A PESTLE analysis of solar home systems in refugee camps in Rwanda

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Abstract

There is a paucity of data on energy access in refugee camps and limited analysis regarding the viability of modern energy technologies such as solar home systems in these contexts. This paper addresses these by presenting an overview of the household and small enterprise electricity access situation in Kigeme, Nyabiheke and Gihembe camps in Rwanda and through the application of a Political, Economic, Social, Technological, Legal and Environmental (PESTLE) analysis to assess the barriers influencing solar home system provision. Most households and small enterprises currently have limited or no access to electricity and there is significant unmet demand for energy services such as mobile phone charging, lighting, and entertainment in the camps. The analysis suggests that solar home systems can meet these energy needs and identifies important factors in ensuring projects are successful. Projects should be informed by the needs and priorities of end-users and should be aligned with national policies, such as achieving Tier 2 energy access, to garner political support. Where possible, local market systems should be nurtured to normalise paying for energy products and to avoid free distribution. This can support private sector engagement and result in longer system lifetimes through improved maintenance. Energy literacy programmes can also improve awareness of solar home systems and their benefits compared to traditional sources of energy. These findings can inform practitioners on the supporting policy/financial frameworks, design requirements and implementation measures needed to maximise the benefits of future solar home system projects and help achieve electrification targets.

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Highlights

- An overview of access to electricity in three refugee camps in Rwanda.
- A PESTLE analysis of solar home systems in the refugee camps.
- Identification and analysis of factors impacting solar home system projects.
- Recommendations to enable better solar home system project design.

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Keywords

Energy Access; Humanitarian Energy; Solar Home Systems; PESTLE Analysis; Refugee; Rwanda

Abbreviations

1 US$ = 953 RWF
CO_2 - Carbon dioxide
CRRF - Comprehensive Refugee Response Framework
EPRSC – Engineering and Physical Sciences Research Council
GPA - Global Plan of Action for Sustainable Energy Solutions in Situations of Displacement
LED - light-emitting diode
MIDIMAR - Ministry of Disaster Management and Refugee Affairs
MINEMA - Ministry of Emergency Management
PAYG - Pay-As-You-Go
PESTLE - political, economic, social, technical, legal and environmental
PV - photovoltaic
RE4R - Renewable Energy for Refugees
RWF – Rwandan Franc
SAFE - Safe Access to Firewood and Alternative Energy in Humanitarian Settings
SDG - Sustainable Development Goal
SHS - solar home systems
UNHCR - United Nations High Commissioner for Refugees
VAT - value-added tax
W – Watt
Wh - Watt hour
Wp - Watt peak

1.0 Introduction

Existing research has established that most refugees and the host communities surrounding them currently rely on unsustainable, unreliable and unsafe forms of energy [1–5]. This is in part because energy is not currently embedded within the humanitarian response system [6–8] and is often not prioritised [9,10]. This lack of access to energy is known to exacerbate multiple issues in humanitarian contexts including impacting the protection [11], health [12,13] and education [14] of displaced people.

To address this challenge, the United Nations High Commissioner for Refugees (UNHCR) made a commitment at the 2019 Global Refugee Forum that all refugee and host community households will have Tier 2 electricity access by 2030 [15]. This means that all households have access to at least 50W of power or 200Wh per day of electricity that can provide lighting, air circulation, television and phone charging services for a minimum of 4 hours during the day and 2 hours in the evening [16]. In order to achieve this goal, humanitarian organisations need to significantly increase energy access levels for at least 20 million people[1] [17] within ten years.

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[1] At the time of writing there were 20.4 million refugees under UNHCR's mandate (excluding Palestinian refugees).

Enabling households to access solar home systems (SHS) which are often able to meet the criteria of Tier 2 energy access [18–20] is one possible solution to this challenge. While there have been SHS projects in refugee camps in Kenya [21,22] and in Burkina Faso [23], these projects have often had limited success because of issues with affordability and because interventions did not consider local conditions or the needs of the intended communities [24]. There is also limited research evaluating why the growth in demand for SHS seen elsewhere in Rwanda [25] has not also been seen in refugee camps in the country.

The objectives of this paper are to address two of the challenges that need to be overcome to increase the diffusion of SHS in the camps: (1) a lack of data on energy provision in humanitarian situations which is inhibiting the ability of organisations to provide energy solutions [26,27] and (2) the identification of political, economic, social, technical, legal and environmental barriers and enablers that must be addressed in order to achieve widespread adoption and use of SHS [25,28–30]. For example, although some studies have indicated that SHS are a viable technology for enabling socio-economic development and alleviating poverty [31–33] there are also several studies that refute this claim [34–36]. Proper alignment of these factors has also been identified by other researchers [39] as an essential component of successful projects. We address this challenge by conducting a PESTLE analysis to explore the factors influencing the implementation of SHS in refugee camps and to identify lessons learnt from previous projects. This type of analysis has been conducted on a range of different energy topics including renewable energy in Malawi [38], Indonesia's fossil fuel industry [39], and the tidal energy industry in the UK [40]. However, this is the first paper to present a PESTLE analysis of SHS as a way of providing access to electricity in humanitarian contexts, and the first academic paper to present data on the energy situation in Kigeme, Nyabiheke and Gihembe refugee camps in Rwanda. This analysis provides a first step in understanding the specific challenges associated with providing energy in these humanitarian contexts. The findings can be used by practitioners and policy makers to guide the development of future SHS projects, and by researchers to identify areas where additional data or analysis would be of value.

This study considers the electricity access situation for households and small enterprises in Kigeme, Nyabiheke and Gihembe refugee camps. Unlike many situations of displacement, these three camps have been the focus of recent energy access assessments as part of the ongoing Renewable Energy for Refugees (RE4R) project and therefore offer a timely and relevant case study. Although caution must be taken before applying the findings of this paper to other refugee contexts, the authors consider that these camps offer similarities to other protracted refugee situations in the East Africa region such as in Tanzania, Burundi, Uganda, Ethiopia, Sudan and Kenya. For example, many of the refugees living in camps in rural and remote areas in these countries have low incomes and poor access to electricity, whilst the region is sun-rich and is experiencing a transition towards decentralised energy systems such as SHS. The RE4R project builds on previous work by the Moving Energy Initiative that described the energy situation in Dadaab refugee camp in Kenya [22] and Goudoubo refugee camp in Burkina Faso [41] and which offer two further cases for comparison.

