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Harrison, R, Eckley, L, Timpson, H, Blickem, C and Van Hout, MC

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**EXPLORING CHARITY WORKER PERCEPTIONS OF THE SOCIAL VALUE AND
SUSTAINABILITY OF SOLAR LIGHTING IN MALAWI, KENYA AND ZAMBIA:
A SCOPING STUDY**

Harrison, Rebecca - Public Health Institute, Liverpool John Moores University

Eckley, Lindsay - North of England Zoological Society (Chester Zoo)

Timpson, Hannah - Public Health Institute, Liverpool John Moores University

Blickem, Christian - Public Health Institute, Liverpool John Moores University

Van-Hout, Marie-Claire - Public Health Institute, Liverpool John Moores University

ABSTRACT

Approximately 600 million people in sub-Saharan Africa have no access to electricity and use kerosene as a source of light. Solar lighting is a safer and cost effective alternative allowing families to study, work and live without the harmful effects of kerosene. Qualitative, semi-structured interviews were undertaken with staff from a United Kingdom (UK) based charity to explore the social value of solar lighting (n=7). These staff were based in the UK, Malawi, Kenya and Zambia. Two overarching themes: '*The Social Value of Solar Lighting*' and '*Improving the Sustainability and Economic Viability of Solar Lighting*' illustrated perceived multi-faceted and wide reaching benefits on the micro-level creating positive social, economic and environmental outcomes. Future studies may look to identify the impact that solar lights may have upon the macro-level, and medium to long-term outcomes; and estimated social return on investment in different developing countries.

Keywords: Solar Lighting, Kerosene, Beneficiaries, Outcomes, Social Value

BACKGROUND

Introduction

The United Nations Sustainable Development Goal (SDG) 7 states that by 2030 there will be universal access to affordable, reliable and modern energy services for all (United Nations, n.d). Currently, between 53% (Lam et al, 2017) and 68% (Rom, Gunther and Harrison, 2017) of the global population of sub-Saharan Africa (SSA) do not have access to live electricity, increasing to 83% in rural households (Rom, Gunther and Harrison, 2017). The SSA population therefore relies on other sources of energy for lighting and power, including fuels such as kerosene and paraffin, with kerosene still seen as the major source of lighting for un-electrified households, as well as those houses that have intermittent access to electricity (Barman, Mahapatra, Palit and Chaudhury, 2017). Solar lighting and energy from solar power is seen as a way of reducing the use of kerosene in rural areas (Mohanty, Dasgupta and Sharma, 2010). Reductions in cost of solar panels due to mass production (KPMG, 2012) also means that *“solar lighting products generally offer better low income energy, a cost-effective and cleaner alternative to the widely used kerosene”* (Amankwah-Amoah, 2014, p19).

Kerosene as a fuel source

The negative health, safety and environmental harms of kerosene upon individuals, families and at a community level have been highlighted in previous studies (Komatsu et al, 2010; Lam et al, 2012; Alstone, Gershenson and Kammen, 2015; Public Health England, 2016; Yaqoot, Diwan and Kandpal, 2015). Kerosene is a combustible hydrocarbon liquid, which is damaging to health. Direct contact with kerosene on skin can cause acute irritation, whilst inhalation of its fumes or smoke can result in symptoms such as coughing and dizziness, leading to possible long-term respiratory illnesses. Ingestion can have adverse health implications from nausea, to loss of consciousness and in severe cases where there is either acute or chronic exposure, death (Public Health England [PHE], 2016). There is also a risk of accidental paediatric poisoning (PHE, 2016). Despite these very real and negative impacts of kerosene, it is still widely used for cooking, heating and lighting in the developing world. Notwithstanding the potential health risks associated with use of kerosene lamps, kerosene is a costly and environmentally harmful product that produces greenhouse gases, contributes to indoor pollution, and represents a serious fire hazard (Obeng et al, 2008; Yaqoot, Diwan and Kandpal, 2015). Hence, the discontinuation of household kerosene use is recommended, alongside an identified need for additional studies to strengthen the evidence base around risks and harms, particularly in the developing world (Mills, 2005; World Health Organisation [WHO], 2014).

