Initial Environmental Impact Assessment for mini-grid in Malawi

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Status: Draft, for comment.

This material has been funded by UKAid from the UK government; however the views expressed do not necessarily reflect the UK government's official policies.

Executive Summary

The objective of this working paper is to provide an environmental assessment of a mini-grid from cradle to gate and was conducted following the principles of BS/EN ISO 14040 and 14044 and other good practice systems. This working paper presents the initial findings, and these may be updated in the light of improved data.

The model for the mini-grid in Malawi was built from the Bill of Materials (BOM) It serves 60 premises, a combination of households and small enterprises. Eighteen midpoint and three endpoint indicators were analysed, using the ReCiPe(H) assessment methodology.

The dominating endpoint indicator was found to be human health, and then midpoint impact categories of concern related predominately to ecotoxity of water and land.

Three design aspects of the mini-grid were identified as potential concerns, the wooden poles and stays, the PV panels and heavy-duty overhead cables.

A scenario assessment, switching the wooden poles and stays for concrete poles significantly reduced impact on human health.

A sensitivity assessment Reducing the impact from the heavy-duty cables could be achieved by a) efficient routing from point of generation to point of use or b) changing the types of cables used. It is not known if it is appropriate to change the type of cables used in this instance.

A sensitivity assessment of the PV panels showed that whilst the panels contributed significantly to total impact, the results are not overly sensitive, in that a small increase in panel size results in a large increase in impact.

1. Background

An environmental assessment was undertaken for a mini-grid currently agreed for construction in Malawi. The description and Bill of Materials (BOM) for this grid was provided by University of Strathclyde. This document presents the initial results for consultation and further refinement. It assesses the mini-grid as a stand-alone system from cradle to gate, i.e. from raw materials extraction to completed construction. No use stage or end of life has been considered. Where possible, country specific data has been used, else generic global averaged data has been employed.

The software used for the analysis was Simapro. It should be noted that the results presented here are interim results, and may change in the light of further data or changes to the underlying model. In addition, the results are only valid for the mini-grid as described in the BOM. Since all mini-grid designs are dependent on location, power source, number of houses and items to be powered, it would not be appropriate to use the results from this study as a 'generic' mini-grid assessment. The study was conducted following the principles of BS/EN ISO 14040 and 14044 and other good practice systems.

2. Limitations

a) Data

Table 1 shows the expected lifetimes of the main components of the mini-grid, and is used to calaulate how many of each component are needed for the mini-grid life of 20 years.

Item	Lifetime, years
Minigrid	20
PV panel	20
Battery	10
Inverter	10
Converter	10
Shipping container	25
Overhead equipment	20
Heavy Duty cabling	30
Light duty cabling	25
PVC components	15

Table 1: Expected lifetimes of main components

The data used in the model this far is a combination of data provided by ecoinvent[1] database, and specific data gathered for a particular product design or location. Table 2 identifies where proxy processes or products have been used to fill data gaps

Item	Data source
Battery	Bespoke model built using base data from Ecoinvent v3.6. Assumed built in China.
PV panel	Existing model in Ecoinvent v3.6. Global averaged data used
Inverter/converter	Scaled from 2.5kW existing model in Ecoinvent v3.6. Global averaged data used
Shipping container	Bespoke model built using base data from Ecoinvent v3.6. Global averaged data used
Wooden poles and stays	Bespoke models built using base data from Ecoinvent v3.6. Data for wood from 'rest of world' (excludes Europe), global averaged data for preservation process.
Concrete poles and stays	Bespoke models built using base data from Ecoinvent v3.6. Concrete production for Zambia used
Cables and wires	Bespoke models built using base data from Ecoinvent v3.6. Global averaged data used
PVC components	Bespoke models built using base data from Ecoinvent v3.6. Global averaged data used
Overhead equipment	Bespoke model built using base data from Ecoinvent v3.6. Global averaged data used

Table 2: Data sources for main components

b) System Boundaries

This report is NOT a LCA study as defined by ISO 14040 series. This report is limited to cradle to gate (raw materials to completed mini-grid for 20 year life) for the analysis of the mini-grid in isolation.

c) Functional Unit

The functional unit is 1 lifetime of the mini-grid (all components and materials needed for the mini-grid to function for 20 years)

d) Impact Assessment Methodology

There are no environmental assessment systems that currently focus on the African continent. For global impacts, such as climate change, this is not a concern. However, for local pathways and associated impacts, the different regions can affect the potential impacts created. The ReCiPe system (which has built on CML 2002 and Eco indicator 99 systems) will be used to assess the midpoint and endpoint environmental categories. ReCiPe integrates the midpoint and endpoint approaches in a consistent framework.

[1] https://www.ecoinvent.org. Accessed 14.07.20

3. Results

All graphs can be found in Appendix A.

a) General Findings

Graph 1 shows which of the main component groups contributes most to environmental impact. Three main groups can be clearly seen, the power system, the poles and stays and the cables/wires/conductors. One particular result of interest is the domination of the human carcinogenic toxicity by the 'poles and stays' group. This is investigated in more detail later in the report.

Graph 2 shows the results normalised against the per capita impacts for each category. This provides an indication of which impact categories have the greatest impact in the real world. Here it can be seen that the impacts of greatest concern are all around toxicity to either human health, aquatic systems or ecological systems.

Digging into Graph 1 in a little more detail to find out which components are causing the high impacts for power, poles and cables, we can see from Graph 3 that it is the PV panels that are the greatest contributors to the power component impacts. The data used for the production of a multi-crystalline PV panel has been taken from generic averaged industry data and does not necessarily accurately reflect the specific processes used by the manufacturer listed in the bill of materials for the mini-grid. As a result, a sensitivity assessment on the efficiency of the panels has been carried out to evaluate how much the contribution to overall impact results from the PV panels. Further analysis of the PV manufacturing system will be undertaken, and the potential to create a bespoke system evaluated.

Graph 5 shows the contribution of the different cables to the environmental impact. Two cable types stand out specifically, the $16mm^2$ twin figure 8 cable with copper core and the 50mm AAC cable, with an aluminium core. All cables used have sheaths, made from, in the majority of cases, flexible PVC. Graph 6 indicates that it is the metals within the cables that contribute most to the environmental impact, and that the sheathing material(s) contribute a significantly smaller amount.

Graphs 7,8 and 9 show the endpoint impacts that result from the mini-grid design. These are the impacts on human health, ecological and resource use, as opposed to the contribution to environmental impact categories. Endpoint impacts are calculated by allocating the environmental impact categories (known as midpoint categories) to one of the three concerns; human health, ecotoxicity and resource use. Graph 7 shows the damage to human health, eco-systems and resource use that may occur from each of the component groups in the mini-grid. As to be expected (since the environmental impact categories are linked to the endpoint issues), the three component groups that contribute most are power, poles and cables. If these results are normalised (Graph 8), it can be easily seen that the endpoint issue of greatest concern is that of human health. This underscores the concern that was initially identified with the use of wood, and its necessary preservative, for the utility poles. Graph 9 shows an aggregated single score for each of the component groupings. This shows the impacts associated with the poles and stays to be significantly greater than that for the power system, or the cables and wires. It also shows that for each of the component groups, it is the impact on human health that is of greatest concern.

b) Poles and stays

Looking at the poles and stays in more detail Graph 10 shows just how much the environmental impact is dominated by the wood preservative. It is thus useful to compare alternative systems to try to reduce the impact from the choice of wood and preservative. Two alternatives have been identified and modelled; the use of wood but using a non-chromium based liquid preservative, using the same application method (vacuum pressure), and concrete poles and stays. Graphs 11 shows the results of this comparison for environmental impacts, and Graph 12 the normalised results. On Graph 11, it is interesting to see that for all impact categories apart from human carcinogen, the non-chromium wood preservative has a higher impact, concrete has the lower contribution across all impact categories. When the results are normalised, it is clear that again, those impacts relating to toxicity and human health are significant.