The following sections provide a brief overview of SHS, followed by a description of the research methodology. The existing energy situation in the camps, including access to energy in households and enterprises, is then provided. A PESTLE analysis is presented which evaluates the opportunities and challenges facing the provision of SHS in the camps, followed by a discussion of the issues. The final sections present some of the limitations associated with the research, future research ideas and concluding remarks.

1.1 Solar Home Systems

The falling costs of photovoltaic (PV) panels, batteries and light-emitting diode (LED) bulbs have helped SHS emerge as a cost-effective technology for providing electricity to low-demand customers in off-grid locations [25,28,42–44]. SHS can provide households with a greater range and quality of services than those available via smaller-scale technologies, such as solar lanterns, but with a smaller overall infrastructure commitment than installing larger-scale options such as a minigrid. A typical SHS (Figure 1) comprises a 10 to 100 W_p PV panel, a rechargeable battery, appliances and associated equipment such as wiring, switches, a charge controller and communication equipment that are not fully shown in Figure 1. Depending on the size of the system a range of appliances including LED lights, fans, televisions, and radios can be connected [45–47]. Most SHS can provide Tier 2 access to electricity services and state-of-the-art systems can reach Tier 3 [48–50].

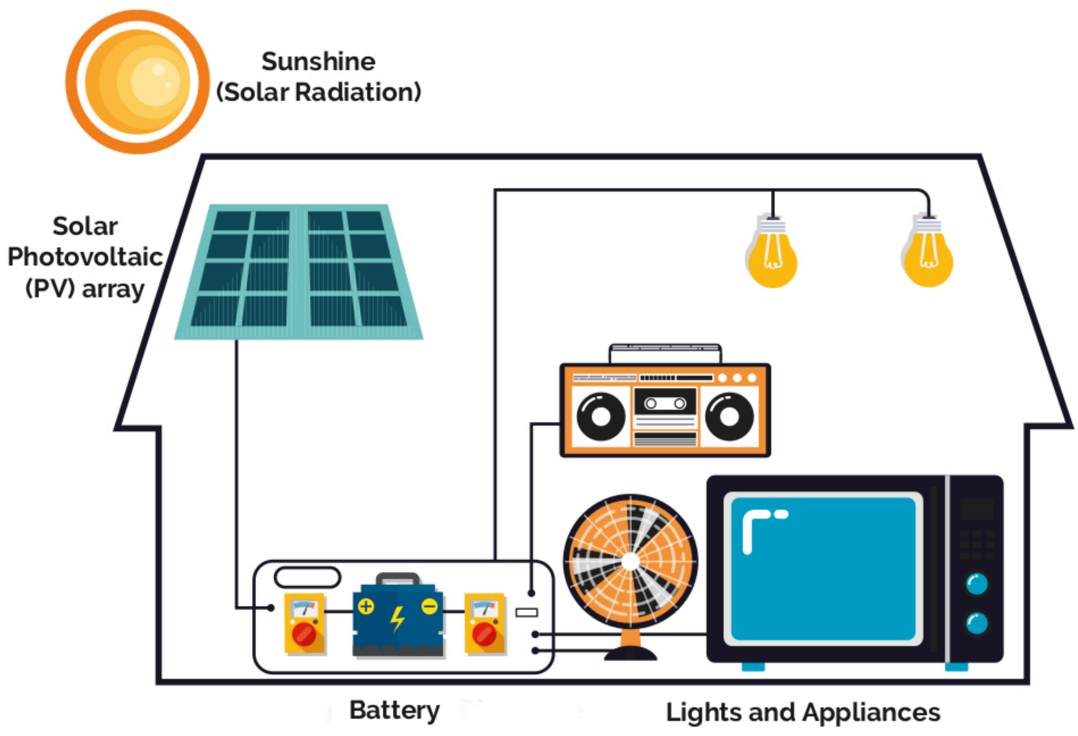

Figure 1: A simplified schematic showing the main components of a typical SHS (authors' own).

It is important to note that while the multi-tier framework has been credited for expanding narrow metrics defining energy access [51] there has been some criticism that there is still too much focus on system attributes such as Watt peak or Watt-hours of systems rather than on the services these systems offer [52]. We focus on Tier 2[2] for consistency with the UNHCR Energy Challenge and Rwandan Government guidelines. However, we support analysis by other research that suggests Tier 3[2] or higher should be the long-term aspiration [51].

[2] Full details of differences between each tier are available in [16].

2.0 Research Methodology

This paper presents a summary[3] of the existing energy situation in Kigeme, Gihembe and Nyabiheke refugee camps in Rwanda that was investigated by Practical Action as part of the RE4R project using quantitative and qualitative approaches. The quantitative assessment aimed to provide numerical evidence describing the demographics of the camp residents, their current access to energy, and their energy needs and priorities. The surveys focused on energy use in households and domestic settings (n. 623; 211 households in Gihembe, 202 in Kigeme, 210 in Nyabiheke), and for enterprises and businesses (n. 155; 64, 34, and 37 enterprises respectively). Building on similar studies by Practical Action [22,41,53,54], and with inputs from both the UNHCR Rwanda and Geneva teams and other partners, the assessment methodology was developed and field tested by RE4R staff before being conducted in the camps by trained enumerators in March and April 2018 via one-to-one interviews of people living and working in the camps.

The surveys were translated from English to Kinyarwanda, conducted in the latter as the language is spoken widely in the camps, and responses were recorded electronically on a tablet in English or numerically, as applicable. Refugee enumerators selected to conduct the survey received a daily stipend and participated in a two-day training workshop before data collection commenced. Enumerators were supervised throughout the data collection process by field staff from Practical Action and UNHCR Rwanda. Respondents for the quantitative survey were selected at random from within predetermined geographical areas to form a representative sample of the camp as a whole, with a full description of the surveying methodology given in [55].

Qualitative data was also collected from a wide range of energy users via unstructured interviews conducted by two researchers from Practical Action who were supported by camp-based staff. These interviews focused on the lived experience of refugee communities, following a process similar to [56], and provide additional depth and detail that is not reflected in quantitative data collection techniques. Data collection was completed in May 2018 and was used to design implementation plans for four renewable energy interventions in the three camps [55].

