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To climb or not to climb? Investigating energy use behaviour among Solar Home System adopters through energy ladder and social practice lens

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ABSTRACT

Solar Home Systems (SHSs) and other off-grid solutions have shown promise in addressing the energy access gap for those with no or unreliable grid services. With that promise comes the expectation to boost socio-economic well-being of newly-connected households, who will continue climbing up the energy ladder. Despite the growing appreciation for the need to go beyond the techno-economics of energy access, and the recognition of the value of socio-technical systems perspective, the wider sociology of energy consumption and behaviour among adopters of off-grid solar solutions has been poorly explored. In this paper, we apply the Social Practice Theory (SPT) and the energy and solar energy ladder framework to analyse energy consumption and the changing social practices of SHSs users in Rwanda. We find that social practices change dynamically and depend on available appliances, whereas energy consumption follows a complex path but does not increase in a linear manner with time or more appliances. Insights can prove useful for public and private agencies working on off-grid electrification, offering a new perspective on the energy and solar energy ladder concepts while also showing the importance of social aspects of energy access even at relatively low levels of provision currently offered by SHSs.

1. Introduction

Over one billion people are still unconnected to modern energy sources, over half of them in Sub-Saharan Africa (SSA) alone [1]. Solar Home Systems (SHSs) and other distributed off-grid solutions (such as solar lanterns) have shown promise in addressing the energy access gap by helping tackle the problem of energy distribution to those with limited or no access to the grid due to high costs, remote locations and insufficient demand making grid extensions financially unviable [2], as well as to another one billion who are grid-connected but experience unreliable, intermittent services [3], often consuming little to no energy at all [4]. Bloomberg New Energy Finance (BNEF) [5] estimate that at least 89 million people across the developing world have one or more solar lighting products and one in three off-grid households will rely on off-grid solar PV solutions by 2020. Sales in the last few years have been steadily gaining pace, particularly in leading markets of East Africa and South-East Asia (SEA), where a range of off-grid solar products and services have been actively included in the electrification plans [63]. Notable examples include Kenya, Tanzania and Rwanda, which follow perhaps one of the most successful SHSs programmes to date in Bangladesh where over four million systems have been installed as part of the country's Infrastructure Development Company Limited (IDCOL) plan for off-grid regions (IDCOL, 2017).

The growing importance and scale of off-grid solar electrification in SSA and SEA have attracted increased attention in the academic research community. Some of the key questions to which answers have been sought include those around technology design (e.g. [6,7]), financing of and for the off-grid sector (e.g. [5,8–11]), designing business models which best suit the poor (e.g. [12–16]), and the affordability of solar solutions with a focus on willingness to pay (WTP) (e.g. [2,17]). Additionally, it has been debated whether such small-scale solutions can meet the growing energy demands at their current capacity (typically 11–100 Wp), supporting productive uses and spurring economic growth (Azimoh et al., [68]; Brew-Hammond, [67]; Jacobson, [69]; Prasad, [70]). Aklin et al. [18,19] have argued that SHSs benefit end-users by displacing kerosene, however, they have questioned if the wider socio-economic impacts are indeed observed based on the weak evidence found in four reviewed randomised controlled trials (RCTs) in South Asia and Africa. As contended by Wamukonya [65], solar systems, with all their advantages and disadvantages, are not a panacea to the energy challenge and more questions need to be raised to understand the socio-cultural and economic priorities of rural households. This is of particular significance given the widely acknowledged energy stacking practices among not only low income, but also other layers of

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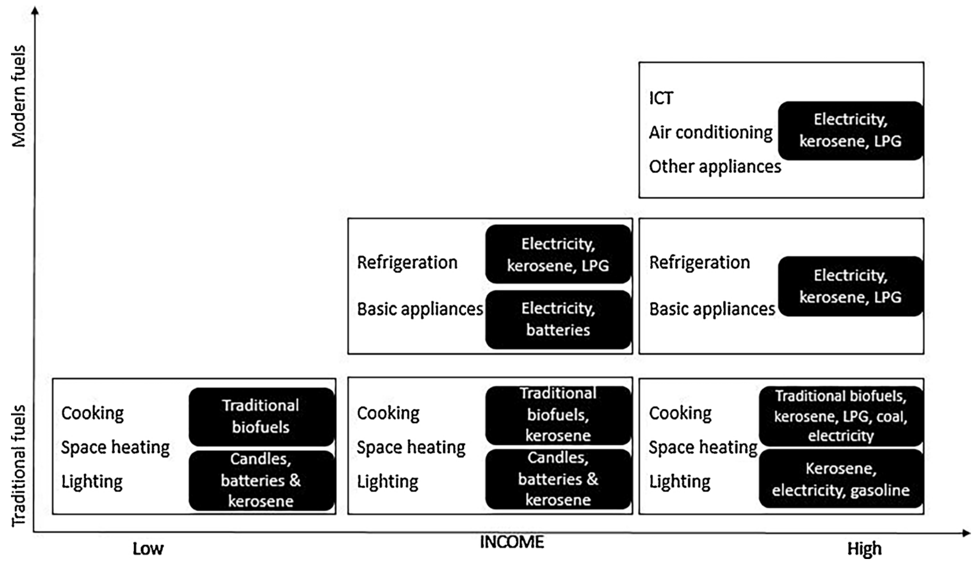

