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A Scoping Review of Adopter Attributes, Motivations, and Barriers of Solar Home Systems Adoption: Lessons for Sub-Saharan Africa

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ABSTRACT

The diffusion of solar home systems in sub-Saharan Africa would reduce the prevalent energy poverty in the region. However, the adoption of solar home systems faces significant barriers that have hampered the adoption process. This paper presents a scoping review that investigates non-institutional factors influencing the Solar Home Systems diffusion process. The study searched three databases, Scopus, ScienceDirect and Web of Science, for conference papers and journal articles that focused on barriers and motivations for adopting solar home systems. The search produced 116 records. After applying the exclusion criteria, 14 papers were included in the thematic analysis. The analysis revealed that affordability and inadequate information on solar home systems are significant barriers to adoption. The analysis further showed that solar home system adopters, typically highly skilled and educated high-income individuals, are motivated by the peer effect, energy security and independence, monetary saving and desire to protect the environment. Finally, the findings suggest that government intervention is essential for the widespread diffusion of solar home systems in sub-Saharan Africa.

Index Terms: barriers, diffusion, motivations, photovoltaic, solar home systems, sub-Saharan Africa

I. INTRODUCTION

Most governments in sub-Saharan Africa (SSA) struggle to provide their populations with access to affordable and clean energy, one of the United Nations' 17 Sustainable Development Goals [1]. One of the forms of clean energy whose usage has grown globally over the past two decades is solar photovoltaic (PV). Solar PV generation has seen rapid increases, reaching 821 Terawatt-hours in 2020, 3.1% of global electricity generation [2]. Most of this increase has been from China, the United States and Europe. The gains were driven by policy interventions such as subsidy-driven deployment, tax credits and feed-in metering [2]. In the absence of similar interventions, Africa has lagged in generating electricity from renewable sources and access to electricity [3]. At 20% in 33 of the 49 SSA countries, the region has the lowest electricity access in the world [4].

In addition to access, SSA suffers from low-quality electricity supply, as evidenced by the frequent electricity shortage problems, often resulting in unannounced load shedding to keep grids from instability [5], [6]. This frequent load shedding has forced middle-class households in SSA to self-generate electricity using diesel generators, thereby contributing to CO2 emissions. This approach is not sustainable. It does not consider the renewable energy sources available in the African continent. Instead, a more sustainable system would be electricity micro-generation using solar thermal, solar photovoltaics, and heat pumps which would be exploited if reliance on fossil fuels is to be reduced [7].

However, Africa's electricity generation from renewables is increasing slowly, only growing by 6% between 1985 and 2020 [3]. The contribution of solar generation is even more minor, only 2.23% as of 2020, despite having excellent conditions for PV electricity [3], [8]. SSA's long term daily power output achievable by PV exceeds 4.5 kilowatt-hours per installed kilowatt peak (kWh/kWp) [8]. As the continent with the lowest

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access to electricity, this high PV electricity potential suggests potential in SSA for future growth of solar home systems (SHS) installations. SHS are solar PV systems that are used in the microgeneration of electricity in individual houses. They could contribute to energy security and autonomy by reducing dependency on the grid [9]–[13]. In addition, SHS installations could mitigate climate by reducing the dependence on biomass for cooking. The use of biomass for cooking and water heating contributes to deforestation and emissions of CO2 [14].

Unlike China, the United States and European countries, most African countries cannot solely depend on institutional level financial incentive approach to fasten SHS adoption. This scoping review investigates non-institutional factors influencing the SHS diffusion process. It builds on a previous review of SHS in SSA [15] by focusing on household-level factors influencing SHS adoption, particularly those relevant to SSA. The findings and recommendations would assist policymakers, academics, and other energy stakeholders in SSA to develop interventions that would promote the adoption of residential SHS. In addition, increasing SHS installations is crucial for SSA countries to ease the pressure on their electricity grids and provide access to off-grid communities.

II METHODOLGY

This scoping review followed the five-step framework developed by Arksey and O'Malley [16].