A PESTLE analysis is conducted to identify factors that may be influencing the adoption of SHS in the camps. PESTLE analysis is an analytical tool for evaluating the impact of existing and future external factors on a system or technology while also evaluating the impact of the system or technology in the context where it is implemented [57,58]. This method is particularly useful for exploring issues that are mainly qualitative in nature and for analysing problems holistically. In the context of this paper, the PESTLE analysis is focused on the factors influencing the diffusion of SHS among households and small enterprises in the camps in Rwanda. The factors identified are wide ranging and include local, national, and international issues. A wide range of stakeholders interested in SHS deployment are considered including refugees living in the camps, the host communities living nearby, humanitarian and government agencies, donors, and private sector companies. The findings of the analysis can be used to improve future projects and to identify areas that require further investigation.

[3] Full details of the RE4R assessment process and findings are available in [55].

The analysis draws on academic and grey literature discussing energy access and humanitarian interventions and the experience of the authors to inform the analysis. The analysis also draws on unpublished literature from the RE4R project such as notes from workshops and programme meetings which include participants from a wide range of organisations involved in the RE4R project including Practical Action, UNHCR, the IKEA Foundation (the project donor) and the Rwandan Ministry of Emergency Management (MINEMA), formerly known as the Ministry of Disaster Management and Refugee Affairs (MIDIMAR).

To ensure validity, the findings of the paper have been discussed with members of the RE4R project including Practical Action staff such as the field coordinators based in each of the camps, the project's technical adviser, the project manager and the monitoring, evaluation and learning advisor. Furthermore experts in the field have been consulted, such as members of the GPA, and comparisons made between the data collected as part of this study and other projects such as [22,41]. The lead and second authors both sat on the RE4R Technical Working Group which met quarterly throughout the project and were participants in decision-making workshops and regular project reviews. These activities will help to mitigate the impact of any emergent discrepancies between the point at which key data were gathered, for example the survey data, and the continually evolving situations in the camps.

3.0 Existing Energy Situation

3.1 Kigeme, Nyabiheke and Gihembe Camps

In this paper we consider three of the six refugee camps operating in Rwanda. The camps host refugees predominantly from North Kivu and South Kivu provinces of the Democratic Republic of the Congo, have similar levels of household income and levels of employment. A summary of these is given in Table 1 and Figure 2 shows the approximate location of the camps and Kigali, the capital city of Rwanda.

Table 1: Overview of the locations, size and economies of the three camps. Data from [55], [59] *and* [60].

Camp	**Gihembe**	**Kigeme**	**Nyabiheke**
Households	2,910	3,998	2,787
People	12,391	22,950	14,289
Average number of people per household	4	6	5
Total household monthly income (RWF)	83,211	43,113	23,782
Total household monthly income (US$)	87.31	45.24	24.95
Households with wage earner in last 12 months (%)	34	42	47
Non-farm businesses (% of all businesses)	8	13	17

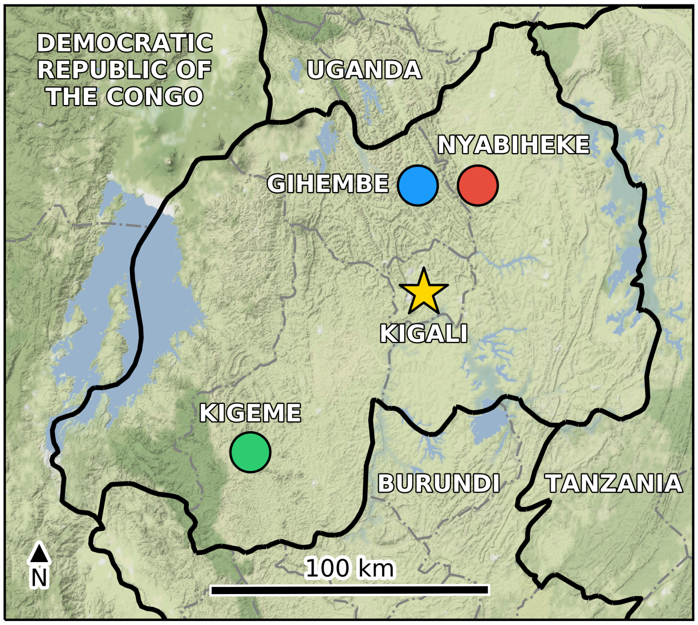

Figure 2: Map of Rwanda showing the locations of Gihembe (blue), Nyabiheke (red) and Kigeme (green) refugee camps and Kigali the capital city of Rwanda (yellow star) [Source: 55].

These camps were the focus of a previous investigation by [60] that investigated the economic life and employment of refugees resident in the camps; although this study did not focus on energy access, some of the data gathered is relevant to assessing the potential economic viability of SHS for households. Household income (including direct aid, wages and remittances), potentially indicative of the ability to pay for a SHS, was highest in Gihembe. Kigeme and Nyabiheke, meanwhile, had higher proportions of the businesses in the camps operating outside of the agricultural sector, such as in retail, trade and food service, which would likely have greater use for a SHS.

All three camps now use a cash and voucher programme in lieu of direct assistance and food distribution, which at the time of that study was only operating in Gihembe. These programmes aim to develop the financial independence of refugee households by offering greater autonomy over purchasing decisions while also helping to facilitate greater integration between the refugee and local host community populations, including access to electricity products and services.

3.2 Access to electricity for households

There is no overall responsibility amongst the camp authorities for the provision of energy for lighting, although a number of distribution programmes have had a limited effect on increasing access. At that time households had very limited access to both electricity and energy for cooking, with most respondents reporting access to only the most basic forms of technologies and fuels.

As shown in Figure 3, which displays the lighting sources used by households in the past 12 months, most households relied on a combination of low-tier lighting technologies – such as candles, lights on mobile phones and improvised battery torches – to meet their lighting needs. When asked about the household's main source of lighting, across the three camps, only 21% of households reported relying primarily on solar lanterns and 16% on SHS as their main source of light. Access to a SHS, and correspondingly access to Tier 2 electricity services or higher, varied between the three camps: in Gihembe this was as high as around one in three households, whereas in Kigeme it was lower than one household in ten. The authors also identified that access to higher tier technologies resulted in greater hours of lighting in the evening: households with Tier 0 technologies received on average 2.6 hours per day of light, those with solar lanterns (assumed to be Tier 1) received 3.3 hours per day, whilst SHS (Tier 2) offered 4.0 hours per day.