Looking at the endpoint impacts, Graphs 13, 14 and 15 show some interesting results. Graph 13 shows that it is only for the human health endpoint that the Chromium based preservative contributes more, for both ecoxtoxicity and resource use, the non-chromium version contributes more. When looking at the normalised Endpoint categories (Graph 14), once again the human health concerns are the most significant. Graph 15 shows what could initially be viewed as a counterintuitive result, that despite the non-chromium wood preserver having a higher environmental impact in all impact categories except human carcinogen, overall it has a significantly lower 'single score' for endpoint impact. This result emphasises the overwhelming dominance of the human carcinogen impact category, and it is this issue with the chromium based preserver that is of concern.

The results for the concrete poles and posts can be seen in graphs 13,14 and 15, and have a lower environmental impact and to contribute less to the endpoint impacts that either of the wooden options.

c) Sensitivity of PV panels for contribution to total impact.

Two tests were undertaken to assess the sensitivity to the overall impact of the PV panels: a +/- 10% change in PV area, and a +/- 25% change in PV panel life. For the varying area, the endpoint impact resulted in a change of less than 10%, and for the varying panel life, a change in impact of less than 25% was seen. These results suggest that the overall impact results from the mini-grid components is not unduly sensitive to the PV panel contribution.

4. Conclusions

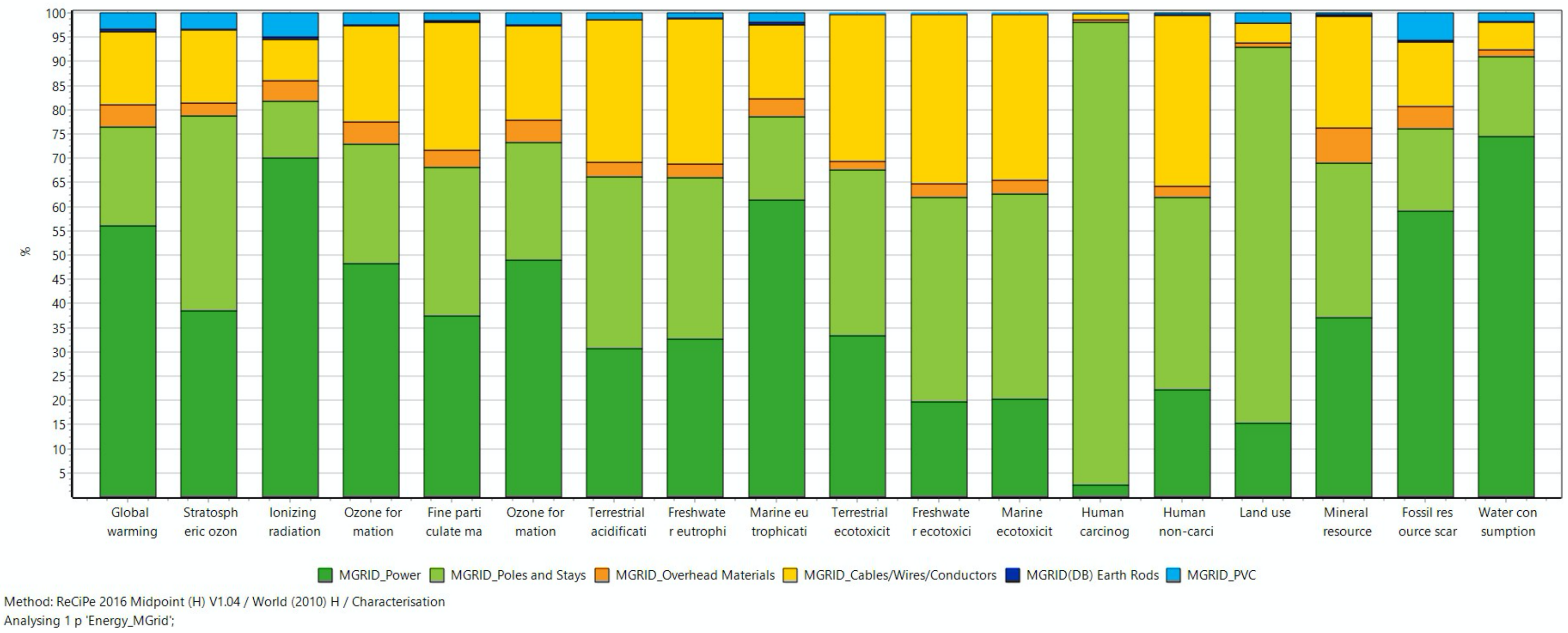
The initial results suggest that the three areas of the mini-grid that show the highest impact scores are for the PV panels, the wooden poles and stays, the AAC cable and the $16mm^2$ twin figure 8 cable.

Of these, the cables cannot be substitutes for alternatives, so the only option is to reduce the quantity required. This may not be possible depending on the local landscape and available space to install the mini-grid.

