End-of-life e-waste guidelines for S4H

This document outlines the challenges with e-waste for S4H and introduces some practical advice for the handling of e-waste at Solar4Health facilities.

1 Recommendations

The main objective for the S4H is to ensure that e-waste is properly handled in the projects.

Three main challenges:

1) The UNDP needs to keep track of all key hardware components from installation until safe disposal/recycling (or transfer to the MOH).
2) For several of the main components, there are not yet established businesses for recycling (e.g. Li batteries), and such businesses will be unprofitable at least in the beginning. This means that there will be a net cost associated with the safe disposal/recycling of components.
3) During the first years of a project, there will be a limited number of faulty components (assuming the ESPs are operating and maintaining the systems sustainably). This means that components need to be aggregated across ESPs, and that some components need to be stored for a while, in order to reach a volume that makes it relevant to ship to a recycling facility.

The project cycle:

<u>Phase 1: Installation and operation:</u>

Time frame: year 1-6 (if contract period is eight years)

Expected scenario on replacements:

- Mainly faulty parts for Li batteries and PV panels (low % of components)
- Mainly inverters, electronics and appliances and that need replacement due to wear during the first 6 years (and lead acid batteries if used)
- Deterioration of capacity of Li batteries and PV solar panels likely to be met with additional components, rather than replacement of components.

Main challenges:

- Li batteries and PV panels
    - Few recycling plants operational world-wide, and possibly none in Africa
    - Negative economics in recycling
    - Too low volume of replaced parts to ship for recycling by each ESP
- What to do with already installed dysfunctional solar equipment (including lead acid batteries) at the facilities?

<u>Phase 2: End of contract/Transfer of ownership (or re-contract)</u>

Time frame: year 7-8 (if contract period is eight years)

Expected scenario on replacements:

- Larger volumes of batteries with low performance at sites
- Poor quality solar panels with low performance.

Main challenges:

- System components in poor condition (or dysfunctional) remain installed at the sites at transfer
- Improved, but likely still negative economics in recycling Li batteries and PV panels
- What to do towards the MOH if and when the responsibility is transferred.

The proposed solutions:

- The UNDP should tender out service contracts for E-Waste Managers that can receive and safely manage broken and replaced components
    - Some components will be required to be recycled and some will be safely stored until recycling businesses are active and volumes sufficient
    - There needs to be clear guidelines for the E-Waste Managers for what to do with each component – just collection will not ensure safe disposal/recycling
- The ESPs must be required to maintain and report on components installed and removed, as well as to document delivery to the designated E-Waste Managers. ESPs need to price this into their tenders and (some) payments to the ESPs should depend on proper asset control and e-waste management.
    - @ Installation: ESPs should be required to establish a register containing a list of the components installed, with serial numbers where relevant.
    - In Operations: The register should be kept up to date with all new components added and removed, and reported to the UNDP at a regular frequency, e.g. annually. All removed components need to be verified delivered to the designated E-Waste Managers.
    - @ Transfer to MOH: To avoid that components with very low performance are transferred to the MOH as a liability, ESPs should be required to replace all components performing below certain minimum requirements. Should be done one year before end of contract to have time to verify sufficient quality of new components.
- To finance end-of-life management and disposal/recycling, the UNDP could require a percentage fee added to all hardware acquired through tenders,
    - In a fee-for-service contract, the fee can be a per unit fee or a percentage mark-up.
- An incentive might be needed to ensure that ESPs manage this properly, e.g. a refund for documented safe disposal/recycling, but such solutions might add substantial additional management.

2 Backdrop

At its end of life, electrical equipment used in S4H facilities should be responsibly disposed of in line with regulations. However, currently there is limited regulation, limited options for some components and limited economic incentives for ESPs to make this happen.

2.1 Regulation

Regulation of e-waste is an area where many African countries are underdeveloped. Also, Africa is an importer of e-waste from other areas of the world, a growing concern stemming from the same lack of regulation.

According to e-waste monitor 2020, Zambia is the only country in the study that has e-waste regulation in place. However, we have not been able to confirm that this is in place in Zambia.