A. *Step 1: Identifying the Research Question*

The following question guided this scoping review of the barriers and enablers of the adoption of SHS: What household-level factors facilitate or constrain the adoption of SHS?

B. *Step 2: Identifying Relevant Studies*

The author searched the three databases, Scopus, ScienceDirect and Web of Science. The searches were performed on 24 November 2021 and targeted the fields, title, abstract, and keywords. The author used search string (*Solar photovoltaic OR PV*) AND (*residential OR home OR domestic*) AND (*barriers OR enablers*) AND (*ownership OR adoption*).

C. *Step 3: Study Selection*

The scoping review included all conference papers and journal articles published up to November 2021. The scope of the review encompassed literature focussing on the barriers and enablers of the adoption of SHS. This included articles focusing on electricity generation from solar for cooking, lighting, and other domestic electricity usage. All records were selected without a time limit.

The titles and abstracts of the records were screened to exclude those that fit the exclusion criteria. The study excluded literature that was not published in English, which focused on policy, commercial electricity users, community solar projects or solar PV as part of microgrids. Also, literature focusing on post-installation issues such as payback period and installed system efficiency was removed. Finally, after eliminating duplicates and initial screening, the full texts were imported in Mendeley reference manager for eligibility screening and to streamline the review process.

The screening process is summarised in Figure 1, and fourteen publications were considered relevant for inclusion in the analysis.

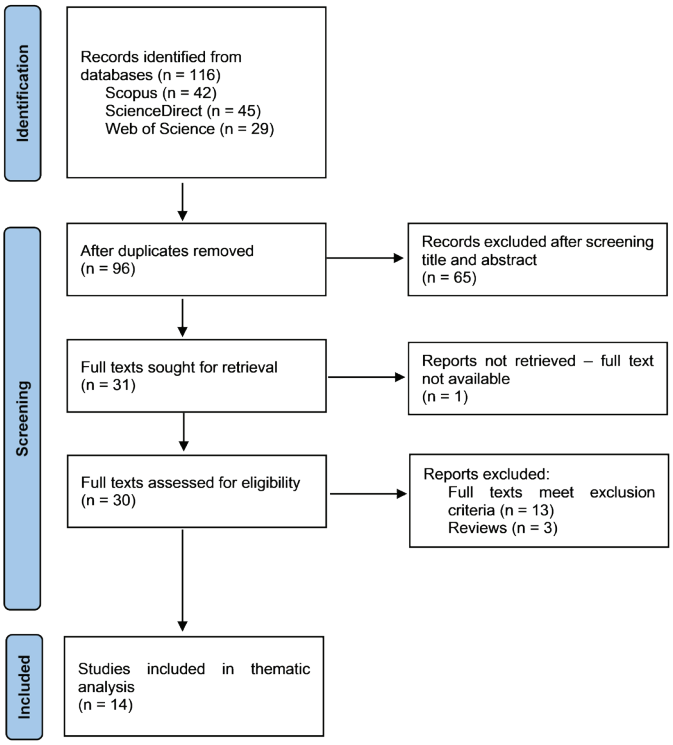

Fig. 1. Modified PRISMA flow diagram illustration of the study screening process.

D. Step 4: Data Charting Process

The included studies were imported into NVivo for thematic synthesis and analysis.

Study characteristics, including the publication type, setting, year, were input as file classifications and attributes in NVivo to facilitate data display and comparison. The author performed the data extraction, and a peer reviewer audited the process for confirmability.

The thematic synthesis comprised three concurrent flows of activity: (1) data condensation through coding, (2) data display through charts, maps and diagrams and (3) theme development and verification [17]. This process was conducted by the author and audited by a peer reviewer.

E. Step 5: Summarising Results

The results are reported according to PRISMA guidelines extension for scoping review [18].

III. RESULTS

The searches returned 116 journal papers and conference papers, 42 in Scopus, 45 in ScienceDirect, and 29 in the Web of Science. Table I summarises the characteristics of the studies included in the scoping review.