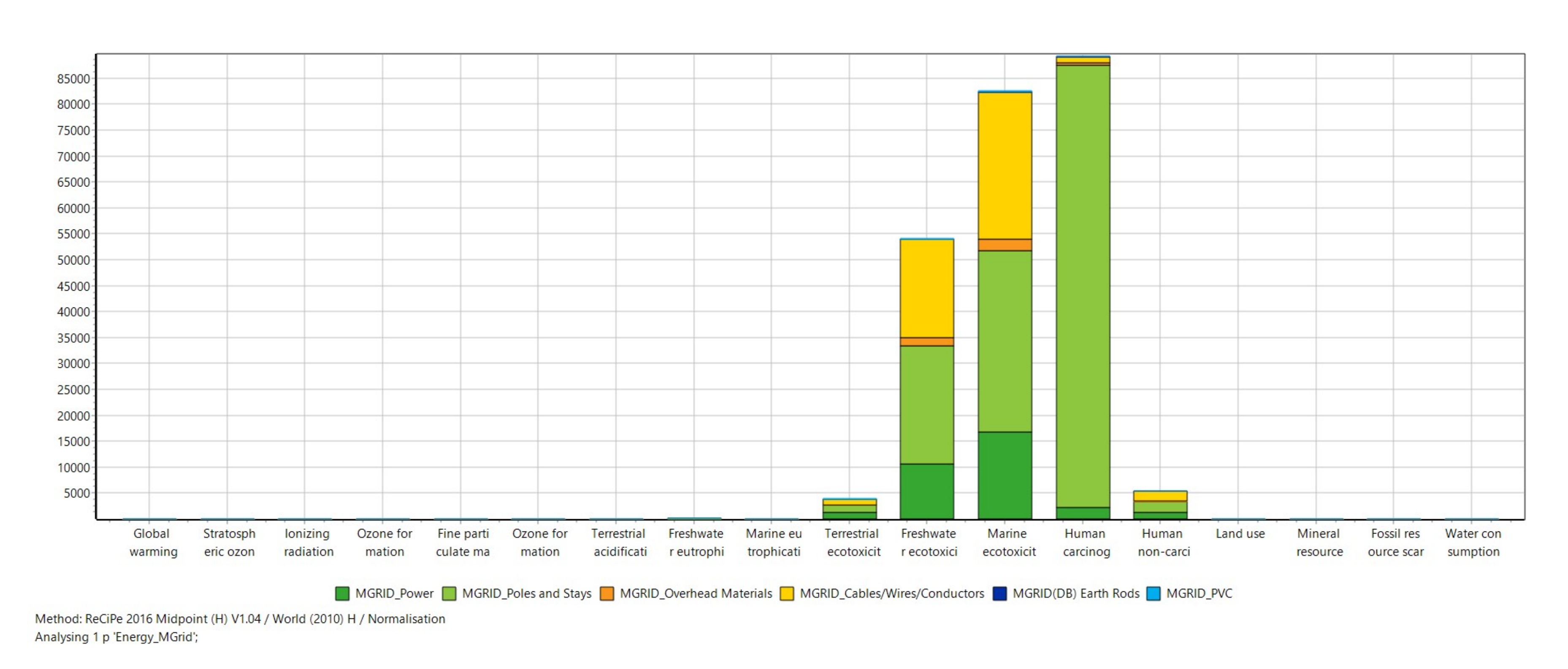
For the poles and stays, it has been shown that concrete may be a suitable alternative material, but further analysis is needed to determine if the transport of concrete poles would outweigh the benefits over locally sourced wooden poles. If local wooden poles are chosen, then a non-chromium based wood preservation process would significantly reduce the impact on human health.

The overall impacts are not unduly sensitive to the panel manufacture, size or life. However, as improvements to the manufacturing technology for PV panels improves, it is sensible to assume that the PV panel contribution will reduce over time.