E-waste is constantly changing, also requiring regulatory updates. While there are general e-waste directives in Western countries, regulation for specific waste is lacking even in Western countries. For example, there is no country-wide specific regulation for PV panel disposal in the USA. However, some states have implemented their own regulation for this, and some companies in the US recycle thin film solar panels, separating the thin film[1] (toxic) materials from glass and electronics.

2.2 E-waste management infrastructure

Namibia is the country in the study that has most e-waste infrastructure. Both Zimbabwe, Zambia and Namibia have professional recycling companies. There is even an agreement between Zambia and Namibian company Namigreen to handle e-waste. In general, there seem to be several recycling companies, particularly in Zimbabwe, Zambia and Namibia targeting valuable waste, and offering collection services for e-waste and refrigerants. For most of the waste collected, at least in Namibia, this seems to be a business with very low margins, and transport/decentralised collection is quoted as a key problem in several countries.

Lead acid batteries has a high toxic potential, is classified as hazardous waste, and could fall under this legislation in the countries in question. Recycling of lead acid batteries seems to have the best financial foundation and seems to be a business with decent margins as the lead scrap is valuable and easily reusable. The recycling process is relatively simple and cheap, and the lead can be used locally for new batteries. Local recycling of lead is therefore present in many African countries already. However, lead acid recycling must be managed to ensure it is conducted at a site that also properly treats/recycles the electrolyte (acid) and plastic casing and protects workers from the acid. Improper lead-acid recycling has been classified as one of the worst polluting industries.

Lithium batteries have a low toxic potential and are mostly linked to safety risks. So far, the business of recycling of lithium ion batteries is limited. This market has seen low volumes because there has been little lithium waste to date, many lithium batteries remain useful longer than lead acid batteries, and also remain useable also when the charging potential is reduced (cycle is still usable with proper battery controllers). However, as volumes now grow, it is likely that this could be made profitable. Recycling lithium batteries is a difficult and costly process involving discharging (before shipment) in sand, international shipping and high-temperature melting. Lithium batteries are built using a range of cathode material, and advancement on the cost side usually means moving to materials that are cheaper and hence implicitly less profitable to recycle.

It seems like there is refrigerant recycling/collection in Namibia, Zambia and Zimbabwe, but we are uncertain to which degree this happens. This is relevant for refrigeration and air conditioning.

While recovery of metals, particularly copper, can be handled by professional companies in many of these countries, it is also likely that there is an informal recycling sector in all these countries. This informal process often involves burning the resulting e-waste after the valuable metals have been removed and is a known problem.

There are some recycling plants for solar PV panels, for example in South Africa, separating modules into wafers, glass, thin film and framing. Here, the main distinction should be made between (toxic) thin film modules and (far more common, non-toxic) silicon wafers. We are not aware of such recycling plants in the five countries.

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[1] Cadmium Teluride (CdTe) is used in thin film panels. Silicon crystal panels are non-toxic.

There are several companies working in e-waste and recycling in the five countries. A non-exhaustive list of companies is shown in the table below. We have not contacted these to check the extent of their services.

Company	Country	Services
TCH e-waste	Zambia	E-waste
ZOL Zimbabwe/Enviroserve	Zimbabwe	E-waste, refrigerants
Trans world Cargo	Namibia	E-waste
Namiwaste	Namibia	E-waste
Umicore	Malawi	Battery Recycling
Simpli Return	International	Li-ion recycling
SolarWorld/SolarMaterial	International/South Africa	Solar PV lifecycle

2.3 Summary

There is limited regulation of e-waste in the five countries, and it is likely to take time before regulation is in place. Lead acid batteries fall under hazardous waste, and might be regulated, requiring recycling plants to have a license.

There are some local companies offering recycling services. This is not unlikely to grow with increased regulation and increased e-waste development. However, we believe these might not have capability to serve the entire country, and particularly lithium batteries are unlikely to be recycled locally in the near future.