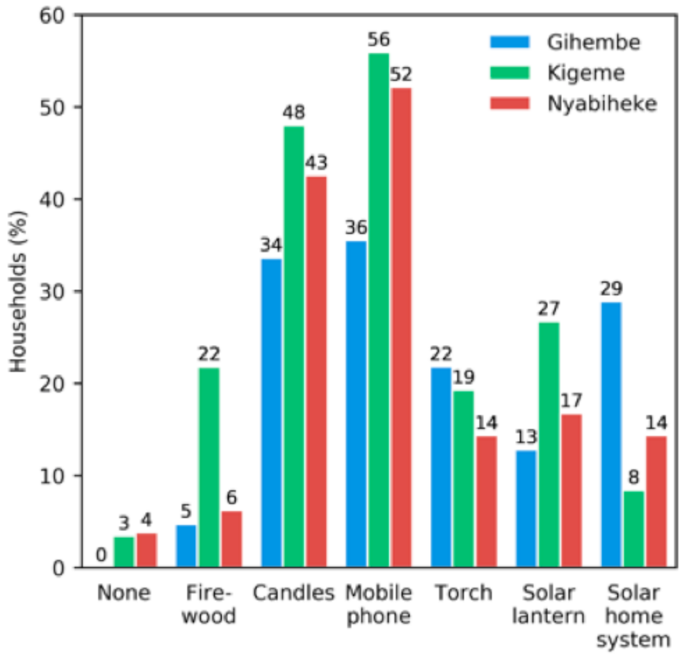

Figure 3: Lighting sources used by households in the past 12 months. Households could report as many of the sources that were relevant to them. Data from the RE4R project.

The delivery model used to provide the energy technology had an impact on its long-term effectiveness [55]. For example, camp residents who received solar products as donations from camp authorities or other organisations were more likely to report issues with them, such as breakages or thefts. This was particularly prevalent in Kigeme, where 57% of solar lanterns were received as donations and more than half of those lanterns suffered problems. In contrast, households that paid for SHS from shops inside or retailers outside of the camps, such as BBOXX, Zola and Ignite, reported fewer issues: 97% of SHS were acquired in these ways, but only between 8% (in Gihembe) and 18% (in Kigeme) suffered issues. Anecdotally, however, several respondents described a perceived lack of customer support from retailers, potentially caused by companies being unsure of the authorisations or permits necessary to enter the camps to fix broken products.

Camp residents without SHS reported spending on non-renewable sources of lighting such as candles and batteries and, whilst there was a wide range or spending practices reported, median expenditure was 500 RWF (US$ 0.53) and mean expenditure was 1,000 RWF (US$ 1.05) per month. Connecting to the national grid network, which was used by camp authorities to varying degrees in all three camps and used by the local host communities, was not permitted for refugee households even if they were able to save enough to pay for the initial connection fee. Anecdotally this was for safety purposes and because the camps were not permanent settlements.

By analysing the prevalence of SHS in the camps, [61] used the data from the RE4R project to estimate the market size of potential new customers if enough interventions were introduced. The analysis found that respondents most valued the benefits electric lighting would bring for working at home (such as for a business, doing chores or studying) with a high importance for charging mobile phones, both of which are promoted selling points of SHS. By considering the monthly tariffs being charged by two SHS companies (BBOXX and Belecom) supported as part of the RE4R project, [61] also estimated that the number of households that would purchase a system at the price offered would be between 1,400 RWF and 2,400 RWF. These estimates, however, could vary significantly dependent on activities that affect household willingness to pay, such as awareness raising campaigns and greater access to retail outlets in or near to the camps. It is also worth noting that disparities often exist between demand predictions and real uptake because of differences between willingness and ability to pay [28].

3.3 Access to electricity for enterprises

There were a variety of enterprises in the three camps such as retail shops, phone charging providers, food shops, restaurants, bars, tailors and hairdressers. Overall levels of electricity access were low and most enterprises relied on Tier 0 or 1 technologies (58% overall) with only a minority having access to SHS enabling Tier 2 access (27%) or higher from connections to minigrid used to power camp operations (15%) [55]. Most enterprises, especially small shops and those offering phone-charging services, operated from within respondent homes whilst only 5% had a dedicated building. This suggests that the same electricity services could benefit both domestic and commercial purposes inhabiting the same physical space. Relatively basic electricity services, such as lighting, phone charging and televisions, were the most frequently desired amongst businesses, indicating a significant potential customer base for SHS that commonly provide these services. There was less desire for other uses of energy such as heating and cooling, potentially due to a lack of technologies available in the camps that would supply these.

4.0 PESTLE Analysis

Although SHS offer a potential solution for improving electricity access levels among households and small enterprises in the camps, with a small minority already benefiting from access to them, there are currently barriers preventing their widespread diffusion. The following sections present the PESTLE analysis conducted as part of this research to break down and evaluate the various factors influencing the diffusion of systems. In some sections, such as sections 4.5 and 4.6, there was very limited information about SHS provision specifically related to humanitarian contexts. We have drawn more widely on literature from other contexts and consulted with experts in the field to ensure validity.

4.1 Political

Policy and governance are central to the sustainability or energy interventions [37,62] and arguments suggesting that the political environment needs to change in order to improve access to energy for refugees have existed since 2015 [2,63]. However, there have been several policy developments since then. For example, the Sustainable Energy for All initiative aims to ensure sustainable energy for all by 2030 [64] and tracking energy access levels among displaced people was included in the Global Tracking Framework for the first time in 2017 [65]. In 2015 the United Nations also agreed on 17 Sustainable Development Goals (SDGs), including SDG 7 which aims to “ensure access to affordable, reliable, sustainable and modern energy for all" [66] and, an indicator on refugees was explicitly included after a review in 2019 [67]. While these political ambitions help demonstrate the importance of energy at a high level, a failure to integrate energy provision into humanitarian coordination mechanisms such as the Cluster System [7,68,69] and the Refugee Coordination Model [70] has led to gaps in response. To help address this, UNHCR launched its Global Strategy for Sustainable Energy and created a clean energy challenge at the end of 2019 [15,71]. Two coordinating bodies, the task force on Safe Access to Firewood and Alternative Energy in Humanitarian Settings (SAFE) and the Global Plan of Action for Sustainable Energy Solutions in Situations of Displacement (GPA) [8,26], have also been established to support the provision of energy in humanitarian settings.