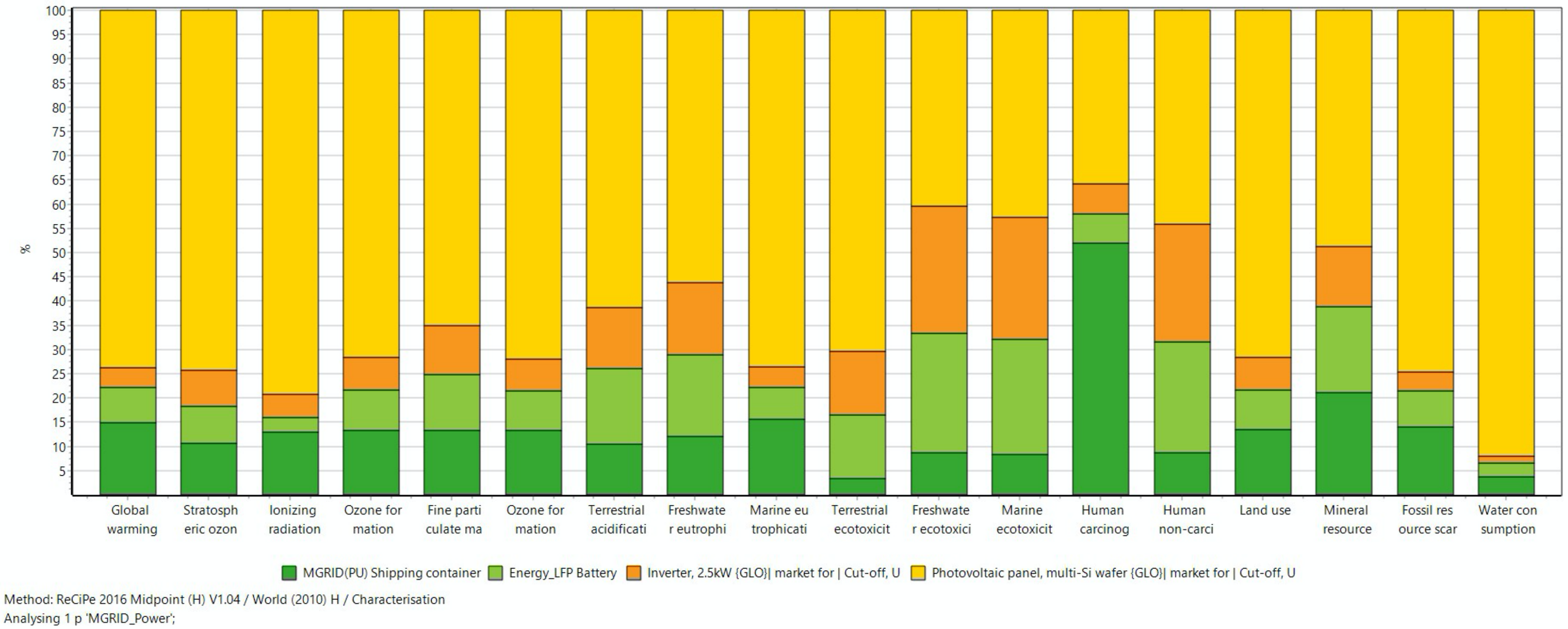
Appendix A



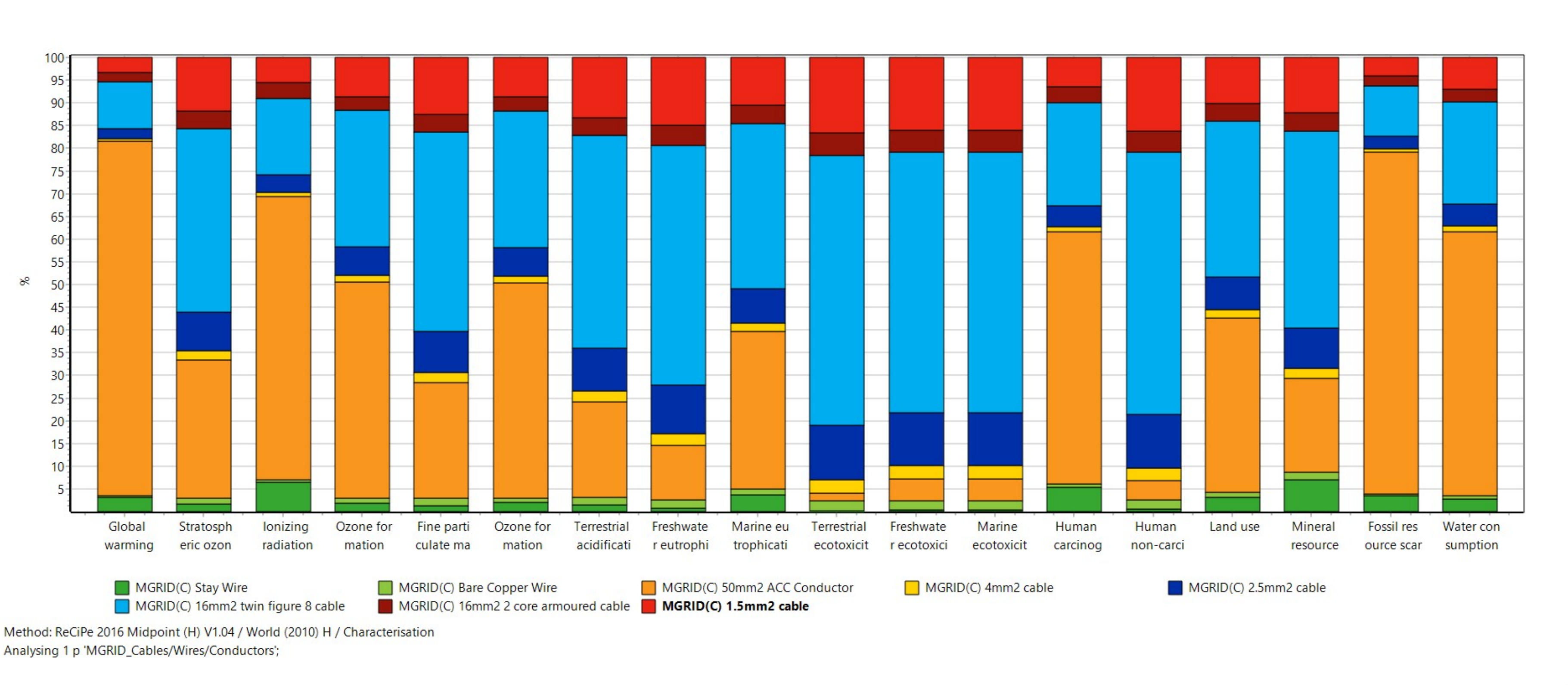
Graph 1: Contribution of main component groupings to environmental impacts



Graph 2: Normalised results (average global impact per capita per year, for the year 2010)

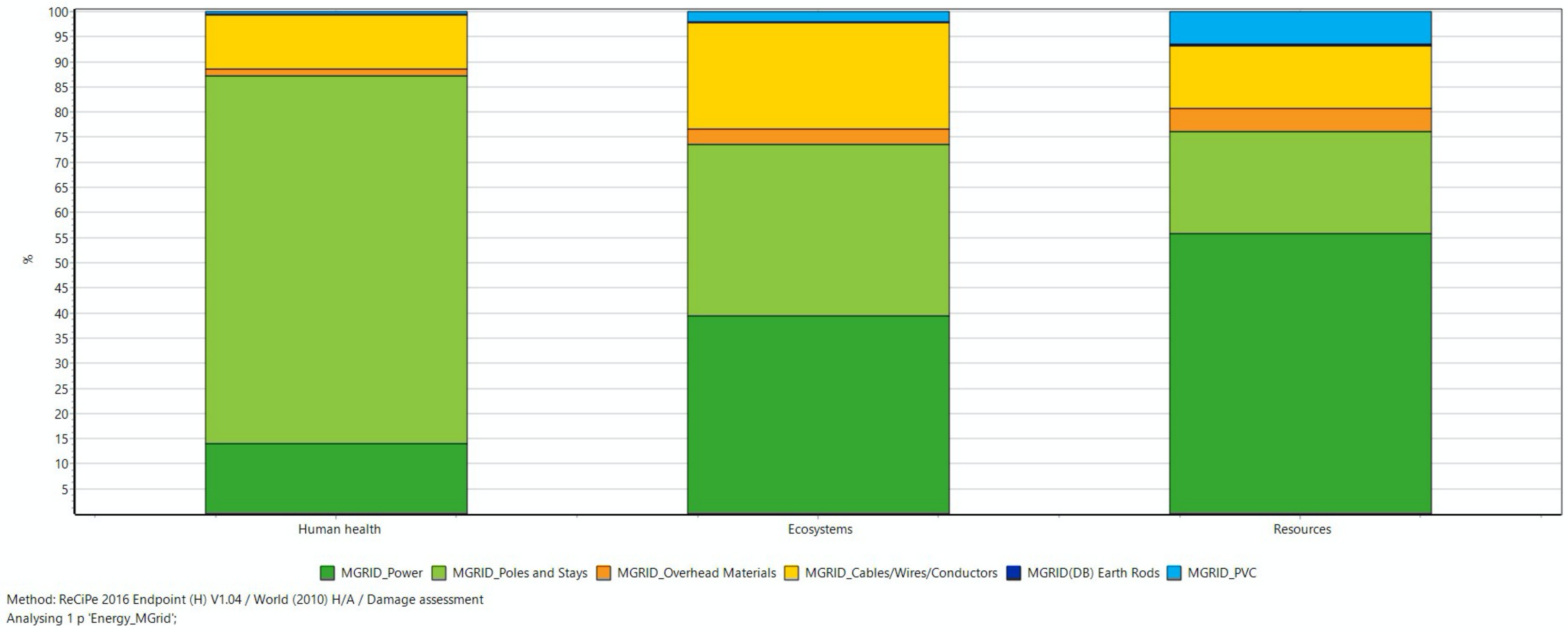


Graph 3: Contribution of main components within the Power component group to environmental impacts