Solar lighting as an alternative fuel source

Solar lighting is a potentially safe, cost-effective and clean lighting alternative to kerosene lamps, which also reduces exposure to pollutants, and hence potentially mitigates against the harmful impacts of household air pollution (Pokhrel et al, 2010; Mondal and Klein, 2011; Lam et al, 2017). Solar lighting has the potential to contribute to the achievement of a variety of SDGs, which include good health and wellbeing (SDG 3), quality education (SDG 4), and climate action (SDG 13) (Solar Aid, 2015). Research carried out in Africa and India has highlighted facilitators and barriers to the uptake of solar lights, as well as the myriad of key outcomes experienced by those who use them (Harish, Icyhettira, Raghavan and Kandlikar, 2013; Buragohain 2012; Lam et al, 2017). One of the main impacts of solar lighting is the reduction in the use of kerosene in households and the cost savings

associated with this (Harish et al, 2013; Mondal and Klein, 2011; Buragohain 2012; Lam et al, 2017; Rom, Gunther and Harrison, 2017). A recent randomised controlled trial (RCT) conducted in rural Kenya provided insights on demand, usage and impact of solar lighting on 1,400 households when sold at market price, at subsidised prices, and given out free (Rom, Gunther and Harrison, 2017). Households who purchased or were given a solar light used it as a replacement for a kerosene lamp, which allowed for a maximum cost saving of 2.5% of their total cash expenditure due to reduced outgoings for kerosene purchase (Rom, Gunther and Harrison, 2017). Similar cost saving outcomes when replacing kerosene with solar lighting are found in research carried out in India (Harish et al, 2013). Replacing kerosene lamps with solar lamps reduces air pollution (Pokhrel et al, 2010; Mondal and Klein, 2011). Specific research has shown reductions in particulate matter 2.5 (PM2.5) and carbon monoxide (CO) levels of parents and children (Lam et al, 2017; Muyanja et al , 2017); with solar lamps displacing most kerosene lamp usage at one month follow-up (Lam et al 2017).

The use of solar lighting as a '*connector*' or enabling connectivity in rural areas (Jacobson, 2007) occurs in a number of different ways. Higher quality light and more hours of light in the evenings (Mondal and Klein, 2011) has the potential to encourage increased socialisation of families and communities (Jacobson, 2007), as well as communication through being able to charge mobile phones (Jacobson, 2007; Komatsu, Kaneko and Ghosh, 2010). In addition, solar lighting may also support widening opportunities for businesses with additional income generation through extended working hours and mobile phone charging (Mondal and Klein, 2010; Barman et al, 2017). Jacobson (2007) suggests that education related uses of solar lamps by children and teachers are a key application of this technology and acknowledges the potential and far reaching longer-term social and economic impacts. Studies report mixed outcomes with one study suggesting that there is an increase in children's light use, but no significant change in children's study time (Rom, Gunther and Harrison, 2017), and others reporting a positive impact on study time (Barman et al, 2017; Mondal and Klein, 2011).

Despite these positive impacts, a number of barriers to the use and uptake of solar lights are identified in the extant literature. The most common relate to unit pricing and sustainability. The uptake of solar lights has been shown to be more likely when offered at a discounted price (Rom, Gunther and Harrison, 2017). Research carried out in India has highlighted that those living in rural households may choose to take out loans from rural banks to purchase solar lighting, for access to and in response to unreliability of grid electricity (Icyhettira, Raghavan and Kandlikar, 2013). Solar lighting has also been identified to have limited sustainability (Barman et al, 2017) associated with poor maintenance. '*Pico-solar*' lamps use light emitting diodes (LEDs) and are powered by batteries recharged with solar photovoltaic cells. They have limited use for lighting and are mainly used for the charging of mobile phones. These issues, along with high initial outlay of costs and lack of consistent financing available reduces the value and viability of the present technology in solar lights (Harish et al, 2013).