Most of the reviewed studies were conducted in United States (n = 4), the remaining in Sweden (n = 2), Pakistan (n =2), Australia (n = 1), Finland (n = 1), New Zealand (n = 1), Vietnam (n = 1), United Kingdom (n = 1) and Nigeria (n = 1). The earliest was conducted in 2013, and the highest number was three studies in 2017, 2019 and 2020. There was one each in 2014 and 2018, two in 2016 and no studies in 2015 and 2021.The synthesis included a thematic analysis process that uncovered four themes: household attributes that influence SHS adoption, household-level barriers to SHS adoption, motivations for SHS adoption and outcomes of SHS adoption. The themes and their subthemes are presented in Table II, and their overviews are presented in the following sections.

TABLE I
SYNTHESIS OF INCLUDED STUDIE

First author, date, reference	Country	Purpose	Sample and data collection	Methods	Relevant/main findings
Balcombe et al., 2014, [7]	United Kingdom	- To identify the motivations and barriers associated with adopting microgeneration. - To determine the relative weight of each factor. - To identify policy interventions that would be implemented and the corresponding target population.	Sample: SHS adopters, considerers and rejectors: - 291 respondents to an online survey - 12 participants for semi-structured interviews	Mixed methods: - Quantitative analysis of online survey results - Qualitative analysis of semi-structured interviews	- SHS adopters are motivated by energy security – protection from future increases and independence from power companies. - SHS adopters think they save money from utility bills/earn money from the feed-in tariffs. - High initial costs are a barrier to SHS adoption. - Insufficient information is a barrier to SHS adoption.
Do et al., 2020, [19]	Vietnam	- To find the drivers of the initial boom in SHS adoption in Vietnam. - To identify potential barriers to future expansion. - To identify approaches that facilitate future expansion.	Sample: government agencies and departments, non-governmental organisations, multilateral partners, universities and research entities: - 46 interviews - Five focus groups - Documents	Mixed method – inductive approach: - Qualitative analysis of interview and focus group data. - Qualitative and quantitative analysis of documents.	- Enabling factor – ready market availability of PV technology and low cost due to proximity to China - Utility-scale PV faces more enormous barriers than SHS. - Barrier to SHS – high upfront costs (65% of respondents) – US$1117/kW. - Barrier to SHS – complex and cumbersome approval procedures. - A barrier to SHS – lack of technical information and assistance (46% of respondents).
Fikru, 2020, [20]	United States	- To examine household, community and county-level variables explaining energy savings of SHS adopters.	Sample: SHS adopters and considerers: - Survey – 1577 households	Quantitative analysis.	- SHS adoption influenced by electricity tariffs – higher tariffs are an incentive to adopt SHS. - Local regulations and policies influence SHS adoptions – electrical and fire codes can be barriers. - Homeowners, retirees, higher income and higher educated occupiers are more likely to adopt SHS.
Ford et al., 2017, [21]	New Zealand	- To explore factors driving PV uptake in New Zealand.	Sample: SHS adopters and stakeholders in the PV supply chain: - 18 interview participants – PV supply chain stakeholders. - 19 interviews with SHS adopters.	Theoretical framework - energy cultures framework and multi-level perspective. Qualitative analysis – thematic analysis.	- SHS adopters motivated by energy security (independence from power companies and protection from future increases). - Perceived poor ROI because of low feed-in tariffs. - Quality and access to information on PV technologies and economics influences SHS adoption. - Peer effect- seeing someone in the community adopting SHS has a positive influence on SHS adoption.