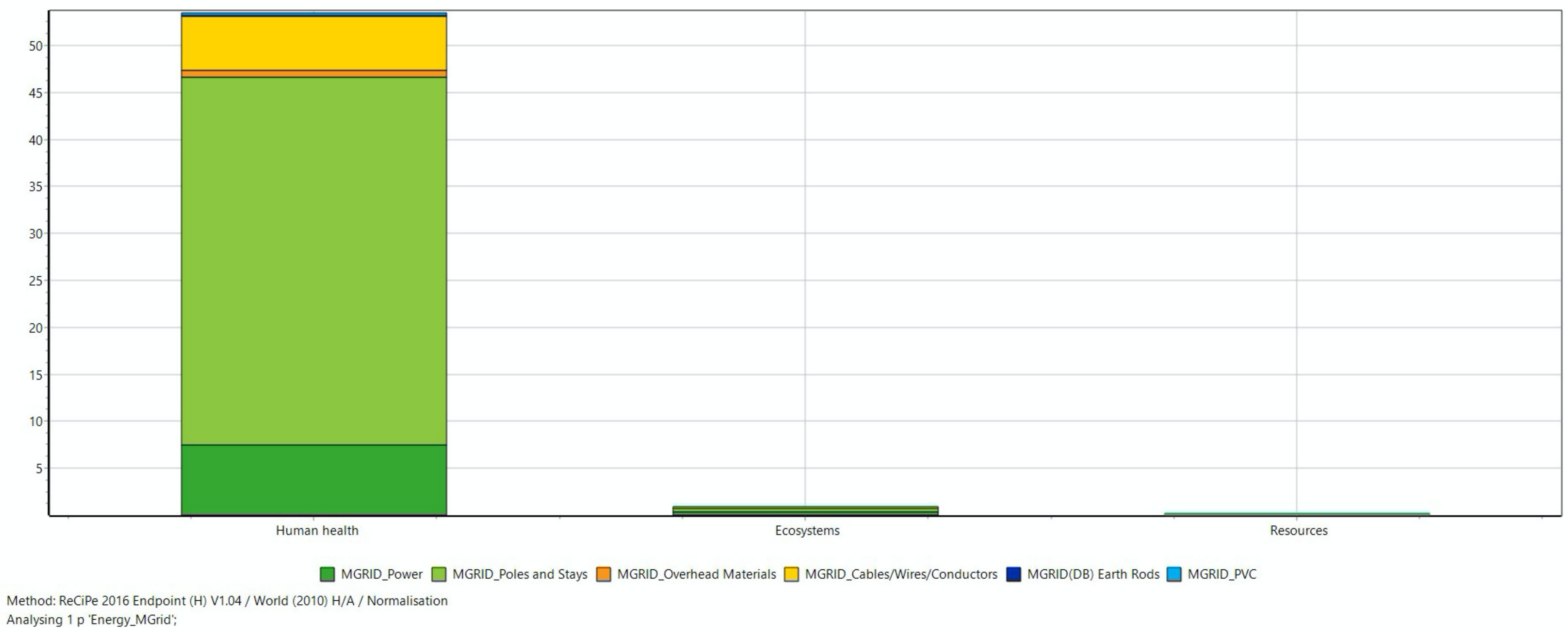


Graph 4: Contribution of main components within the Cables component group to environmental impacts

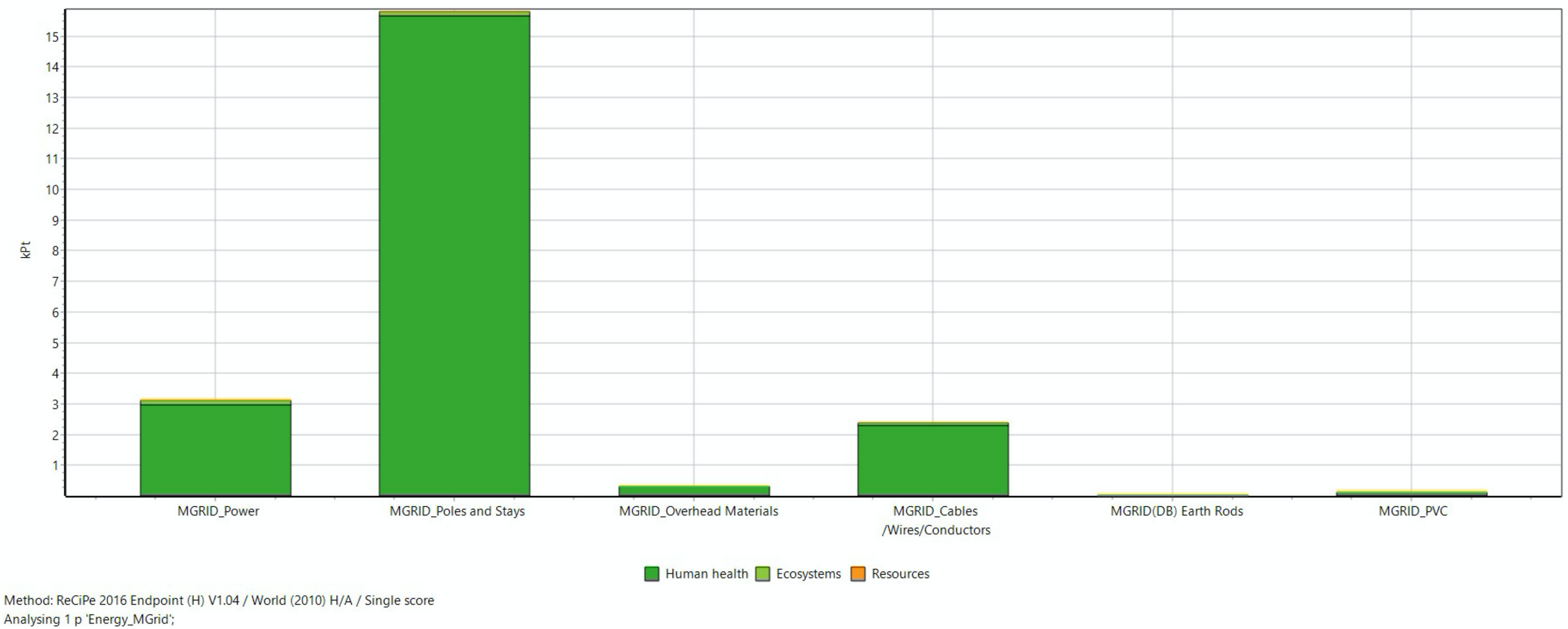
Graph 5: Contribution of main components within 16mm^2 twin figure 8 cable



Graph 6: Damage assessment to human health, ecosystems and resource use for the mini-grid.

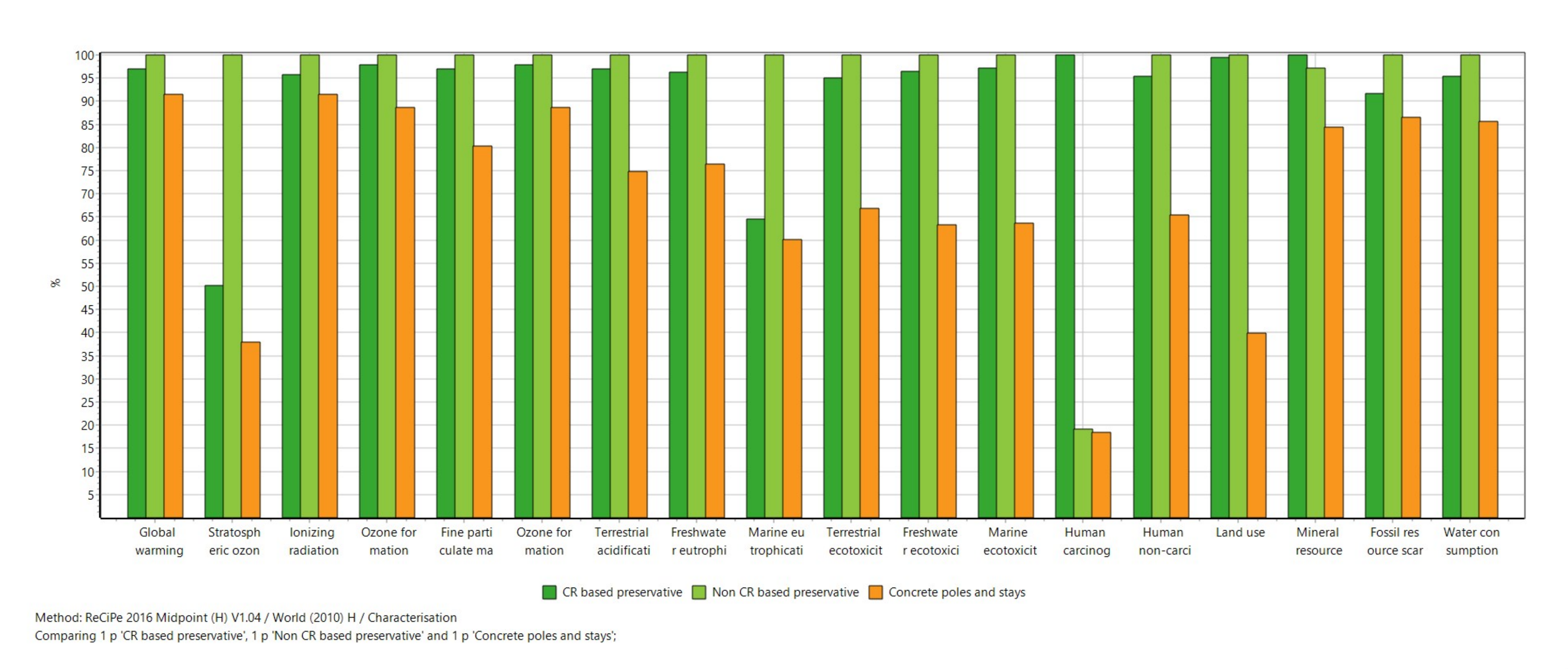


Graph 7: Normalised Endpoint assessment (average global damage per capita per year, for the year 2010 per capita)