The many benefits of using solar lighting instead of kerosene may be initially observed at the micro-level, but have the potential to extend to the macro-level (Komatsu, Kaneko and Ghosh, 2010). A review of specific documents and databases carried out by Eckley et al, (2014) highlighted a number of key beneficiaries and actual / potential outcomes associated with the use of solar lighting (see **Table 1**).

Table 1: Key beneficiary groups and outcomes identified from document and database analysis

Beneficiary stakeholder group	Outcome	Actual or potential benefit
General/all customers	Financial savings	Actual
	Better overall health / health improvements	Actual
	Providing jobs and business opportunities	business opportunities (actual); jobs (potential)
Children (general)	Increased study hours	Actual
	Increased or improved performance in school	Actual and potential
	Better aspirations and developing higher expectations around education and employment seeking	Actual
	Improved reading and writing skills	Actual
	Increased attendance, motivation and concentration in class	Actual
	Reduced tiredness in children attending school	Actual
	Improved health and psychological wellbeing of students	Actual
Environment/local community	Overall improvements in air quality (reduced pollution from smoke)	Actual
	Reduced risk of fire	Actual
	Increase/improved social activities	Actual
	Increased safety	Actual
Families	Improved general wellbeing	Actual and potential
	Perceived improved standard of living	Actual and potential
	Socialising and Family connectivity-	Actual
	Leisure and Household Time	Actual
Healthcare system	Financial savings	Actual
Health workers	Work-related safety	Actual
	Safety during travel	Actual
Local/wider economy	Financial savings-	Actual
Patients	Quality of care for patients	Actual

Source: Adapted from Eckley et al, 2014)

The UK-based, international charity involved in this study provides clean, affordable solar lights to deprived communities in Africa. At the time that the study took place, they were working in four countries in Africa - Kenya, Malawi, Tanzania and Zambia (see **Figure 1**), providing solar lights which are sold through the charity's social enterprise, which also supported local entrepreneurs in these countries to develop a business selling solar lights, which supports the local economy. Once successful, the social enterprise then focuses on developing the model in another region.

Whilst the impact of solar lamps may be evident in the literature, this study aims to highlight the missing components, primarily from the perspective of holistic considerations of impacts/outcomes and key beneficiaries

Figure 1: Map of Africa highlighting the areas of Kenya, Malawi, Tanzania and Zambia



METHODS

The Public Services (Social Value) Act 2012 highlighted the importance of public bodies being able to evidence how they improve the social, economic and environmental wellbeing of an area or community. The design of this study was informed by a social value framework approach (Social Value International & Social Value UK, 2016) that attempts to begin measure the wider benefits and value of commissioning or spending on customers, communities and the public.

This qualitative study focussed upon establishing the potential scope of solar lighting provision in African countries, and identifying key beneficiaries for solar lamps in the chosen countries, Malawi, Kenya and Zambia. The research also began to explore, from the perspective of charity workers, the potential outcomes (these outcomes may be positive or negative and intended/expected or unintended/unexpected) and wider impacts that may occur. This study utilised the perspectives of the employees of the charity/social enterprise selling solar lights in Malawi, Kenya and Zambia to reduce the use of kerosene. Ethical approval was granted by the LJMU Research Ethics Committee.

As part of a wider study, this paper focuses specifically upon the qualitative interviews that were undertaken with seven charity staff (four males and three females). Those interviewed included: two staff from the UK based charity who provided context to the charity and the solar lights programme; and five people involved in the social enterprise associated with the charity based in Malawi, Kenya and Zambia who's roles included: field staff who focussed on selling solar lights; members of the charity/social enterprise research team; and individuals involved in running a school campaign. A purposive sampling strategy was adopted (Bowling, 2014), with participants of the study being purposefully selected.

The interview schedule was semi-structured in order to achieve optimum use of the interview time and so that topics could be explored in a systematic way (DiCicco-Bloom and Crabtree, 2006). Interview questions were based on a mapping exercise of extant literature on solar lamps in developing countries (Eckley et al, 2014). Participants were asked a number of key questions relating to solar lights that enabled the researchers to explore how solar lights were received within African communities and the potential outcomes experienced by those using solar lights when compared to other fuel sources. The interviews were undertaken by the researchers and were recorded using a Dictaphone in order that the interview data could be captured effectively (Jamshed, 2014) and lasted between 9.25 and 17.24 minutes. Transcripts were coded for anonymity.