Ford et al., 2017, [21]	New Zealand	- To explore factors driving PV uptake in New Zealand.	Sample: SHS adopters and stakeholders in the PV supply chain: - 18 interview participants – PV supply chain stakeholders. - 19 interviews with SHS adopters.	Theoretical framework - energy cultures framework and multi-level perspective. Qualitative analysis – thematic analysis.	- SHS adopters motivated by energy security (independence from power companies and protection from future increases). - Perceived poor ROI because of low feed-in tariffs. - Quality and access to information on PV technologies and economics influences SHS adoption. - Peer effect- seeing someone in the community adopting SHS has a positive influence on SHS adoption.
Graziano et al., 2019, [22]	United States	- To typify SHS adopters and characterise the influence of peer effects in the PV diffusion process.	Sample: SHS adopters in four Connecticut towns – Hartford, East Hartford, Glastonbury and Manchester - Data from Census 200 and 2010 and Connecticut Energy Financial and Investment Authority (CEFIA).	Quantitative approach: - Inferential statistics and spatial modelling	- SHS adopters are typically high income and older homeowners. - Peer effects – keeping up with the Joneses – are influential in the short-range (0.5 miles). - Renters have less incentive to adopt SHS.
Karjalainen et al., 2019, [23]	Finland	- To deepen understanding of barriers faced and the experiences of early SHS adopters in Finland.	Sample - 28 owners of single-families houses (all over Finland). Data collection - 6 face-to-face interviews and 22 telephone interviews.	Qualitative analysis of interview data. - thematic analysis.	- It is possible to overcome some of the barriers to SHS adoption: - Some SHS adopters overcame inadequate knowledge by sharing knowledge and pooling resources to solicit expert advice. - Some SHS adopters reduced initial PV costs by pooling resources, buying in bulk, and self-installing SHS. - Adopters derive socio-psycho- and ideo- pleasures from using SHS. They become more aware of their energy usage.
Khalil et al., 2017, [13]	Pakistan	- To investigate the issues, including barriers, of diffusion of solar PV at the household level.	Sample – 48 households in Peshawar Pakistan – sample included 24 SHS adopters and 24 non-adopters. Data collection - semi-structured questionnaire-based interviews.	Quantitative data analysis: - descriptive statistics.	- Most respondents (74%) believe that impact of load shedding can be eliminated by using SHS. - Some people (50%) worry about battery cost and lifespan when considering adopting SHS. - There is some distrust in SHS that needs to be overcome before widespread adoption of SHS.
A. Palm, 2017, [24]	Sweden	- To deepen understanding of the underlying mechanisms behind the social influence of peers in SHS adoption,	Sample - 95 SHS adopters (65 valid responses) and 16 telephone interviews, sample not representative. Data collection – questionnaire and semi-structured interviews.	Mixed methods approach - Quantitative analysed using descriptive statistics. - Qualitative data mainly was for confirmation/explanation of qualitative data.	- Peer effects are more potent when considerers know the adopters before contact – 20% influenced (25% raised interest) by someone in their neighbourhood, 20% (22% reported an increased interest) by someone outside their community, 18% (20% reported an increased interest) by seeing SHS in their neighbourhood. - Considerers inquiries focused on SHS economic performance, technical characteristics and subsidies. - Most SHS adopters were old, youngest 49 years old and highly skilled/educated. - Adopters expressed interest in environmental issues - Peers influential in raising interest in SHS.
J. Palm & Eriksson, 2018, [25]	Sweden	- To uncover how households gather and use information about SHS and to discuss how this can be optimised.	Sample – 44 households (14 had SHS installed, 25 bought but waiting for installation). Data collection – semi-structured interviews.	Qualitative approach - Thematic analysis.	- Some non-adopters do not have sufficient information on SHS- e.g. confusing SHS with solar water heaters. - Some non-adopter worry about perceived violation of SHS to esthetics to their house. - Environmental engagement is antecedent to SHS adoption.
Qureshi et al., 2017, [12]	Pakistan	- To investigate household level issues affecting the adoption of SHS.	Sample – 36 households (9 off-grid SHS, nine on-grid SHS and 18 non-adopters) – Lahore. Data collection – interviews, semi-structured questionnaire-based interviews.	Mixed method approach – informed by Rogers' model of innovation diffusion.	- 86% of respondents cite energy security (eliminating impacts of power outages) as a driver of SHS adoption. - Most SHS adopters use other energy sources – including generators. - High initial cost and absence of financing are significant barriers to SHS adoption. - Social acceptance of SHS (peer effect) is crucial for the adoption and sustenance of SHS. - Environment concerns ranked highest among the motivators of SHS adoption.
Rai and Robinson, 2013, [26]	United States	- To study and characterise information networks associated with SHS adoption in Texas. - To uncover how potential adopters mitigate uncertainties and non-monetary costs associated with SHS adoption.	Sample – 365 SHS adopters (40% of the 922 contacted). Data collection – online survey (questionnaire).	Quantitative approach: - Descriptive statistics. - Hypothesis testing.	- The level of uncertainty about SHS adoption is reduced if SHS information is acquired from a trustworthy source. - Peer effects are not limited to the same neighbour – could be friends or family that do not stay in the same neighbourhood. - Peer effects reduce the time a considerer takes to become an adopter. - One of the underlying drivers of peer effect is the perceived trustworthiness of neighbourhood contacts, friends and family.