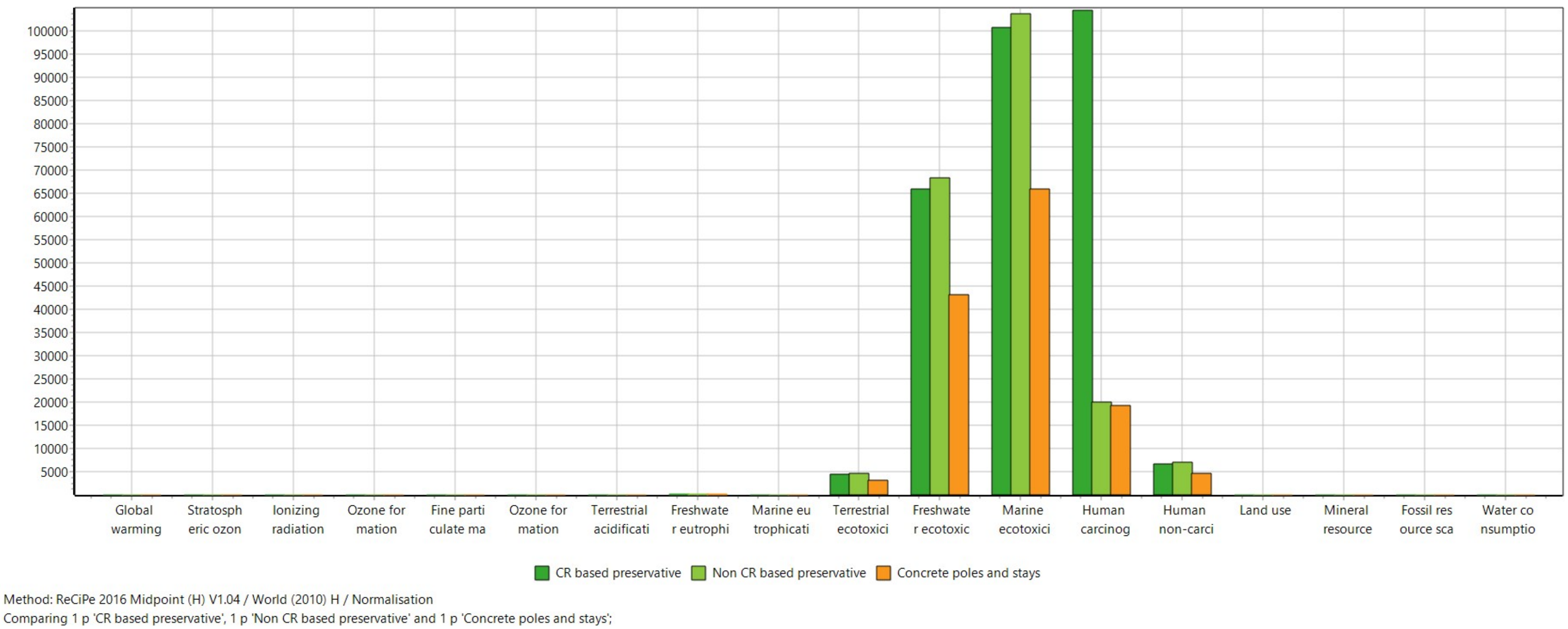


Graph 8: Single Score endpoint impact for each of the component groups in the mini-grid.

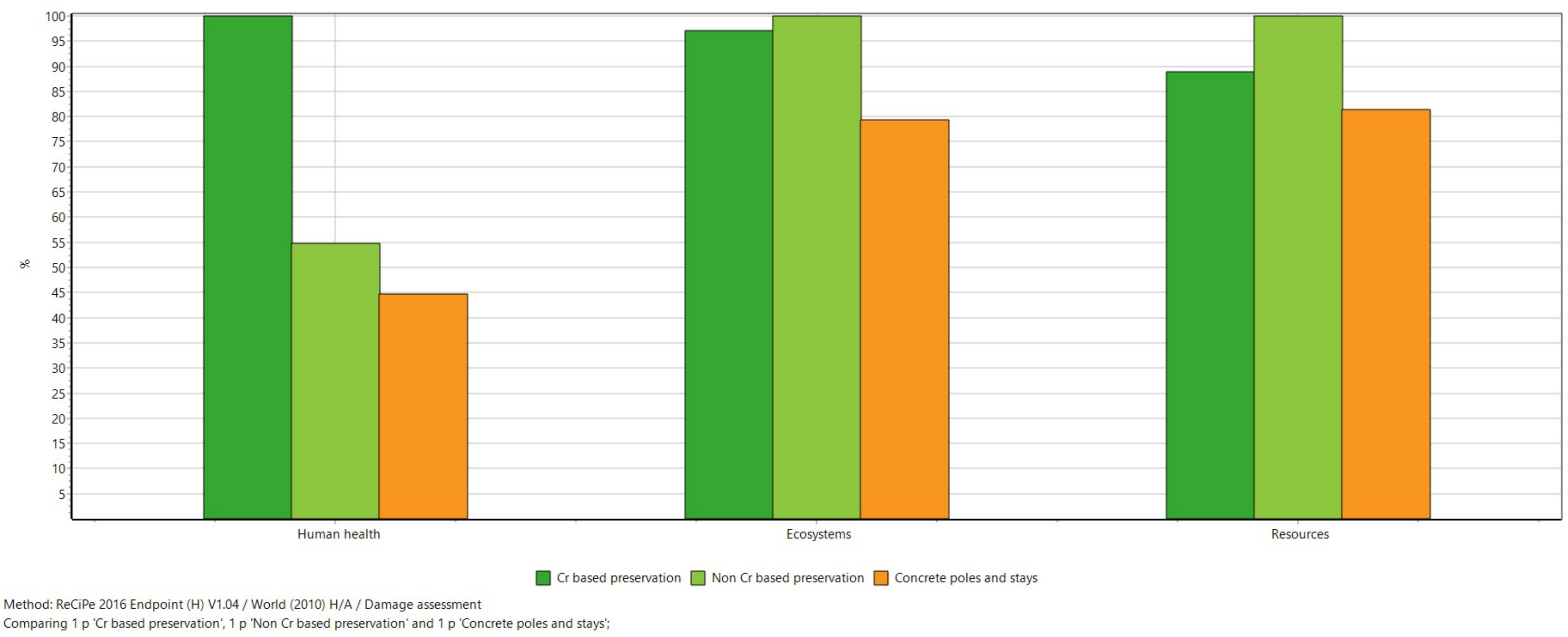
Graph 9: Contribution of main components to environmental impact for poles