Solar4Health waste

For this analysis, we have assumed the following non-exhaustive list of equipment needs to have an end of life plan:

- **General e-waste:** Wiring, machinery used on the facilities, including lamps, inverters, fuses, controllers. This includes scrap metal, particularly copper and/or aluminium wiring.
- **Solar PV panels:** Broken and/or end-of-life solar PV panels.
- **Lead acid batteries**: (Hazardous waste). Car/solar/AGM/etc, particularly for old equipment
- **Lithium batteries**: Increasingly taking over for lead acid batteries in solar installations.
- **Refrigerants:** Refrigerators and air conditioners + e-waste

The main e-waste generation from S4H is generated at three events:

2.4 Waste from installation in new S4H facilities

When installing new S4H facilities, the following e-waste exists:

- E-waste generated at installation (cut wires, equipment broken at installation, etc)
- Removal of old wiring/obsolete appliances
- Removal of old lead acid batteries

This waste disposal can be planned for and incorporated into the installation contract. It should be collected and deposited responsibly against receipt by the installer before final payment is done by S4H.

2.5 Waste from planned replacements

Waste from planned replacements mainly comprise replacement of end of life batteries (and other minor equipment). This is done as a central operation, can contain a sizeable amount of waste, and can include a central collection process for e-waste. Payment for the maintenance service should be contingent on correct disposal of replaced equipment.

For lithium batteries, the planned replacement can sometimes mean only top up battery capacity, as these batteries are still useable at lower capacities, and will not require scrapping. This reduces waste at the regular replacement cycles.

In some countries, there are functional lead acid recycling structures also in rural areas. In Kenya, there have been attempts to use gas stations as e-waste collection points. Battery retailers are also useful as return points, particularly if the country has Extended Producer Responsibility (EPR) regulation requiring these to offer collection services, and licensed lead acid recycling plants. If S4H believes this return method is credible in the country of operation, these facilities can be used for collection.

2.6 Waste from corrective maintenance

Waste from corrective maintenance is all equipment that is changed outside maintenance cycles, for example broken equipment such as inverters, batteries, led lamps, panels, refrigerators etc. This will likely be modest amounts of waste.

Since this will be generated irregularly, and not associated with general maintenance intervals, this e-waste could be kept at the facility until a regular maintenance round is conducted. At this point, it should be part of the maintenance contract to collect e-waste.

3 Organisation of e-waste collection

Collection of certain scrap metals, refrigerants and lead acid batteries could show to have a value today. However, collection/recycling of most e-waste is unlikely to be economically feasible without fiduciary support. Even for the mentioned categories, lack of regulation and cost of collection could mean that also these recycling businesses are unsustainable without support.

S4H should therefore expect that they would have to pay disposal facilities for the e-waste, and S4H can not expect that replaced e-waste is automatically recycled.

S4H is likely to be a small player in the e-waste sector in the foreseeable future, as equipment lifetimes are relatively long, and the amount of waste generated during the first years is relatively low. To do this properly, we suggest the following approach:

- **Find a suitable disposal facility:**
    - S4H should avoid collecting own e-waste centrally, and as far as possible use professional waste management companies in the country. If none exist, S4H should contact mobile companies or electronics retailers to investigate how this can be done jointly.
    - Countries like Zimbabwe, Zambia and Namibia clearly have recycling companies that could be contacted for possible framework agreements. This might also be available in Liberia and Malawi. In countries where no disposal facility is available, S4H might have to look in neighbouring countries for alternatives.
    - Locate local lead acid recycling plants with license to handle hazardous waste.

    - S4H should use some resources to audit such facilities to make sure they handle waste properly, and ensure that the process has satisfactory traceability (receipts for delivery, documentation of waste handling procedures)
    - There might be a need for periodical shipments of lithium batteries and potentially PV modules to international recycling facilities until this service becomes available locally.
    - S4H should expect to pay for some of these services.
- **Organise transport to disposal facility:**
    - Disposal/transport of e-waste at installation and corrective maintenance shall be the responsibility of the ESPs and be worked into their contracts. Proof of delivery shall be presented to S4H.
- **Maintain logging of equipment/replacements**
    - S4H should have equipment lists and checklists for replacements so that correct disposal can be verified before disbursement to service providers.
    - Service providers should be required to log disposal process
    - Disposal companies should be able to provide proof of acceptance.
- **Sustainability and responsibility**
    - ESP is formally responsible for handling and documenting handling during contract period.
    - S4H can look to the EU WEEE directive for handling of hazardous e-waste.