Rai et al., 2016, [27]	United States	- To analyse SHS adopters decision-making process with a focus on the role of the information search process in mitigating adoption barriers.	Sample - 380 completed responses (out of 2131) Data collection – survey (questionnaire).	Quantitative approach - Descriptive statistics. - Multivariate econometric modelling.	- An increase in electricity tariffs motivates SHS adoption, particularly for those approaching retirement. - It is possible to have high SHS adoption without peer effects – 53% reported no prior SHS in their neighbourhood. - Interest ins SHS adoption can be initiated by spark events such as direct marketing, an encounter with an SHS company at a retail store event. - 82% co-adopted SHS with other energy-saving products.
Ugulu and Aigbayboa, 2019, [10]	Nigeria	- To investigate the motives for SHS adoption by private consumers in urban Nigeria.	Sample – 14 SHS adopters Data collection – open-ended semi-structured interviews.	Mixed method approach – primarily qualitative with some quantitative reporting: - Thematic analysis - Descriptive statistics	- 80% of the respondents indicated that the adopted SHS to ensure reliable energy supply – Nigeria has frequent load shedding. - Slightly less than 60% were motivated by savings in utility bills.
Zander, 2020, [28]	Australia	- To assess the relative importance of barriers and motivations of those adopting SHS in Australia.	Sample – 1126 respondents from 1400 selected to participate. Data collection – online questionnaire – data collection subcontracted to an external company.	Quantitative approach: - Descriptive statistics.	- For Australian SHS adopters, reducing electricity bills (16%) was more important than avoiding future increases in electricity prices. - Contributing to the reduction of CO_2 was the 4th most crucial motivation for SHS adoption. - High initial costs and low feed-in tariffs were considered significant barriers for lower-income adopters, not so much for high-income adopters.

TABLE II
THE THEMES AND SUBTHEMES THAT EMERGED FROM THEMATIC ANALYSIS OF INCLUDED STUDIES

Theme	Subtheme
Household attributes that influence SHS adoption	Skilled, educated, older and high household income Interested in preserving the environment Energy efficiency literate Co-adoption of other renewable energy and efficiency measures
Household-level barriers to SHS adoption	Affordability - high capital investment and maintenance costs - components such as batteries Scepticism about benefits of SHS Inadequate and untrustworthy SHS information Complex administrative requirements for SHS installation
Motivations for SHS adoption	Peer effect - keeping up with the neighbours Energy security – protection against future electricity price increases Energy autonomy independence from electricity supply companies Monetary savings - save money due to reduced utility bills Environmental – help protect the environment
Outcomes of SHS adoption	**Awareness and interest in energy politics** **A better understanding of own energy usage** **Socio-, psycho- and ideo-pleasures of SHS ownership** **Energy behaviour change**

A. Household Attributes that Influence SHS Adoption

Most of the studies found that adopters shared similar attributes. They were older than average [7], [25], [27], professionally skilled or highly educated [7], [20], [23]–[25], [27], [28], had a higher household income, were energy efficiency literate [10], [21], [23], [25] and were interested in environmental issues [24], [25]. It is worth noting that there was one contrary finding on the age of adopters. An Australian study by Zander [28] found that younger people, motivated by environmental concerns, also adopt SHS.