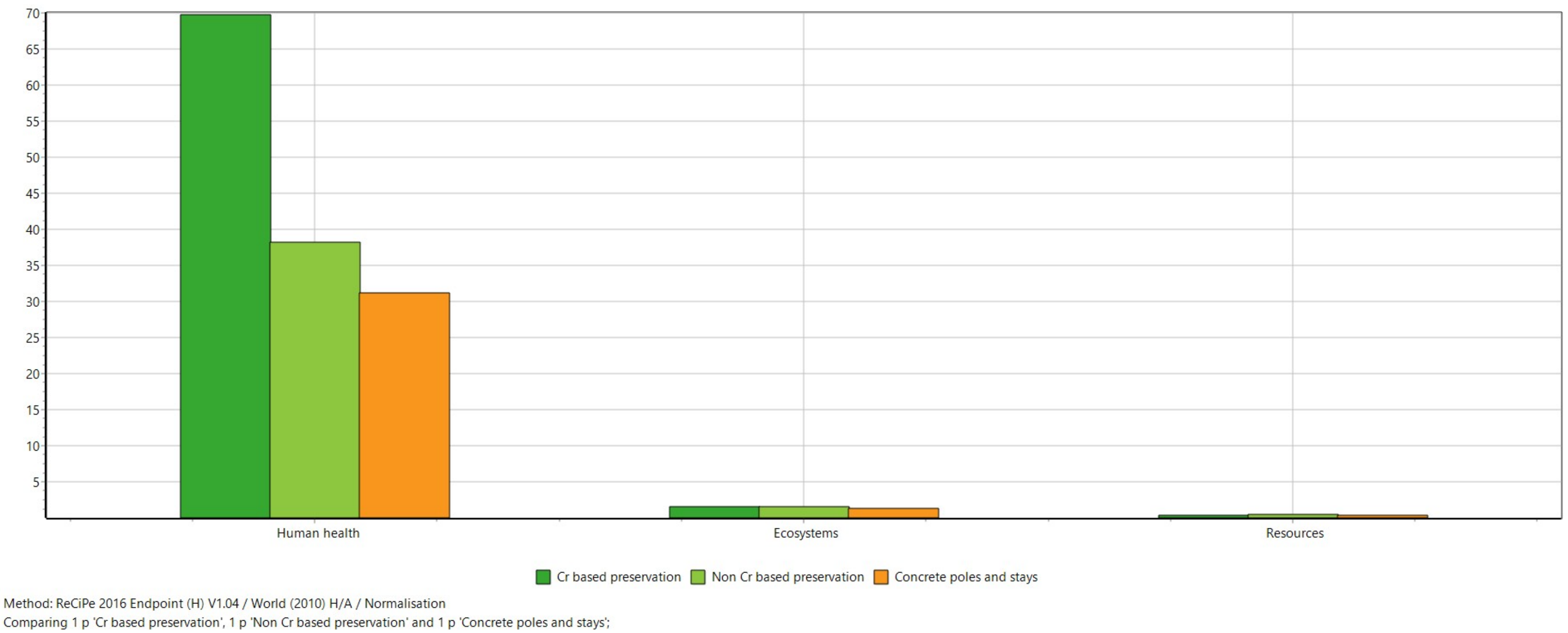
Graph 10: Comparison of environmental impacts for three different pole systems, Chromium based preservative, Non Chromium based preservative and concrete poles



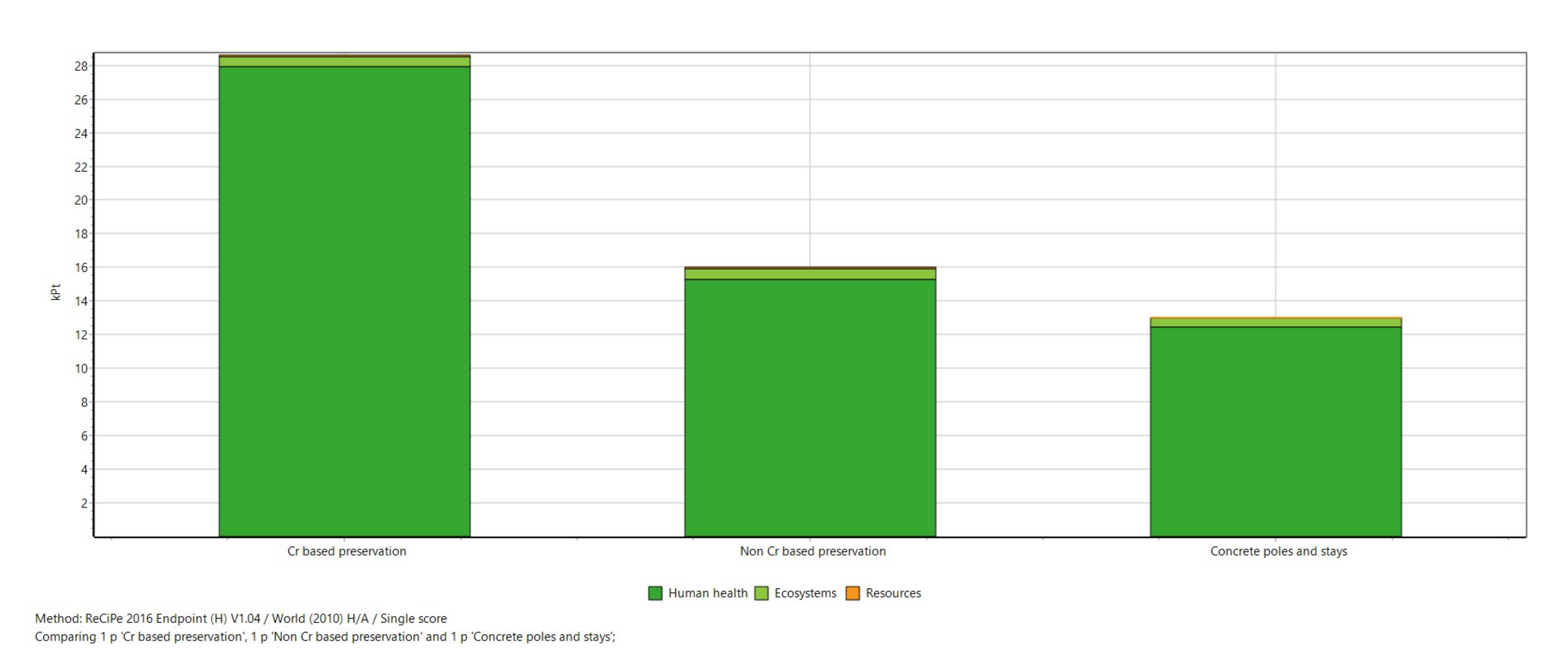
Graph 11: Normalised environmental impacts for three different pole systems, Chromium based preservative, Non-Chromium based preservative and concrete poles (average global impact per capita per year, for the year 2010)