Interviews were transcribed and thematically analysed to generate key themes or patterns that emerged from the interview data. Two overarching themes emerged from the data analysis; '*The Social Value of Solar Lighting*'; and '*Improving the Sustainability and Economic Viability of Solar Lighting*'. Higher-level abstraction revealed that purchase and use of solar lighting in the SSA region was perceived across the theme levels to support better overall quality of life and health and wellbeing. All raw data were reread with these abstract concepts described by participants in distinct ways, for example, having solar lighting provided people with better opportunities, such as improved financial stability, improved educational attainment, and better social interaction and relationships.

RESULTS

Theme One: The Social Value of Solar Lighting

Interviewees described how the beneficiaries of the solar lights included individuals, households, families, communities, small enterprises and the local community/wider environment itself. **Table 2** summarises the findings of the interviews illustrating the key beneficiaries and perceived outcomes of solar light use in Malawi, Kenya and Zambia. The researchers acknowledged that Zambia, Malawi and Kenya were very different countries; however, beneficiaries, outcomes and impacts were consistently identified across all of the participants despite the geographical differences. It was also acknowledged that some outcomes might create a chain of events so that there may be future, more significant, social impacts that cannot yet be captured yet. For example, an outcome of improved health may lead to a potential future impact of individuals being less reliant on medical interventions/services/medication (this has long-term impacts that are possibly greater for children than adults) as well as higher productivity and less time off work. Whilst education is very important for children and families in these African countries, therefore having access to clean, safe lighting may increase the amount of time students spend on study in the evening. Whilst this is an important result for scholastic achievements, there are intermediate

and long-term outcomes that may signify a higher social value, such as the ability to move on to further education and/or secure a better job.

Table 2: Key beneficiaries and perceived outcomes of solar light use in the SSA region, identified by interviewees

Beneficiaries of solar lighting in Malawi, Kenya and Zambia	Outcome
General/all customers	Improved health
	Improved wellbeing including feelings of safety
	Better communication/socialisation
Local community/ environment	Redirection of finances not spent on kerosene (food/household items)
	Improved local air quality
Schools	Redirection of finances not spent on kerosene (school fees)
	Better attendance of students at school
Children	Increased study hours leading to better educational performance
	Increased aspirations
Families	More family time and socialisation
	Redirection of finances not spent on kerosene (farming inputs and/or businesses)

Communication and connectivity

Generally, the use of solar lights was viewed by interviewees to encourage and improve social relationships, with one individual stating that there was the perception from customers that they felt more developed at an individual or household level in terms of their standard of living because they have access to this form of lighting.

“[there is the] Perception that they feel more developed, important, when people say ‘it feels like we’re living in town’ because the electricity’s that bright...they have an awareness of development, of improvement.” (P 1 - UK)

Solar lights were observed to enable people to spend more free time together as a family, as well as being able to interact with community social networks more often because they had bright light available. It was also seen to improve social networking and overall communication because people were able, for example, to use the solar power to charge their phones and listen to the radio. This increase in social connection was considered a very important benefit of the solar lights often overlooked by those actually using the solar lights.

“What we’ve found is a lot of customers telling us that they use their solar lights for just sitting around and talking in the evening or being able to spend time as a family and that’s a really important if often overlooked benefit of having [solar] lights.” (P7 - UK)

“With technology, most of the solar lights also have other components like phone charging and radio, so it means there are much more benefits that the community is getting when they get solar lamps like the ones that we are selling which have a phone charging element everyone needs access

to better communication. There are phones in the community, but where do they charge them they have to walk long distances or pay extra money. So apart from just lighting it brings other necessities that the community needs like phone charging and radio, so better communication and information sharing.” (P6 – Malawi)

Education as a key application of solar technology

All stakeholders suggested that the solar lights were predominantly used for child study because of the way in which the lights were marketed and distributed via a campaign that promoted the solar lights through schools. This campaign worked alongside schools through the Ministry of Education in specific regions in Malawi, Kenya and Zambia.