The adopters were generally interested in environmental issues and technologies that developed over time [24], [25]. As a result, their interest was broader than SHS, covering broader renewable energy issues and politics. This broader interest was shown in their co-adoption

of renewable technologies [7], [12], [20], [21], [23], [27]. They co-adopted efficient heating/cooling systems, solar thermal systems, hydro, wind turbines, battery storage, and smart thermostats. These other technologies had been adopted either prior, simultaneously or after adopting SHS. Qureshi et al. (2017) and Ugulu and Aigbayboa (2019) found a different co-adoption pattern in Pakistan and Nigeria. The SHS adopters co-adopted fossil fuel-driven power generators.

The studies suggest that adopters and rejectors have similar income and education statuses, whereas considerers have lower incomes. It is worth noting that although adopters and rejectors share several traits, J. Palm and Eriksson [25] found that rejectors had relatively lower knowledge of energy efficiency technologies. Also, rejectors had different motivations than adopters. For example, J. Palm and Eriksson [25] report that rejectors in their study were more concerned about the impact of SHS on the esthetics of their houses and of whether their neighbours would approve of SHS installations.

B. Household-level Barriers to SHS Adoption

The studies showed that households are deterred from adopting SHS by affordability - high capital investment [12], [13], [19], [21], [28] and high maintenance costs – components such as batteries need to be replaced at some intervals [12], [13], [21], [28], inadequate and untrustworthy SHS information[7], [19], [21], [23], [25], [26], scepticism about benefits of SHS[12], [21], [23], [27], [28] and complex administrative requirements for SHS installation [19], [20].

The two elements of affordability, high initial costs and the cost of batteries, are related [12]. However, it is possible to have an SHS without incorporating energy storage through batteries. Although this would reduce the initial cost of SHS, it would mean that some of the electricity generated would not be used unless there is some feed-in to the grid. Having a feed-in system when the household energy demand is lower than self-generated electricity then recouping this when household demand is high would eliminate the need for batteries. Unfortunately, this is beyond the control of households and depends on the energy policies of countries [21], [28].

With or without battery storage, there is consensus among adopters, considerers and rejectors [13] that high initial costs are the most significant barrier to SHS adoption [12]. In Zander's study [28], owners ranked high initial costs as almost two times more important than the second rated barrier. Also, Balcombe et al. [7] found that for considerers and adopters, the high initial costs were 50% more significant than any cost saving that they would make from installing SHS.

SHS adoption is also constrained by a lack of clear, impartial, and trustworthy technical and financial information on SHS viability [7]. Because of the significant initial capital investments, households want real tax incentives, feed-in tariffs and future electricity pricing estimates. However, when potential adopters have difficulty processing the available information, they become sceptical of potential financial and environmental benefits of installing SHS or prolong the period they take to move from considerer to adopter [26]. Do et al. [19] showed that households are also concerned about the lack of credible information about the quality and reliability of SHS and service providers. This is a challenge because most of the information on SHS is provided by service providers. Some studies suggest that this anxiety is reduced if the information on SHS was provided by a government entity, the utility companies or the potential adopter's peers [24]–[26].

In some cases, the barrier of the lack of credible information on SHS was accompanied by the scepticism of SHS financial benefits, often associated with the uncertainties of calculating the payback period for SHS installations [21]. In their study, Karjalainen et al. [23] reported that the payback period for SHS installations is often long, 15 to 25 years. This long payback deters older potential adopters. In addition, there are uncertainties in the estimates of payback for such long periods because the future pricing of electricity is unknown. Furthermore, Zander [28] reported that some potential adopters are sceptical of the environmental benefits of solar panels.

C. Motivations for SHS Adoption

The included studies showed that SHS adopters are motivated by the desire for energy security [7], [21], [28], energy autonomy [10], [12], [13], [21],

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[28], saving money from reduced electricity bills [10], [20], [28], environmental protection [7], [12], [23], [28] and the peer effect [12], [22]–[24], [26], [27].

