Technical Notes

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Product Repair Part II: Manufacturer best practices

This Eco Design Note outlines a series of steps manufacturers can take to facilitate the development of a viable repair market. A three-part process is described that starts with design decisions, continues with the availability of replacement components, and finishes through the sharing of information with repair technicians. Specific suggestions are provided that help make product repair a viable option for consumers.

Introduction

Broadly speaking, there are three general categories where manufacturer involvement is necessary or even critical to repair efforts. The first starts in the design of the product, where design decisions can enable or facilitate repair efforts to extend product life. In many cases these decisions can be ones that are cost neutral to the product, relying on the manufacturer's commitment to the underlying concept of repairability as a positive product attribute that enhances the product brand.

Secondly, manufacturers can play a critical role in making replacement parts available to distributors and repair shops. This starts at the appliance level and, in some cases, is compatible with manufacturer plans for distribution of additional light points, add-on devices, and solar modules. Other sub-components, including both replacement circuit boards and replacement electronic parts (connectors, switches, etc.), are often impossible for repair shops to obtain without either manufacturer support or scavenging other products.

The final category concerns technical information about the operational parameters of the product. This includes multiple elements ranging from product schematics, bill of materials listings, labelling marks on the product itself as well as key components, and the creation of repair manuals or guidelines that will assist a repair technician. Information is critical to electronic repair efforts.

Designing a product to allow repair

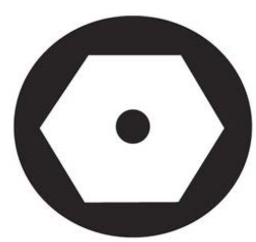
Product design specifics play an important role in allowing repairs to be made on a product. Engineering and design choices made during the development phase rightly emphasize performance and cost factors that will contribute to the success of the product. If repair is not a consideration there may be lost opportunities, often at little or no additional cost, that would facilitate lifetime extension.

Access for repair: screws, clips, and adhesives

Opening and closing a product enclosure is very frequently necessary to perform a repair. Once inside, an engineer should be able to non-destructively remove and reattach components. These enclosure design practices will help facilitate repair efforts:

- The product should be held together with screws, and not ultrasonically welded or glued together.
- Security screws (Figure 1) may be used so that a consumer cannot open the unit. Screw heads should be standard security hex or security torx type.

security torx



security hex

Figure 1. Security screws for renewable energy products

- Security screws should not be at the bottom of a deep narrow hole, such that a universal hex screwdriver cannot reach them.
- Screws should be of one sort. If this is not possible, they should be obviously different, so that during reassembly it is easy to put the correct screw in each location.
- Where other screws are accessible on the outer casing of the unit, cover fixing screws can be indicated with a special symbol, eg ➔ or ※.
- One-time (single use) fixing clips should not be used. *(Replacing cable ties is acceptable but not ideal.)*
- Repairable or replaceable components must not be potted in epoxy.
- If components are glued or taped in place, it must be possible to break the bond to remove a broken part, without damaging the product *(For example: the glass in front of a display should not be so tightly bonded to the display that replacing a broken glass breaks the display as well; removal of a battery bonded to a case or a circuit board should not damage the case or the circuit board).*

Port and circuit board labels included on the product

Labels on connector ports (printed on the outside of the enclosure) and circuit board silkscreen labels (Figure 2) are common and can be used in conjunction with electronic schematics and repair manuals to identify appropriate test points. These labels can serve as key identifiers when conveying schematic and other functional product information to a repair technician and are indispensable when performing electrical diagnostics.