Providing access to electricity is also increasingly a priority for national governments and energy policies can be a key driver of SHS adoption [72,73]. Investment in energy provision can be enabled where there is government support for it [74] or can be a major barrier to the diffusion when there is a lack of it [75,76], or when there is support for other means of electrification such as the national grid. Although this issue has not been identified in Rwanda, in some countries, such as Ghana and Malawi, politicians have promised off-grid communities access to electricity during political campaigns [28,38,77]. This can lead to an unwillingness to adopt off-grid technology [78,79], although domestic grid connections are unlikely in many humanitarian settings, including in Rwanda.

The administration of refugee camps is typically highly regulated and the process of working in camps, particularly for private companies and external organisations is often challenging [80]. The host government's approach to refugees impacts the capacity of agencies to provide refugees with access to energy [12] which can be politically unpopular [81]. In part, the challenges of improving energy access for local populations have discouraged governments from prioritising energy access for refugees [21]. The delivery of energy can also be hampered by the willingness of host governments to support long-term interventions [82,83]. Furthermore, by engaging with the host country government and ensuring interventions align with existing policies, for example, rural electrification plans and environmental commitments, can help to avoid negative disruption and unintended consequences [74,84]. The inclusion of the local host communities in energy programmes can help address this challenge [21].

Rwanda has relatively progressive policies towards both energy access and refugee inclusion. The Rwandan Government has recognised the importance of energy access in several policies including its Economic Development and Poverty Reduction Strategy II [85], Vision 2020 framework [86] and National Strategy for Transformation [87]. The Rural Electrification Strategy also includes SHS as a way of providing access to electricity [88], using Tier 2 as a minimum standard similar to the commitment of UNHCR, and the Government has supported private SHS businesses to establish and grow their operations in Rwanda [25]. Energy provision for displaced people, meanwhile, is supported by the Government signing up to the Comprehensive Refugee Response Framework (CRRF) in February 2018 which affords refugees with progressive legal and economic rights and aims for better inclusion of refugees in Rwandan policies and programmes [89,90]. Alignments between humanitarian energy programmes and these existing policy initiatives, for example sharing the goal of Tier 2 access, can help ensure adoption of systems.

4.2 Economic

Funding for energy has not historically been a priority for donors and humanitarian agencies are usually unable to provide household energy technologies [83,91] as a result. Some solar lanterns have been provided in the three camps but the diffusion of SHS has mostly been market-led. Supported by research that has established that freely distributing similar technologies reduces diffusion amongst users in areas where market-based delivery is being implemented [21,23], some humanitarian actors are now arguing that free distribution of products should be avoided in all but emergency situations [92–94] because of the negative impacts it has on local market systems [80,95].

The delivery of SHS through market-based models has significant challenges that need to be addressed. For example, the high cost of purchasing a SHS outright is a barrier identified in several studies [20,32]: although system costs can vary between countries [76]. In Rwanda, a 50 W_p SHS is available to purchase in markets for around 250,000 RWF (US$ 262) [96] but this is a significant proportion of household income to pay in a single installment. Existing SHS project have sometimes failed to reach the poorest members of society and are typically purchased by higher-income households [92,97,98]. Pay-As-You-Go (PAYG) has emerged as a way to overcome this limited purchasing capacity and for low-income households to spread the costs of a system more flexibly and better take account of fluctuating priorities and income [20,92]. For example the cost of a BBOXX system with two lights and mobile phone charging is around 6,000 RWF (US$ 6) per month in the camp [25], subsidised by the RE4R project by 40%, far lower than the cost to purchase a similar system outright but comparable when considering the three-year repayment period. However, access to finance for consumers remains a significant barrier to the diffusion of SHS identified in several countries [99–101], which affects the ability of households to purchase a system and limits SHS providers from scaling their businesses. Attempts were made to address this as part of the RE4R project, for example, the creation of a revolving fund [102] which provides access to microloans which households can use to purchase a SHS. The introduction of cash-based transfers [103] where refugees receive cash and make the decision about what they need has been an enabling factor in the camps by setting an expectation that payment should be made for products or services which supports the PAYG model [92].

Despite innovative delivery models and subsidies in the case of the RE4R project, these payments still represent a significant expenditure for low income households and, in some cases, SHS have been paid for by diverting funds from other needs [104]. Acquiring a SHS via PAYG requires regular monthly payments and represents a long-term financial commitment compared to traditional energy sources which can be purchased or not depending on income constraints [104,105] and so may not be compatible with variable incomes of many refugee households. This also presents a challenge for SHS providers, who are reliant on consistent income streams [92]. To mitigate this risk some systems are able to remotely lock which can reduce the frequency of late and missed payments [81,106]. For refugee households with more variable incomes this may mean that, despite having a SHS in their home, their access to improved electricity services remains limited.

The majority of studies on the topic report that SHS can help to improve household incomes primarily through enabling work to take place after dark [107,108]; given that many enterprises in the camps are located in households, this would likely also be the case in camps. Some households also generate income through charging mobile phones [25] although this opportunity may be diminished if SHS are adopted by most households. However, households that do own a SHS can save money and time that they previously would have spent on energy services such as mobile phone charging and traditional sources of lighting [25,105,109], which is also commonplace in the camps. It is worth noting that there are a similar number of studies that contradict these finding and suggest the potential SHS can have on income generation and poverty reduction is low because increased operating hours enabled by improved access to lighting has a limited impact on income [96,104,105,110].

4.3 Social

SHS need to meet the needs of users and be adapted to the contexts in which they operate to ensure acceptance and diffusion [38,84,104,111–114]. However, identifying what people want or need can be challenging because, in some cases, recipients tell providers that they want certain technologies because they think that is what they want to hear and not because it necessarily reflects their true priorities [115]. Projects have also failed in the past because users have a limited choice of system which do not meet their needs [75,116] and there are examples in humanitarian contexts of energy products being unused or re-sold [94]. As a result, projects should consider offering a range of systems or provide systems that are flexible [28,117] so that consumers have choice. However, it is worth noting that offering one system can help reduce costs [76] which is an important consideration in humanitarian contexts where funding is limited [2].