“What we have seen from our schools campaign, is that for people in Africa, education is an investment, so solar is being used mostly, so around 80 per cent of the sales that we get it’s solar lights being given or purchased for the students to use at home.” (P5 – Kenya)

There were a number of positive outcomes reported by head teachers and customers. One stakeholder illustrated how such lamps had improved educational quality overall by helping teachers and pupils.

“Educational quality at both ends, so for teachers – they are given lights as well so that they are able to plan lessons better – and students.” (P1 - UK)

Children were generally seen to be more motivated to study when solar lamps were available. They spent longer studying, attended school more often and had better concentration. Previously, kerosene would have provided limited light to study after dark. Cost implications studying by kerosene light were also reported.

“...children are studying together more, so studying in a group around a solar light and I don’t know if that’s just because solar lights give off more light or because people are motivated to study with the light there. And these are only really early observations, but I think that’s really exciting.” (P7 - UK)

Cost savings

It was felt by all stakeholders that kerosene was very expensive (taking up to 25% of a household’s income) with fluctuating prices due to poor availability and sales on the black market. After an initial outlay, it was suggested that solar power was cheaper as there was no regular outgoing of family or individual funds (just one payment for the solar light). Stakeholders described how data collected by the UK based charity suggested that the money spent on a solar light could be recouped in up to 12 weeks.

“The biggest one and the most direct one customers talk about the most is the savings they make, so [the customers] purchase the light then they can recoup the cost of that lights quite quickly within

12 weeks, so yeah it's a big investment but after 12 weeks all of that extra income is total savings."
(P1 - UK)

"The return on investment when you buy Pico solar lights should be mostly one or two months, rather than buying kerosene, which has a lot of harmful effects and then it doesn't have any return."
(P5 – Kenya)

The money that the solar lamp customers no longer spent on kerosene was now spent on necessary items, such as food, education, transport and business. This additional income was viewed as greatly improving their quality of life.

"So families can reduce whatever method it is that they've been using before, so batteries for torches or kerosene for lamps. And so once the solar panels are there to charge from the light that money's not being spent on lighting and their savings are spent on food, educational costs (school fees, books, uniforms) and farming inputs, business development (such as a market stall)." (P1 - UK)

Improvements in health

When discussing specific negative health related outcomes a number of common health complaints were described with the use of kerosene, including sore eyes, coughs and lung complaints such as chest infections, and kerosene poisoning.

"...also for the small kids at home because for some reason people decide to keep kerosene in a soda bottle, I don't know why, so you can get a kid taking a soda bottle and trying to drink it thinking it's water." (P5 – Kenya)

All stakeholders stated that self-reported improvement in health was common amongst those who had purchased solar lights. One also highlighted that families were saving money because they were not spending as much money on medicines because they did not have as many health issues (related to kerosene use) which needed to be treated.

"...where families have stopped using kerosene they have reported less coughing in the house, fewer/less chest problems." (P1 - UK)

The Wider Environment

It was suggested by most stakeholders that the impact of solar lighting upon the wider environment was not necessarily something that was reflected on at a household level by those people who had bought the solar lights. From an organisational level, many acknowledged that solar energy was a 'clean' form of energy that has a global impact as it indirectly reduces (through the reduced use of kerosene) CO₂ emissions that contribute to greenhouse gases. It was also highlighted that a reduced use of kerosene has an immediate impact upon the local environment and levels of air pollution in terms of reduced smoke (which contains black carbon and CO₂). Stakeholders

generally reported that solar lights provided instant, brighter light and made people feel more confident and safer. For example, nearly all described the reduced risk of house fires related to kerosene and associated impact on homes and families. Two stakeholders stated that the lights also assist people to see potential threats such as snakes as the solar lamps were used as torches to check livestock after dark.