The respondents in most of the cited protection from futures rise in electricity prices and protection from load shedding as critical motivators of SHS adoption. Most SHS adopters, notably those older, indicated that they needed protection against future rises in electricity prices [21]. This motivation was cited by those who had retired or were near retirement and those who became off-grid. The past rises in electricity costs informed the stance of these households. For example, one adopter from the study by Ford et al.[21] indicated that they installed SHS because electricity prices had gone up by 24% over the previous three years.

SHS adopters, particularly those in developing countries, also mentioned protection from loading shedding as a critical motivator for their adopting SHS [10], [12], [13]. In a Nigerian study by Ugulu and Aigbayboa [10], 80% of SHS adopters cited energy security in the form of reliable energy supply as the main reason they adopted SHS. These SHS adopters co-adopted power generators with SHS installations, further signalling the importance of reliable energy supply, even more, important than improving the environment. Khalil et al. [13] suggested that the co-adoption with power generators might sign of distrust in standalone SHS.

Another frequently stated motivation for adopting SHS was protecting the environment. However, the relative importance of adopting SHS to preserve the environment is unclear. For example, the study by Balcombe et al. [5] ranked protecting the environment as the fourth most crucial motivator, less important than saving or earning money. Despite this, the study found that SHS adopters were more inclined to present their SHS installation to others to indicate their environmental commitment. The study by Zander [27] ranked protecting the environment as the third overall. However, they found that it was the dominant reason among younger adopters.

Several studies suggested that some SHS adopters were influenced by their peers [12], [22], [24], [27] or by the desire to inspire others to produce clean energy [7], [23]. Graziano et al. [22] suggested that these peer effects are effective in the short range as potential adopters as vicariously influenced by their neighbour SHS installations. Also, it is efficacious for potential adopters could seek information on the quality and economics of SHS installations from people in their community other than from outsiders. Finally, A. Palm [24] extended the peer effect beyond the same neighbourhood blocks to include potential adopters' co-workers and friends.

Peer effects are essential for raising potential SHS adopters' interest and speeding the decision time between considering and adopting [22], [24], [26], [27]. A. Palm [24] categorised peer effects into active, where there is direct interpersonal contact, and passive, where there is vicarious influence. A. Palm's study [24] found that passive peer effects were less influential than active peer effects in the SHS diffusion process. As a result, they were less likely to lead to direct contact with SHS adopters. Potential adopters use direct communication to obtain and verify SHS information and confirm that SHS adoption would be a sound choice. According to Rai and Robinson [26], direct contact with SHS adopters is the single most effective strategy to spending up decision time between considering and adopting. They found that direct contact can shorten decision times by as much as 4.6 months.

D. Outcomes of SHS Adoption

Most respondents indicated that they found the potential financial return of SHS adoption challenging to establish because of uncertainties of computing the SHS payback period study [23]. However, the SHS adopters realised monthly savings in electricity bills [20]. The included studies showed that SHS adoption has other non-monetary outcomes. SHS adoption often contributes to energy behaviour change, such as using high power-consuming appliances when solar energy is available. Also, SHS adopters co-adopt other renewable energy interventions, monitor their energy consumption and purchase more efficient appliances [12], [23], [27]. Furthermore, some SHS adopters gain new awareness and interest in energy politics; SHS adopters often talk about energy policies and energy-saving technologies, thereby contributing to peer effects [23].

IV. DISCUSSION

This scoping review provides an overview of household-level factors that influence SHS diffusion that might potentially influence SHS diffusion in sub-Saharan Africa, thereby extending the work of Kezilcec and Parikh [15], a general review of SHS diffusion in sub-Saharan Africa. Although the review aims to inform policy on SHS diffusion in sub-Saharan Africa, the included studies were not geographically limited to maximise the factors that would be uncovered.