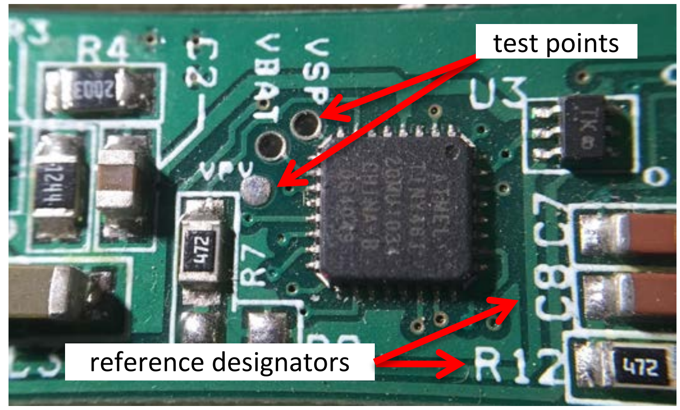


Figure 2. circuit board silkscreen labels

Repair procedures and replacement components

Repair procedures for renewable energy products can vary from simple replacement (as with batteries) to more complex procedures requiring a skilled technician (replacing a component on a circuit board) (Table 1). Most require access to replacement parts, and often these parts are unique to the product family.

The availability of components can make the difference between success and failure when a product repair is attempted. Access to distribution channels and delivery services are restricted in many off-grid communities and getting the right parts can be impossible without a working system in place that both stocks common parts and provides a way to replenish repair supplies.

The first repair components available for a particular product model are often scavenged from other broken units. This can help establish a repair market early on but is ultimately unsustainable, as the most common broken parts become scarce. As the renewable energy product sector grows, however, there are new incentives to strengthen supply chains and distribution channels for repair components, and new market opportunities open up for dedicated repair service providers.

Appliances

Light points, information products (radios, TVs), tools, and other product accessories are available for some systems as add-on appliances. In some respects, these can be considered repair components and the distribution channels for them can be a model for the distribution of components inside product enclosures.

Solar modules

Solar module failures can occur inside the panel encapsulation, in the junction box, or in the cord. A failure inside the panel will require its replacement. This may be simply a matter of finding a compatible module but may often also involve the re-use of an existing cable and junction box. Failures in the junction box or cord are caused from corrosion or physical stress which leads to a broken conductor. These failures can be diagnosed quickly and repair becomes dependent on the skill of the technician, the ability to access the location of the break, and the availability of a replacement cord or plug that is compatible with the system.

Given the prevalence of DC barrel plugs for PV module cables, many repair attempts will be made with PV modules from different manufacturers and different power ratings. As the growth of the sector proceeds, more working modules will accumulate in off-grid communities and these will be deployed across product brands. The result is a mismatch between module and battery/charger that may lead to damage of the system electronics or overcharging of the battery. In extreme cases this could lead to safety issues of battery overheating and fire.

Manufacturers can help prevent these mismatches by properly labelling their solar modules and input/output ports. They can include specific instructions with their products warning consumers and repair technicians of the risks involved in using modules and appliances from other brands or model numbers. Solar module ratings should include power ratings (the maximum power of the module), open circuit voltage (Voc), and short circuit current (Isc). Input/output ports should be clearly labelled to identify the different PV module, appliance, and phone charger ports and ideally would also include nominal voltage and maximum current ratings.

Batteries

Table 1. Failure mechanisms and repair options

Component	Cause of malfunction	Repair options
solar module	Broken connection inside module, inside junction box, or cable damage.	Cables can be repaired by removing damaged sections or splicing in a new cable. Repairs inside the junction box can only be performed if the box is not permanently sealed and/or encapsulated.
battery	Battery end of life or internal malfunction	Replace battery with a compatible new unit. Polarity and connector must match existing OR old connector can be salvaged for new battery.
circuit board	Broken electronic component, broken connector, broken circuit trace, corrosion	Trace damage/corrosion can be identified by visual inspection. Circuit traces can be repaired by a skilled technician. Circuit boards can be replaced by non-skilled technicians.
appliances	Varies according to appliance type	Replace appliance or diagnose and repair.
connectors	Damaged pin, corroded pin, damaged circuit board connection	Connector replacement requires circuit board rework, access to replacement part, and skilled technician.

