive development trajectories that developed nations followed in the twentieth century. Reduced carbon development pathways present Myanmar businesses with a number of problems, which are the focal points for the RBF. First, technologies and business models are unproven and hence present greater financial risk for purely commercial investors. Second cleaner technologies typically require higher CAPEX and hence longer payback periods.

The RBF seeks to demonstrate successful decarbonized business models for all sectors, where they meet one of the following: (i) resource efficiency (energy, water), (ii) OH&S to prepare Myanmar enterprise for export markets, and (iii) Skill and human resource development. The projects must also be: locally-led, cannot use grant-monies for working capital, and must provide at least 50% matching finance.

The fund is valued at 500 million Danish Kronor, and there have been four calls for proposals since 2017, through which all current funds have been committed.

A second phase (2021-2025) is currently under consideration by DANIDA. During the second phase the grant size will reduce from 50% to 30%[23]. In addition to the grant, the RBF will support projects to utlise their grant as leverage and mobilise commercial bank financing, by using the grant as an interest free deposit as a way to de-risk the bank commitment and leverage lower interest rates.

Conclusions for e-waste to e-cook:

- Establishing a locally registered enterprise would enable us to apply for RBF funding.
- Suggestion from RBF to expand the technology into larger units, RBF has undertaken preliminary market research[24] into the potential for electric tourist boats on Inle Lake which would be well suited to the recycled power pack unit.

PRIVATE FINANCING ADVISORY NETWORK (PFAN)

PFAN is a network of climate and clean energy finance experts that provide match-making services between clean energy projects and private sector investors. PFAN is hosted at UNIDO and Renewable Energy and Energy Efficiency Partnership (REEP), with funding from the Governments of Australia, Austria, Japan, Norway, Sweden and the United States of America.

PFAN maintains a network of private financiers who are actively looking for climate mitigation projects. They service this network by working with developers to get clean energy projects 'investment ready'. PFANS main tool is a Climate Investment Platform.

Myanmar activities are managed by the regional network, with a Regional Coordinator based in Bangkok, and two Myanmar based Mentor-coaches. PFAN also includes two Myanmar Network partners: WWF Myanmar, and Smart Power Myanmar.

Conclusions for e-waste to e-cook:

- PFAN consider our project highly suitable for financing through their network and strongly encouraged us to submit a funding application – even before pilots are completed.
- Include a submission of an application to Phase 4 (scaling out) activities in January 2020.

ASIA VENTURE CAPITAL PHILANTHROPIC NETWORK (AVPN)

AVPN is a Singapore-based membership[25] driven not-for-profit platform providing match-making services between social enterprises and venture capital investors. AVPN offers members access to conferences and networking events, as well as their 'deal-share' platform. Upcoming events include: India (Nov 2019), Jakarta (Feb 2020), and their main annual forum in Singapore (June 2020).

The network is active in Myanmar with 15 local members and 60+ regional members with offices in Yangon. AVPN have identified two main challenges for achieving scale in Myanmar: (i) lots of social enterprises, but limited understanding of inclusive

[23] Projects focused on wastewater or on non-monetisable environmental benefits may be eligible for 50% grant-financing.
[24] Preliminary market research found that there are several thousand tourist boats on Inle lake which could be electrified, and that tourist are willing to pay 50% more on the USD 12 ticket price for a silent boat ride. There is also potential to encourage lake-side restaurants to offer free PV charging to attract e-boat passengers.
[25] Membership costs USD 1,200 p.a.

business models, and (ii) conventional companies are disinterested and/or disengaged from the impact ecosystem.

Conclusions for e-waste to e-cook:

- AVPN presents an option to explore seed funding to scale out the project post-March 2020, should we choose an equity financing route.
- We would need to present the business plan and findings of pilot activities at the June 2020 AVPN Annual Conference.

ANDAMAN CAPITAL PARTNERS (ACP)

ACP are an investment and advisory firm focused on supporting foreign investors entering the Myanmar market. They also manage their own fund for investment in multiple sectors.

Conclusions for e-waste to e-cook:

- Potential source of equity financing.
- Include ACP in the Business prospectus launch seminar.