Energy plays a huge part in the everyday lives of displaced communities [118,119] and SHS have the ability to improve household living standards [75]. Refugees have reported that access to electricity has improved their children's ability to study [12,14,120] and lighting enables people to move around camps at night and increases operating hours for enterprises [12,121]. In Rwanda, the RE4R surveys found that SHS provided 90 minutes more lighting per day compared to traditional sources [45]. However, it is worth noting that while an increase in lighting hours can increase study and operating hours, it does not necessarily lead to increased incomes or an improvement in educational attainment [31,110]. SHS can also enable people to engage in social activities after dark [75,76,104,113] and improve access to information through radio and televisions, which can help people monitor the situation in their home country, and is a widely cited positive impact of larger SHS [75,76,104,105,109,110,122]. However, in some cases, households continue using traditional lighting technologies to conserve power for television viewing [123] which can negate the expected benefits of electric lighting.

There are also health and safety benefits associated with SHS, for example improvements in indoor air quality and a reduction in the likelihood or burns and fires [13,32,75,104,124–128]. Although lighting is not a panacea for protection challenges in refugee camps, it can improve people's perception of safety [11,12,120,129]. However, there are some negative impacts such as social exclusion and indebtedness among groups who are unable or struggle to afford SHS [75,105]. Vandalism and theft of systems can also be a problem in some humanitarian contexts [31,115].

One potential barrier to the diffusion of systems is that levels of education and awareness about renewable energy remains low among potential consumers of SHS [76,130]. End-users may be unaware that over time, SHS may be comparable with what they are currently spending on energy [92]. Users can also have unrealistic expectations about what a SHS can achieve and have misunderstandings about how to use the technology or be unaware of the potential benefits [92,109,115,131]. As a result, capacity building of local communities is widely cited to be an important component of program success

[76,114,116,132]. A lack of funding to provide this [76] and advertising that doesn't illustrate the limitations of SHS [133] has exacerbated this challenge.

4.4 Technological

The limited capacity of SHS to power productive and thermal uses is one of the main reasons they are unable to reach beyond Tier 3 [31,134,135] and this is one of the reasons why users often have a preference for a grid connection [77]. However, grid connections are often impractical, prohibitively expensive and can fail to deliver the promised economic development [81,105,135–137]. Furthermore the organic, unplanned nature of informal settlements makes them particularly challenging and expensive contexts in which to retrofit conventional infrastructures [81]. In Rwanda, the Government is reluctant to connect refugee households to the grid or to the minigrids that supply power to institutional facilities in the camps. The deployment of SHS is comparatively flexible as they can be installed on individual households, which places them at an advantage compared to other types of larger-scale systems.

Previous research has identified that the performance of SHS has been reduced because of shading or because solar panels had not been cleaned [104]. This is an important issue because improper use affects the economics and sustainability of the system [138]. This highlights the need for proper maintenance; however, according to [116] previous programmes have underestimated the need for repair and maintenance. As a result, most SHS are poorly maintained by the users [116,139], a problem exacerbated by a lack of user training [115,116,140]. Poor maintenance can limit rates of adoption [114,141] and previous research suggest that households have not been satisfied with the maintenance services provided by suppliers [109,142]. To address this challenge, some modern systems can be remotely monitored and adjusted to ensure better performance and identify maintenance issues [81,106]. However, preliminary findings from the RE4R project indicate that the capacity of the SHS suppliers to deal with maintenance issues has been higher where there is a permanent presence in the camps.

Tier 2 SHS have the capacity to deliver the three most important energy needs identified by refugee households in the RE4R survey (mobile charging, lighting and entertainment such as via radios and television) [55] and can improve the energy situation in comparison to existing energy basic sources. For lighting, the average light output from a SHS is about 44 lumens per bulb, compared to 12 lumens for candlelight and 25 lumens for kerosene lamps [75] and is significantly safer. Providing the additional service of mobile charging within the household can increase convenience and help to save time and expenditure on mobile phone charging. Previous project evaluations in non-refugee settings in Rwanda suggest weekly savings of 200 RWF (US$ 0.21) per phone [97], and the RE4R assessment similarly identified an average weekly expenditure on phone charging among households of 150-300 RWF (US$ 0.16-0.32) [55], which could potentially be mitigated. Finally, more powerful SHS can enable access to radios and television but, as noted earlier, these are typically more expensive and may be out of reach of many households even if subsidised. Therefore, a balance needs to be achieved between the cost of the system and the services it can provide. While it is not within the scope to this paper to fully assess the impact of technology development, it is worth noting that the components used in SHS are projected to improve over the coming years which can help improve the capability and performance of SHS. For example, analysis by [141 and 142] suggests improvements in battery and solar technology as well as reductions in cost. There has also been an increase in the range of low-power appliances alongside improvements in efficiency and reductions in costs [145].

4.5 Legal

Overall, there is very limited literature on the nexus between the law and energy access in humanitarian settings. Most national constitutions and laws in sub-Saharan Africa do not yet recognise the right of access to energy [146] and some authors argue that this needs to happen in order to achieve universal access [81]. This applies to Rwanda in that it has multiple polices and targets (see section 4.1), but no laws on energy provision or rights to access for refugees or the host community. Formalising these, in particular regarding the inclusion of displaced people, would help to integrate refugees into host country electricity provision. At present the ability to make a connection to an existing electricity supply either illegally or informally can be a problem [147] and power theft has been reported in other humanitarian settings [2,3], although this has not been reported in Rwanda. Displaced people being afforded the right to work and permission to move outside the camp can also enable access to energy in humanitarian settings [4]. These rights can help refugees become self-reliant, rebuild their lives, secure their dignity and allow them to contribute to their host community [148]. However, there have been no studies that specifically investigate how rights to work or freedom of movement for displaced communities impacts their ability to access energy via any means.

Evidence from the development literature suggests that clarity in terms of taxation and import duties can also help support SHS diffusion by simplifying the process for SHS suppliers and distributors. Although evidence for the humanitarian sector is not available, some research has criticised the Rwandan Government for a lack of clarity on value-added tax (VAT) and tariffs [149]. However, also it recognises that the Rwandan Government has adopted progressive tax policies that enable SHS sales including exempting solar products from import duties and VAT [150]. While spare parts and accessories, including appliances, are exempt for VAT they are not exempt from import duties [150].