“Kerosene and candles are a big fire hazard, with poor light they can’t see what they’re doing. They are more confident and feel safer having this [solar] light.” (P1 - UK)

“...villages burning due to falling down of kerosene lamps causing death of children especially, loss of property.” (P2 – Malawi)

Theme Two: Improving the Sustainability and Economic Viability of Solar Lighting

Awareness and trust in the Solar Lamp product

It was highlighted by all stakeholders that because solar lighting technology and its products are relatively new, there are counterfeit, poor quality products on the market, meaning that consumer trust is an issue. One stakeholder also stated that there was mistrust because community members think the lights should be free and that someone is trying to make a profit from selling solar lights.

“So they really are very integral to everything we do because we’ve found that the main barrier we had when we first started trying to sell solar lights was trust in the product, affordability is a problem, availability is a problem, but actually even once you get in to a community for someone who has been using kerosene all their life and they need to make a big investment in the solar lamp. It’s a huge debt to make, but by seeing a trusted figure in the community use the solar light and advise that they should also use them, we are kind of breaking that barrier of trust. So they really are very, very integral to our model.” (P7 - UK)

Within the school campaign, head teachers who are generally well respected and trusted community members, were used as a vehicle through which to promote and increase knowledge and trust in solar lamps. Hence, stakeholders emphasised that recommendations and referrals are important to raise awareness and enhance the reach of the solar lighting market to all communities. The initial wave of beneficiaries buying solar lights through the school campaign sometimes recommended the product, and encouraged others to buy a unit. This was supported by follow up deliveries of solar lights to the head teachers from the social enterprise that were conducted at regular intervals. Entry level lights were very popular as they were most affordable. Follow-up sales were also provided for those people who were interested in buying a solar light, but needed additional time to save.

“We use head teachers as we want to promote the solar light as an educational tool, but they are also well respected and trusted members of the community. They are a good access point and also a good way of educating people and raising awareness as some people have never seen the lights before.” (P1 - UK)

Overall it was highlighted by stakeholders that in order to widen the availability of solar lamps to African communities, there was a need to raise awareness of the technology, the products available, and the range of positive social and health related consequences for individuals, families, households and communities of solar light, in comparison to that of kerosene. This was considered to be of particular importance in rural areas.

“The demand is there, but awareness is a challenge...In general people want and like solar lights. They do understand why they need them. So we need to raise awareness as most people don’t realise/don’t believe there are other alternatives out there.” (P6 – Malawi)

“...maybe the level of awareness for solar lights needs to be increased as it is low in rural areas and it gets lower the further you go in to more rural settings. That’s where you find the response to the lights gets even more positive as people are looking for one option for lighting.” (P3 - Zambia)

Word of mouth was considered very important in raising awareness and also encouraged people to purchase solar lights. It was highlighted that once customers had bought one light, many went on to buy more. In addition, where there was possible doubt about the efficacy of the product, for example, with the ‘Pico’ lights and the amount of light produced, once customers had purchased a light, they could see how they worked and were encouraged by this.

“...there is one response that cuts across most respondents [customers]...most of them are surprised and a little bit impressed with the lights. They are impressed by it and develop an interest, and I haven’t met anyone who has been shown the light and has had a negative response to it.” (P3 – Zambia)

“...because of word of mouth there is a tendency of [mis] trust in the product where actually they don’t know if this is a true product, but if they see a neighbour with this light then they say ‘wow, I want to buy this, where can I get it?’ so they tell them where they get it from....anything up to 50-60 per cent of sales are from people who are buying because of word of mouth.” (P5 – Kenya)

Availability, Pricing and Timing

One stakeholder suggested that customers and potential customers required access to the social enterprise team on a more permanent basis, or at specific time of the year. In response to this, improvements were being made with the introduction of the solar lamp agent network, which enables people in the community to sell the lights. This would have direct benefits in terms of sustainable livelihoods and the related SDGs.