Fig. 1. Energy stacking visualisation. Different energy sources continue to be used over time and regardless of income level.
Source: [23].

society in developing countries. Contrary to the idea of climbing the hypothetical energy ladder, which assumes that both traditional and modern forms of energy are available and households will choose to switch to the next best source as soon as it becomes available and they can afford it (e.g. [20]), it has been shown that both rural and urban households follow more complex energy transition trajectories and tend to rely on more than one energy source as their income increases and improved solutions become available, a term that has been coined as 'energy stacking' (see Fig. 1) ([21–23]; Nansaior et al., [71]; [20]) or 'energy staircase' [24].

In light of the expanding off-grid solar energy market, the idea of a solar energy ladder has emerged (e.g. [25]). It assumes that households will gradually progress from small-scale solar technologies, such as solar lanterns, to bigger SHSs, adding new appliances and increasingly using more energy, eventually switching to solar micro/mini-grids and, if available, the grid [26]. Within that notion, there is an expectation that such progression will automatically contribute to boosting the socio-economic condition of the households concerned (e.g. [27]). To date, studies on the subject have been scarce and present a mixed-results evidence [4,18,19,28]. Harrison and Adams [24] demonstrate that households familiar with smaller solar products are more likely to purchase bigger solar systems, having become familiar and confident with the entry-level solar product. Stojanovski et al. [29] examined approximately 500 early adopters of SHSs and found a significant reduction in the use of kerosene, which points towards a step up the energy ladder for lighting, however, they did not observe substantial income-generation resulting from the use of SHSs. The range of used appliances was also limited. In their study of large-scale infrastructure, Lenz et al. [28] investigated the impact of grid access on households 3.5 years after being connected and found that even after that time energy consumption and uptake of appliances remained low, with no significant impacts on income. These findings challenge the idea that energy consumption increases over time, even when the energy source is, in theory, unlimited and cost-competitive.

While the energy ladder concept recognises the complex social processes which underpin energy stacking behaviour, such as socio-economic and cultural preference for cooking fuels, often associated with history and tradition [22], it still primarily focuses on the techno-economics of energy access. A similar trend has developed in the exploration of the off-grid solutions. As pointed out by Rolffs et al. [30], the dominant considerations of the provision of renewable, off-grid access options have typically been around two-dimensional categories of finance – technology and economics – engineering, often missing the social contexts. A relatively early study that stands out was carried out in Papua New Guinea by Sovacool et al. [31] and through the application of socio-technical change showed how the lack of understanding of social barriers might hinder the success of SHSs adoption and sustainability. In a recent study of rural community energy projects, Cloke et al. [32] put forward a Social Energy Systems (SES) approach for the exploration of scalable delivery models of renewable energy technologies (RET) which tends to the particular needs and aspirations of end-users. In doing so, it moves away from the two-dimensional, techno-logic of understanding the changing landscape of energy transitions in the developing context. In a similar study of a village-level solar power project in Kenya, Ulsrud et al. [33] have applied a socio-technical model design paying close attention to the socio-cultural context and end-users' challenges, demonstrating the value of such approaches in building sustainable, context-relevant off-grid energy systems. Similarly, Urmee and Md [34] have advocated the need to pay closer attention to the social, cultural and political issues while designing off-grid renewable energy programmes, calling for community involvement and the inclusion of community needs in energy policy work.

Despite the growing appreciation for the need to go beyond the techno-economics of energy access, and the recognition of the value the socio-technical systems perspective offers by putting the society and, effectively, the end-user's needs en par with the technology, the wider sociology of energy consumption and behaviour among adopters of off-grid solar solutions, including SHSs users, has been relatively poorly explored. Studies have mostly focused on understanding the experience of end-users concerned by focusing on the array of impacts, with key socio-economic metrics including health improvements due to smoke reduction, extended productive and study hours, savings on energy expenditure and access to phone charging and information [24,35,36].

Given the rapid expansion of off-grid electrification and the predicted continuation of high levels of adoption of off-grid solar PV for energy access, it is important to better understand the energy behaviour as experienced and practiced by end-users. While the energy ladder framework offers a lens of looking at energy consumption and associated behaviours (e.g. appliance adoption), the social practice theories [37,38] provide a framework for deeper exploration of social aspects of energy use in households with off-grid solutions. So far, they have predominantly been used in the context of energy sustainability transitions in the developed countries, particularly in Europe and the US (e.g. [39–42]). Within that discourse, Tang and Bhamra [43] have

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