Previous studies have also identified that poor quality SHS sold without warranties can have a negative impact on the wider market and consumer trust in systems [29,106]. Although existing research has established that the quality of products in Rwanda was relatively high [149], the Rwandan Government mandated in 2018 that all imported SHS are Lighting Global certified[4] to ensure the quality of products available to consumers [149,150]. The Government also requires that system components such as lights, solar panels and batteries are labeled and include certain information such as technical specifications [150]. Although the capacity of the Standards Board to implement regulations has been criticised [149], this represents an important step in ensuring good quality products are available to households. However, according to some authors, the laws needs to go further in dealing with substandard systems to protect consumers [151]. There is limited documented evidence regarding whether these findings apply in humanitarian contexts, although anecdotal evidence suggests that poor quality products are a major challenge, and so efforts have been made to ensure minimum standards in humanitarian settings for aspects such as household lighting [i.e. 152].

[4] Further information on the Lighting Global standards are available in [182].

4.6 Environmental

There is a lack of evidence regarding the impact of environmental factors on the provision of SHS in humanitarian contexts. As a result, this section draws on literature from other contexts. For example, evidence suggests that in many contexts the infrastructure required to provide SHS including transport and telecommunication networks is often lacking which can increase costs and delivery times of SHS [99,115,153]. Although roads between major towns are generally good in Rwanda [154], roads to remote towns and villages are often unpaved and can become impassable in the rainy season [155]. Since refugee camps are often located in remote areas [156] this challenge could be further exacerbated in these contexts. Furthermore, Rwanda is landlocked and transporting products from majors ports can add 7-12% to the price of products [157]. The remoteness of some locations can also mean the end users need to be responsible for ongoing maintenance and operation of the system [116]. Local weather can also reduce the performance of SHS [155]. For example, in Rwanda problems with lights cutting out and dissatisfaction with the brightness of lights have been linked to insufficient charging caused by poor climatic conditions [97]. Similar issues have been identified in other countries such as in Bangladesh [104] and in French Guyana [111].

SHS are often promoted for environmental reasons [105] and are widely considered to be an environmentally friendly solution for supplying electricity [158–160]. However, the manufacture and distribution of SHS has a potentially significant environmental impact [46,159,161–165]. Depending on several variables, particularly the predicted battery recycling rates and the number of kerosene lanterns replaced, a SHS was shown to have a 0.5-2 year payback time for greenhouse gas emissions, whereas replacing a diesel generator with a SHS was found to have a 6-13 year payback time [165]. However, it is worth noting that the continent of Africa has relatively low greenhouse gas emissions, at an estimated 2–3% of global CO_2 emissions [28], and the existing environmental impact of refugees is extremely low. The aggregated potential to mitigate greenhouse gas emissions for all refugee households in Rwanda, for example, would be similarly low but providing SHS would offer moderate CO_2 savings at an individual level.

An estimated 20,000 displaced people die each year because of poor indoor air quality [2] and very few studies have considered the issue specifically in humanitarian contexts [166]. However, evidence does indicate that users can also benefit from improved indoor air quality where a SHS replaces traditional lighting sources which release particulate matter, carbon monoxide, nitric oxides and sulphur dioxide [46,97,167–169]. Although the RE4R survey identified limited use of traditional lighting sources, households typically have few rooms with poor ventilation, which exacerbates the impact of any emissions. Caution needs to be taken because smaller SHS are sometimes not sufficient for household needs, which can cause households to supplement the SHS with traditional lighting technologies [110]. Furthermore, the amount of emissions released by traditional lighting technologies is relatively small compared to emissions from household cooking [170]. Although cooking cannot be supported by existing SHS there are a range of electric cooking developments emerging that could potentially enable this in the future [36,106,171,172].

What happens to solar power products when they break down has also been neglected [173,174]. This is in part because waste management systems are often nonexistent in rural Africa, for example in Rwanda people are known to have disposed of batteries in latrines [175,176]. At the time of publication there were no studies specifically addressing this challenge in humanitarian contexts although there was an ongoing study being conducted by [177]. Furthermore, many of the raw materials needed to produce the components of a SHS including the solar panel and battery are sourced from fragile states or those that suffer high levels of corruption [178], and where poverty and the potential for resource related conflict exists [179,180]. Existing research suggests that end users need to be aware of environmental issues and support environmental policies and regulations for waste management to be successful [46]. However, there are often problems associated with the dissemination of information on environmental issues among refugee camps, although traditional forms of communication such as storytelling and dance have proved effective in some cases [181]. This approach was utilised by the RE4R project which engaged a community theatre group as part of a wider strategy to raise awareness about SHS and renewable energy generally in the camps.

5.0 Discussion

There are an increasing number of political commitments highlighting the importance of energy and the inclusion of displaced people in these policies is an important contribution to ensuring refugees are not left behind. However, many refugees have historically been left behind; for example, at the time of the RE4R survey, fewer than one in five households across Gihembe, Kigeme and Nyabiheke camps primarily used technologies capable of providing Tier 2 electricity access. These policies are not enough on their own and more progress could be made if countries enshrined in law that access to energy is a legal right. Our analysis also suggests that aligning energy interventions with existing government policy and humanitarian agencies' targets is likely to increase the success of any project. For example, in the case of Rwanda, the Government has multiple policies promoting energy access and SHS that refugee energy initiatives, such as the RE4R project, can align with. However, energy interventions can also be hindered by the lack of government support and future projects should evaluate whether operating in these contexts would be effective. Although there is limited evidence at present, ensuring the refugees have the legal right to work and freedom of movement could help people access energy in refugee camp contexts. Furthermore, ensuring products meet minimum legally binding standards could improve customer trust in products and increase levels of diffusion.

The economic analysis has identified that there is a shortage of funding inhibiting access to energy in refugee situations. However, it also identified an increasing focus, particularly in protracted crises, on providing energy through market-based delivery models which can be impeded by the free distribution of products. Furthermore, the cost of systems, fluctuating and insecure incomes, and resettlement aspiration are a major barrier preventing households from purchasing SHS. The use of cash-based transfers in the three camps, and the results of the survey that suggest that households which paid for solar products suffered fewer issues, indicate that market-based delivery would be successful in the camps. An important consideration for future programmes is how to enable access among lower-income households without causing damage to market-delivery models, particularly as a minority of households in the camps were found to have a wage earner which may limit their capacity to make consistent payments to SHS suppliers.