“One of the common requests is that they want us to be there in the community all the time for that they want us there at a specific time of year, for example, during harvest time as that’s when the families have a lot of disposable income; whereas if you’re going at a different time of the year they’re just never going to be able to have that income to hand. So that’s another one of the biggest barriers.” (P7 - UK)

All agreed that the cost of the lights was still seen as a huge barrier, as purchasing one required people to make a significant initial investment (\$10USD for an entry-level light). This is money that they may not necessarily be able to spare (even though in terms of comparing to cost of kerosene it is cheaper in the long term).

“...I think there is a different culture around savings than you might have in a developed country, so it’s not often easy and again that’s why it’s important teaching and raising awareness about solar lights and why it’s good to buy one and then people understand that they will save money in the long run because when you’re living without savings it’s not something you think about every day.” (P7 - UK)

However, it was highlighted by one stakeholder that different and flexible ways of paying were being explored, such as ‘pay-as-you-go’ technology.

“..we only have a small percentage uptake, but we’re doing lots of work to explore pay-as-you-go technology, that will enable people to pay by weekly instalments or monthly instalments that will enable them to not have to pay out more than they would normally pay on kerosene each week.” (P7 - UK)

It was also suggested that if the solar lights were a product that the individual/families really wanted they would find the money from somewhere.

“..if it’s something they value and truly want they will find the money from somewhere.” (P7 - UK)

DISCUSSION

The study presents an initial insight into charity stakeholder views on the social value and sustainability of provision and sale of solar lights to communities in Malawi, Kenya and Zambia. Whilst this article reports many of the same barriers and successes as previously identified in the literature, it also identifies some key approaches to overcoming them.

We recognise that limitations of the study centre on its small-scale nature, and the sample of those employed by a charity with vested interest in promotion and sale of solar lamps in developing countries. We also acknowledge that the study did not seek to engage with those in the local communities where the solar lights were for sale. However, this is an important process to be carried out when following a social value methodology approach – that is the value of interviewing these types of stakeholders in order to understand and evidence outcomes (Social Value International & Social Value UK, 2016). The narratives described here support the analysis provided by this study and develops upon additional findings elicited within a previous review (conducted by the same authors (reported in Eckley et al, 2014). It also illustrates a host of beneficiaries of solar lamps (children, adults, families, households, communities, and teachers), the benefits pertaining to environmental, health, education and social value, and the complexities in encouraging purchase in poor African communities.

Firstly, solar lighting was perceived to provide a cleaner, safer and cost-effective alternative to kerosene with no installation or maintenance requirements (Lam et al, 2017; Mohanty, Dasgupta and Sharma, 2010). The cost savings of using solar lights compared to kerosene, and the benefits of this are illustrated by our study and have been highlighted in the literature (Harish, Icyhettira, Raghavan and Kandlikar, 2013; Mondal and Klein, 2011; Buragohain 2012; Lam et al, 2017; Rom, Gunther and Harrison, 2017). Narratives in our study highlight that whilst there was an initial outlay for the purchase of the solar lights, anecdotally individuals, households and families now had more disposable income to spend on food, medication, education, transport and business. This was considered to have positive impact upon health, wellbeing and quality of life of solar lamp users (Obeng et al, 2008; Komatsu et al, 2010; Lam et al, 2012; Alstone, Gershenson and Kammen, 2015; Public Health England, 2016; Yagoot, Diwan and Kandpal, 2015).

Secondly, our study is aligned with those that report on environmental impacts of using solar lights in terms of reducing levels of particulate matter and carbon monoxide levels in households (Pokhrel et al, 2010; Mondal and Klein, 2011; Lam et al, 2017; Muyanja et al , 2017). The importance of solar lamps as an environmentally friendly alternative was viewed at an organisational rather than personal level in this study, with charity staff seeing solar lighting as a '*clean*' energy that has the potential to create great impact on a global scale. It was also reported that customers and owners of solar lights felt safer (both in terms of going out at night and also relating to safety issues such as fire related to use of kerosene).