The availability of replacement batteries for renewable energy products will become an increasingly important issue as the market grows. Battery replacement is typically one of the first repair items considered by a technician, and under the right circumstances can be one of the easiest repairs. As battery quality improves and manufacturers gain experience with proper battery management techniques, battery repairs may become lower in frequency in relation to other repair types. However, the battery is ultimately a consumable component and at some point will need to be replaced for the product to continue its useful service life.

Circuit boards

Replacing a circuit board within an enclosure is an easy, quick repair operation that can be performed with a minimal degree of training. Identifying the circuit board as the malfunctioning component is the primary technical challenge to this repair. The actual replacement is usually just a matter of removing screws and transferring the battery and other connectors from the old board to the new.

Having access to a replacement circuit board becomes the main technical hurdle for this type of repair. Given this access, however, the repair can cover many different failure modes including failed solder joints, broken connectors, and corroded circuit traces and component pins. Circuit boards could be sealed in electrostatic discharge (ESD) bags with desicants for storage, and ready for use when needed.

Connectors

Connectors are another common failure mode of electronic devices, particularly those used for appliances, PV modules, and phone chargers because of the regular plugging and unplugging of these devices. These repetitive physical stresses can break solder joints where headers and jacks connect to circuit boards, bend crimps and pins, and break wires inside plugs at the strain relief where the cable joins to the overmold connector plug. Water tends to enter the enclosure through the connector ports where it can be trapped in and around the connector component, resulting in corrosive failure of the connector pins, solder joints, or wire crimps.

Replacing the plug on an appliance or PV module cord requires a new (correctly sized) plug and a moderate level of soldering skill by the repair technician. Plugs are available with solder pins that can attach directly to cable conductors, or they can have overmold strain reliefs and a short length of cable that can be used to attach as a wire-to-wire connection.

Coaxial power connectors, also known as **DC barrel plugs**, are commonly used on product cables to connect appliances and solar modules to a central power unit. The *plugs* have an outer barrel and an inner sleeve that mates with a corresponding *jack (also referred to as a header or socket)*. The plug can be characterized by the dimensions of the outer barrel and inner sleeve (the inner sleeve of a barrel mates with a pin in the receptacle). IEC 60130-10 is one standard that defines size categories and ratings for different connectors (Table 2).

Table 2. IEC 60130-10 designations

Type	OD	ID
A	5.5 mm	2.1 mm
A	5.5 mm	2.5 mm
B	6.0 mm	2.1 mm
B	6.0 mm	2.5 mm
C	3.8 mm	1.4 mm
D	6.3 mm	3.1 mm
E	3.4 mm	1.3 mm

Product documentation

Technical specifications are critical to a technician or engineer attempting an electronic repair, as well as to organizations involved in the training of repair service providers. On a basic level, system voltages and basic performance parameters can allow an engineer to identify improper performance and make a diagnosis of an underlying problem. More detailed information regarding specific component identification and system operation can allow for more involved repairs.

Manufacturers are often hesitant to reveal technical details about their products. Intellectual property and product forgery concerns may argue against publishing information that could be used to make it easier to copy a design. This necessitates, then, a balance between the information a manufacturer makes available and the information it retains. It should be realized, however, that a good deal of information is readily available from the product itself, and withholding this information from the repair community does not protect it from pirating. Providing it to the repair community, on the other hand, removes a key barrier to the development to a successful repair environment.

Replacement parts list

A listing of replacement parts, with corresponding size descriptors, would be very useful to a repair technician. This list could include battery type, voltage, and capacity, plug/connector sizes, screw sizes, and part numbers for circuit boards and other manufacturer specific components. Parts lists are similar, but less detailed, than a Bill of Materials (BOM) that a manufacturer uses when designing and manufacturing a product.

Electronic schematics

An electronic schematic is one of the most powerful tools a repair technician can have when servicing a product. The schematic allows for the most thorough analysis of system function. Without a detailed schematic, many electronic repairs are very difficult or impossible to perform.