The findings suggest that SHS can have positive impacts on the social wellbeing of households primarily through better lighting and access to entertainment. In all the three camps households with access to SHS had a greater duration of lighting in the evening. However, there is limited evidence on the role SHS can play in improving household income, but home-based entrepreneurs may have a greater capacity to access these systems, as a greater proportion of businesses in the three camps had SHS compared to households. Our analysis also highlights the importance of embedding end-user preferences into projects and identifies the challenges associated with achieving this. For example, research suggests that survey respondents may mislead enumerators or be unable to recall information that is later used to guide decision making; in the case of the RE4R survey, respondents expressed a desire for services that can be readily provided by SHS, but may have been unaware of others or unwilling to suggest them in case they might be considered unfeasible. Allowing for the delivery of multiple products and services to ensure users can choose what meets their needs is also important, although this needs to be balanced against minimising programme costs.

The technological analysis established that SHS can meet the energy needs identified by users and highlighted the importance of minimum standards for ensuring quality products are available to households. Rwanda has the legal mechanisms in place to oversee this, however these need to be enforced appropriately. Our analysis also indicates that projected improvements in battery and solar PV technology could improve the capacity of systems while also reducing costs. Furthermore, a wider range of appliances may contribute towards enabling enterprises to generate additional income beyond those associated with lighting and mobile phone charging.

Although SHS are often portrayed as an environmentally friendly product, our analysis has identified that there are important issues regarding waste that should be addressed. The findings also indicate that SHS have limited potential to improve indoor air pollution because the majority of this comes from cooking which SHS cannot currently support. The variability of the local climate is also highlighted as an issue that has led to user dissatisfaction with systems.

The importance of embedding sufficient training for users and technicians, as well as ensuring the provision of accurate information on the benefits and limitations of SHS has been identified across all the PESTLE factors analysed. For example, training needs to be provided on the proper installation and maintenance of systems to ensure optimum performance and user satisfaction, and to rectify issues when they occur. Energy and financial literacy education can also improve user awareness of the benefits which can improve uptake.

6.0 Limitations

There are several limitations of this research that needed to be addressed in future studies. This paper focuses on Rwanda, a country with relatively progressive policies towards energy access and refugees, and the findings may not easily translate to other country contexts, particularly those outside East Africa. The three camps considered here are likely to be broadly reflective of the situations in the other refugee camps in Rwanda, but each will have their own levels of access to energy technologies and enabling and limiting factors of SHS diffusion. It is also worth noting that because there is a limited amount of research on humanitarian energy [95], elements of our analysis have been based on evidence from the wider development literature. New challenges could emerge in humanitarian contexts such as the impact prospects of repatriation or claiming asylum has on household willingness to adopt systems. This paper also only considers SHS and future research could conduct similar analysis of other technologies, such as minigrids or solar lanterns, as well as further research on cooking and institutional energy which could help lower emissions and reduce costs. In terms of the methodological limitations, the PESTLE analysis provides a snapshot which is likely to change as SHS technologies and delivery models develop and the humanitarian energy sector develops. The description of the energy situation in the camps is also only a brief overview and does not capture the full details of energy access in the three camps. There are also methodological limitations associated with the survey used, for example the potential misinterpretation of questions or responses and accuracy of responses, particularly when respondents were asked to recall data over a period of time, such as for energy expenditure. The processes used to validate the findings of this paper are described in more detail in section 2.0 but inevitably would require further repetition to remain up-to-date as the situation in the camps develops.

7.0 Conclusion and Future Research

The objectives of this paper were to address a lack of data currently available on the energy situation in humanitarian settings and to conduct a novel analysis of the political, economic, social, technological, legal and environmental barriers and enablers that need to be addressed to enable widespread adoption and use of SHS. These two objectives were achieved for the case of three refugee camps in Rwanda by presenting an overview of the electricity access situation in households and small enterprises and through the application of a PESTLE analysis which investigated the factors influencing the success of SHS projects.

The results of this analysis demonstrate that access to electricity in the camps is low and that there is limited penetration of modern energy technologies despite demand for the services they can provide. The PESTLE analysis established that there are multiple opportunities, such as ensuring energy interventions align with host country policies and also benefit the local host community, and threats, such as the low and variable incomes of many refugees as well as ensuring good maintenance provision is made that impact the diffusion of SHS in the camps.

Our analysis has also identified a number of areas that justify further research. In particular, there is limited information available in the existing literature regarding how legal (section 4.5) and environmental (section 4.6) factors can influence the diffusion of SHS in humanitarian contexts. Furthermore, while we have been able to identify multiple barriers and concerns present, we have not been able to conduct a barrier analysis which could capture the perceptions of different stakeholders; analyses how these could be addressed would be of value to the sector. As discussed in section 6.0, our analysis only covers the Rwandan context and while efforts have been made to ensure our findings are valid for other contexts, comparison studies that review different countries, particularly those with different climates or policies towards refugees, would be useful.

Overall, the findings of our analysis demonstrate that in order to maximise the diffusion and sustainability of interventions, future SHS projects in refugee camps should aim to (1) evaluate the needs and priorities of refugee and the surrounding host communities in order to match interventions to their requirements; (2) align projects with host country policies related to energy access and policies associated with refugee rights to work and freedom to move outside the camps; (3) ensure that host communities are also able to access the interventions made to avoid potential conflict between local populations; (4) avoid the free distribution of products in all but emergency contexts and especially where local markets are already operating or where they can be developed; (5) integrate the provision of training on energy literacy including the benefits of access to modern energy and delivery models into projects; and (6) ensure minimum standards are adhered to and adequate maintenance is provided by SHS suppliers to avoid system failure and customer dissatisfaction. Addressing these factors will help ensure SHS success in humanitarian settings and will contribute to achieving targets such as the UNHCR Clean Energy Challenge.

Data Availability

Data from the quantitative surveying activities undertaken as part of the RE4R project are available from both the Humanitarian Data Exchange (Humanitarian Data Exchange Practical Action Datasets, 2019, https://data.humdata.org/organization/practicalaction) and the HEED project (HEED Project Data Portal, 2019, http://heed-refugee.coventry.ac.uk/data-portal/).

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