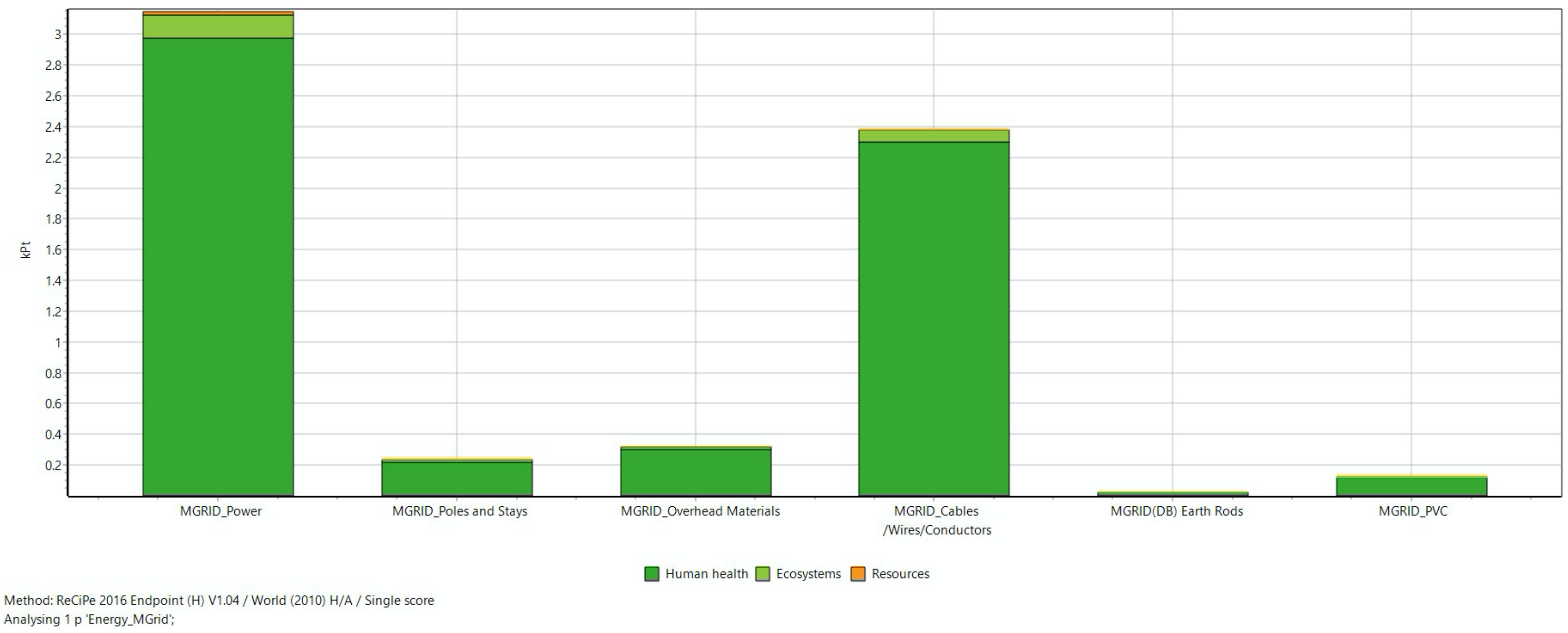
Graph 12: Damage assessment to human health, ecosystems and resource use for the three different pole systems



Graph 13: Normalised human health, ecosystems and resource use for the three different pole systems



Graph 14: Single Score endpoint impact for each of the different pole systems.



Graph 15: Single Score endpoint impact for mini grid system using concrete poles. (compare to Graph 8 to see effect of the change from wood to concrete)

Appendix B

Malawi Mini-Grid BOM					
			OH	House	
Section	**Description**	**Unit**	**Qty**	**Qty**	**Comments / Queries**
Poles					
	9m poles 140-160mm	ea	75		buried 1.5m deep, no concrete
	Stay Blocks	ea	50		standard wooden block with hook, 1m deep
Cables / Conductors					
	50mm AAC Conductor	m	6000		Al core
	16mm Twin figure 8	m	1000		Copper core
	2 x 16mm Armored Cable	m	80		from generation to first poles 2 runs
	Stay wire 7/12	m	500		Steel
	4mm2 Single Core Cable Red 100m	ea		2	Assume copper core
	4mm2 Single Core Cable Black 100m	ea		2	Assume copper core

	2.5mm2 Single Core Cable Red 100m	ea		8	Assume copper core
	2.5mm2 Single Core Cable Black 100m	ea		8	Assume copper core
	2.5mm2 Single Core Cable Green 100m	ea		10	used for earthing
	1.5mm2 Single Core Cable Red 100m	ea		30	Assume copper core
	1.5mm2 Single Core Cable Black 100m	ea		15	Assume copper core
	1.5mm2 Single Core Cable Green 100m	ea		15	Assume copper core
	Bare Copper Cable	ea		10	for generation (OH uses aluminium)
Overhead Materials					
	Bobbin Insulator	ea	100		ceramic
	D-Iron, 2 Bolts, 2 Nuts, 2 Washers, complete with Bobbin	ea	50	60	60 for hoses, 50 for use with poles with angle or junction
	M16x200 GI Bolt, Nut, Washer	ea	48		For the D-iron through pole
	M16x260 GI Bolt, Nut & Washer	ea	100		For the Bobbin through pole
	LV Stay Insulator	ea	100		ceramic
	M16 Stay Rod Complete	ea	50		Steel
	Guy Grip	ea	110		Steel
	PG Clamp 50mm AL/AL	ea	150		overhead line
	PG Clamp 50mm AL/CU	ea	150		house connections
	cable lug 16mm	ea	240		Steel

Distribution Board					
	4-Way Distribution Board			60	
	DB Space Covers	ea		120	
	63A 2-Pole Mainswitch RCCB 30mA	ea		60	2 pole confirmed - low Amps would be better
	5A MCB	ea		60	
	Earth Rod 4ft	ea		60	
PVC					
	20mm PVC Conduits	bundle		18	25 pieces in a bundle
	20mm PVC Couplings	ea		2200	
	20mm PVC Nipples	ea		2000	
	20mm PVC Saddles	ea		800	
	Round Boxes	ea		900	
	Round Box Covers	ea		700	
	PVC Boxes 175x150mm	ea		60	
	PVC Boxes 75x75mm	ea		240	
Electrical Fittings					
	Batten Lampholder	ea		128	ceramic
	LED Bulb 5W	ea		128	indoor light bulbs
	Wall Glass fitting	ea		56	outside light bulb holder

	LED Bulb 10W	ea		56	outside light bulb
	Double Sockets	ea		60	
	Switch 1 Gang 1 Way	ea		184	Every light gets a 1 gang one way switch - option for 2 gang below
	Switch 2 Gang 2 Way	ea		30	enough for half the houses if needed
Consumables					
	Self Tapping Screws 1" 8G for PVC boxes	packet		10	
	Insulation Tape	roll		10	
	Hacksaw Blades	ea		10	
	2" nails	kg		4	
	fisher plugs and screws S10	packets		10	

Note: Lines highlighted in green were included in environmental model

MECS Modern Energy Cooking Services

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Loughborough University

ESMAP Energy Sector Management Assistance Program

UKaid from the British people