Annex 2 | Daily Cooking Diary survey questionnaire[26]

Village:	
HH identifier:	
Enumerator Identifier:	
Date:	

ID	Question	Early Morning				Breakfast time				Mid-morning				Lunch time				Mid-afternoon				Dinner time				Late evening			
1	**What did you eat?**																												
	Bought Food																												
	Ate food cooked earlier without re-heating																												
	Ate at friend/family members' place																												
	Did not eat																												
	Cooked food at home																												
	Other: _____																												
2	**How many people**																												
	Adults																												
	Children																												
3	**What did you cook?**	**cook time (min)**	**Device**	**Quantity (kg)**	**With a lid?**	**cook time (min)**	**Device**	**Quantity (kg)**	**With a lid?**	**cook time (min)**	**Device**	**Quantity (kg)**	**With a lid?**	**cook time (min)**	**Device**	**Quantity (kg)**	**With a lid?**	**cook time (min)**	**Device**	**Quantity (kg)**	**With a lid?**	**cook time (min)**	**Device**	**Quantity (kg)**	**With a lid?**	**cook time (min)**	**Device**	**Quantity (kg)**	**With a lid?**

[26] Completed cooking diaries are annexed separately

Pancakes																												
Sticky Rice																												
Rice																												
Eggs																												
Dry fish																												
Myanmar vermicelli																												
French fries																												
coconut milk noodles																												
Curry (meat/fish/veg/eggs)																												
other meat/fish or tofu																												
Other vegetable																												
Beans																												
Noodles																												
Soup																												
Tea/ coffee/ boiling water																												
Other: _____																												
Did you serve any food that you didn't cook (if yes, describe)																												
4 Why did you cook?																												
For eating at the time of cooking																												
Preparing food to eat later																												
Both for eating now and later																												
5 How did you cook?	**Fry**	**Boil/steam**	**Bake/grill**	**pressure cook**	**Fry**	**Boil/steam**	**Bake/grill**	**pressure cook**	**Fry**	**Boil/steam**	**Bake/grill**	**pressure cook**	**Fry**	**Boil/steam**	**Bake/grill**	**pressure cook**	**Fry**	**Boil/steam**	**Bake/grill**	**pressure cook**	**Fry**	**Boil/steam**	**Bake/grill**	**pressure cook**	**Fry**	**Boil/steam**	**Bake/grill**	**pressure cook**
e-cook powerpack																												
LPG cylinder																												

Charcoal stove							
Firewood stove							
Pellets/briquettes							
Rice/husk							
Other: _____							
6 How did the cooking device perform?	**Performance score**	**Performance score**	**Performance score**	**Performance score**	**Performance score**	**Performance score**	**Performance score**
e-cook powerpack							
LPG cylinder							
Charcoal stove							
Firewood stove							
Pellets/briquettes							
Rice/husk							
Other: _____							
Description of performance, why did you score?							
7 Enumerators comments							

Annex 3 – Scale up Plan

	TASK	MONTH 1	2	3	4	5	6	7	8	9	10	11	12
Phase 1	**Staffing**												
	Initial hires COO, CEO												
	Logistics												
	Establish premisses												
	Arrange utility connections etc.												
	Equip premises												
	Identify suppliers and agree supply contracts												
	Sales and marketing												
	Identify bulk customers												
	Identify sites for pilot operations												
	Product development												
	Legal and administrative												
	Company registration												
	Tax registration												
Phase 2	**Staffing**												
	Secondary hires, CTO, MO, accountant, forst technician												
	Logistics												
	Establish storage, inverntory and warehousing procedures												
	Establish manufacturing process (cell harvest, testing, sub-module assemby, powerpack assembly)												
	Estblish QA process												
	Sales and marketing												
	Develop marketing materiels/branding												
	Monitor pilot operations sites												
	Product development												
	ISO certifiation for powrpacks and manufacturing process												
	Legal and administrative												
	Establish accounting systems												
Phase 3	**Staffing**												
	Hire additional technicians, comms officers and sales officers												
	Logistics												
	Investigate possibilities for localisation of manufacturing, supply chains												
	Bring assembly to scale												
	Sales and marketing												
	Develop sales plan												
	Product development												
	Develop medium sized powerpack												
	Develop large sized powerpack												
	Legal and administrative												

Annex 4 – Assembly Manual

See separate attachment

Annex 5 – Switch Myanmar Business Prospectus

See separate attachment