Thirdly, and perhaps most importantly for African communities, solar lights are viewed as a '*social connector*' (Jacobson, 2007; Komatsu, Kaneko and Ghosh, 2010; Mondal and Klein, 2011). Having solar lights was deemed to improve social relationships and improved channels of communication (using solar power to charge phones and play radios). Our study highlighted education as a key application of solar light technology (Jacobson, 2007), with perceived benefits not only for students but also for teachers, leading to improved overall quality of education – e.g., teacher preparation time for lessons, longer study time for students (Barman et al, 2017; Mondal and Klein, 2011), and studying in groups (educational and social outcomes).

In terms of raising awareness of solar technology and solar light products in Malawi, Kenya and Zambia, the initial purchase of solar lights appeared dependent on cost, trust in the organisation selling the product, consumer trust due to variety of products available. When introduction to the product was facilitated by trusted members of the community, the trust in the product grew quicker, which could lead to repeat purchases based on satisfaction, and flexible purchasing methods. Word of mouth proved the most successful way of raising awareness of the lights; with many customers returning to purchase more once they had seen them in use for themselves. This adds to existing literature on this topic. The campaign that was run through schools increased knowledge and trust in product. Many myths (regarding quality of the light) were dispelled once the lights had been seen in communities, which led to more sales. Barriers to purchasing were underpinned by low awareness of the solar lights; the variety of lighting products available; the initial outlay of the solar lights; and trust in reputable /genuine products. Previous studies also highlight pricing and sustainability as barriers to purchasing (Harish et al, 2013; Rom, Gunther and Harrison, 2017; Icyhettira, Raghavan and Kandlikar, 2013; Barman et al, 2017).

Despite the small-scale nature of the study, findings are encouraging and span the micro and potentially macro level impacts of social lamp provision in Africa (Komatsu et al, 2010). Provision of light in a way that is environmentally friendly, safe in terms of health, can only boost individual, child, family, household and community level connectivity and social cohesion, and in so doing, significantly contribute to the attainment of SDGs including good health and wellbeing (SDG 3), quality education (SDG 4) and climate action (SDG 13) (Solar Aid, 2015). Some of the perceived outcomes identified in this study may also create a chain of events so that there may be future, more significant, social, economic and environmental impact that cannot yet be captured.

CONCLUSION

Solar lighting provides people in Africa with better opportunities, such as improved financial stability, improved educational attainment, and better social interaction and relationships. Purchase and use of solar lighting was perceived to support better overall quality of life and health and wellbeing, socio-economic benefits, and socialisation within and outside of the family. This study adds to the literature by bringing together the perceived outcomes from the perspective of each beneficiary and includes a range of stakeholders. Other studies have focussed solely on one aspect and/or one group, lacking references to the wider impacts (e.g., health, education, environmental, social).

Future studies may look to identify not only the micro-level, more immediate outcomes of solar lamps, but also the impact that solar lights may have upon the macro-level, and medium to long-term outcomes experienced by families and communities. The findings of this study may also be used to inform the development of analysis to identify the estimated social return on investment in different developing countries; and provide charities such as the one detailed in this study with information to support their impact using financial approaches that balances the value of investment with the value of the impacts observed.

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The authors declare that there is no conflict of interest. The authors alone are responsible for the content and writing of this article.

Contributions

RH was involved in data collection, had full access to the interview data and analyses, and interpreted the data, drafted and critically reviewed the manuscript and had full control, including final responsibility for the decision to submit the paper for publication.

LE was involved in the study design, data collection, had full access to the interview data and analyses, interpreted the data, and critically reviewed the manuscript.

HT was involved in the study design and critically reviewed the manuscript.

CB critically reviewed the manuscript.

MCVH drafted and critically reviewed the manuscript.

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ABOUT THE AUTHORS

Mrs Rebecca Harrison, Public Health Impact Officer, Public Health Institute, Liverpool John Moores University

Dr Lindsay Eckley, Research Officer, North of England Zoological Society (Chester Zoo)

Dr Hannah Timpson, Reader in Socioeconomic Engagement in Health, Public Health Institute, Liverpool John Moores University

Dr Christian Blickem, Clinical Trial Coordinator (GENIE), Public Health Institute, Liverpool John Moores University

Professor Marie-Claire Van Hout, Professor in Public Health Policy and Practice, Public Health Institute, Liverpool John Moores University