The review found that the SHS diffusion is influenced by household attributes, including income, age, and education status of potential SHS adopters. SHS adopters are motivated by monetary, environmental, energy security and independence concerns. Also, peer effects influence SHS adoption. On the other hand, affordability arising from high capital and maintenance costs was found to be a major barrier to SHS adoption. The other barriers are inadequate and untrustworthy information on SHS, the complex administrative approval process for SHS installations and scepticism about the potential benefits of SHS adoption.

A. Practical Implications for Sub-Saharan Africa

The findings suggest that government support is required for the widespread adoption of SHS in regions such as SSA because most potential adopters have low incomes and are not highly educated. Increasing SHS uptake would be the most productive way of minimising the energy poverty prevalent in SSA. For this to be done, there is a need to reduce the barriers to SHS adoption, particularly the significant barriers of affordability and availability of quality SHS information.

Minimising the affordability barrier is crucial for SHS adoption in SSA as most households cannot afford the high one-off payment for SHS [4]. Therefore, there is a need for SSA countries to develop financing systems for SHS installations. One approach is the Pay-As-You-Go (PAYG) system was tried in Kenya [29], [30]. PAYG approach eliminates the initial costs of SHS, thereby allowing homes to make payments based on their electricity. However, the disadvantage of the PAYG approach is that the household will never become owners of the SHS, thereby limiting their direct economic benefits of ownership.

Other approaches include supporting hire purchase of SHS through access to government-supported microfinancing, subsidies for purchasing SHS and generous feed-in tariffs. SHS ownership in SSA is unsustainable without government support due to payback period uncertainties and high repayment due to most banks' preference for short loan periods [4]. Short loan periods require higher repayments, making SHS financing less attractive for most SSA households who live below the poverty line. Thus, SSA governments need to subsidise or finance SHS loans to mitigate this challenge. Examples from other developing countries such as Laos and Vietnam show that if properly implemented, financing and cost recovery of SHS installations through generous feed-in tariffs could contribute to SSA's rapid electrification [4], [19].

For sustainable and rapid adoption of SHS, the challenge of the availability of clear and trustworthy information needs to be addressed [19], [21], [23], [25]. Evidence from the scoping review suggests that the barrier of inadequate information might be more potent in SSA as most people in SSA are not as educated as the participants in the included studies. A multi-sector approach to SHS information dissemination might be more appropriate to counter the barrier. Governments, SHS experts and the private sector could collaborate to provide information on various options of SHS and to champion SHS adopters. These stakeholders would also facilitate joint ordering of SHS, a proven effective strategy speeding the SHS diffusion in Finland [23].

B. Limitations and Future Research

The scoping review is not without limitations. The review inadvertently excluded other relevant literature by limiting the search to publications indexed in Scopus, ScienceDirect and Web of Science. For example, the study excluded reports from entities such as the World Bank and the International Energy Agency, which potentially contribute to the subject. In addition, the literature search was not geographically limited, and as a result, some of the nuanced contextual issues relevant to SSA might not have been captured. Therefore, this limitation needs to be addressed in future research to determine

which factors highlighted in this study apply to SSA. Further, future research needs to quantify the relative importance of each of the identified factors to SSA countries. This information would facilitate more targeted interventions to fasten SHS adoption in the region.

V. CONCLUSION

The findings of this scoping review suggest that widescale diffusion of SHS cannot happen in SSA without government support. The included studies showed that a typical adopter of SHS is a highly skilled and educated high-income individual who is energy efficiency literate and environmentally cognisant. This profile is opposite to that of a typical resident of sub-Saharan Africa, indicating that it is unlikely that household driven SHS adoption would happen in SSA. The profile of residents of SSA makes the two main barriers, the affordability and information barriers, more potent. Therefore, SSA governments would need to intervene to mitigate the influence of these barriers.

The reviewed papers highlight gaps for further research. Further research is needed to uncover which factors are relevant for SSA and quantify their relative importance in the SHS adoption process. This information is essential for developing targeted interventions to mitigate the barriers and promote SHS adoption in the region. In addition, speeding up SHS adoption is crucial for eliminating energy poverty prevalent in the region. This review contributes by uncovering the factors that need to be considered in developing SHS diffusion policy.

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