A repair schematic can be customized to show the most important system voltages and components without revealing detailed product functions that the manufacturer considers proprietary. Black box block diagrams (Figure 3) can be used in a schematic to conceal these details while still providing information on power supply (Vcc rail) voltages, PV and appliance input/output voltages, and other signal voltage levels. If components are labelled on the circuit board silkscreen, these reference designators can be used on the schematic. If they are not labelled, the manufacturer must provide photographic or other written documentation that can allow a technician to physically identify relevant circuit traces, component pins, or solder (test) points.

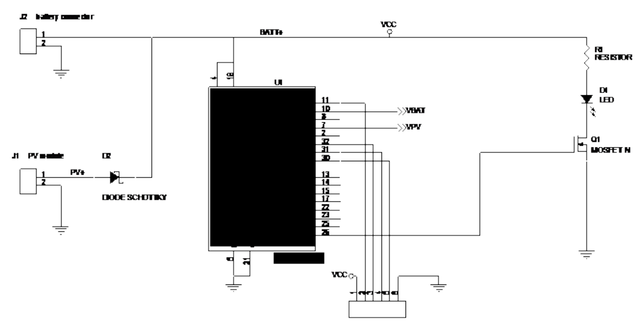


Figure 3. Schematic with hidden component identifier

Repair manuals

Repair manuals and troubleshooting guides allow the manufacturer to control the information revealed about a product while still allowing for the most common types of repair. A typical repair manual lists diagnostic procedures, identifies test points, and provides repair instructions. Additional information can include product warranty details, manufacturer contact addresses, and component replacement instructions where applicable.

Off Grid Solar Scorecard

The Off Grid Solar Scorecard - available online at http://www.offgridsolarscorecard.com/ - assesses the sustainable design of small renewable energy products. The scorecard grades products from A to E in three categories: Repairability, Recyclability, and Service and Spares (i.e. spare parts). The Scorecard provides an overall grade as well as a detailed assessment of specific product features that relate to the ease of repair and the potential for recycling a product at end of life. The grading system was developed through consultation with stakeholders in the off grid solar industry and is based upon international protocols for sustainable design (including, 'design for environment' and 'design for disassembly').

The Off Grid Solar Scorecard was developed by the University of Edinburgh, with support from the UK's Engineering and Physical Sciences Research Council. The Scorecard was designed to work alongside and extend Lighting Global's quality assurance standards. The Scorecard provides information for specific products that may help identify key sustainability features, such as the potential for recycling and the ease of performing product repairs. The Scorecard also offers an online tool that allows users to evaluate products.

The Scorecard provides a look at the overall renewable energy product market, with many products receiving a grade of 'C' or lower for their sustainable design attributes, leaving a good deal of room for improvement.

Conclusion

Today, organized markets for solar repair services and component supply ecosystems in sub Saharan Africa and South Asia remain underdeveloped and unstructured. The opportunities for manufacturers to facilitate the development of a viable repair market are wide open, if they see the benefits.

First, there is considerable scope for manufacturers to innovate in markets for after sales and repair services. Product repair success stories can play an important role in establishing trust in the various technologies involved, and manufacturers can play a key role by fostering the development of repair infrastructures. New off grid solar repair businesses - like Urjaa Samadhan in India - are leveraging mobile technologies to aggregate demand for repair services and supplies, and to manage component supply chains. As they do so, there are opportunities for manufacturers to establish novel partnerships that link the provision of after sales servicing and repairs to the supply and distribution of parts and components.

Second, there are also clear opportunities for manufacturers to win new accolades by designing for cost, performance as well as repairability. As demand dynamics involving small renewable products become established, customers will regard the underlying technologies based on experiences they have with reliability and product longevity. Building in features that allow consumers to extend the lifetimes of products can only create new incentives in increasingly competitive markets.

As the various components in these systems accumulate in local communities, there are already attempts underway to salvage as many of the useable parts as possible. As the renewable energy product sector expands further, so too will attempts to start repair businesses for these products.