Title: Adoption rationales and effects of off-grid renewable energy access for African youth: A case study from Tanzania

Abstract

Inclusive energy access remains elusive globally. Centrally planned energy infrastructures tend to neglect marginalised and disparate populations while upfront costs make it rare for lower-income actors to adopt off-grid renewable energy. This article identifies one emerging response by low-income actors to secure access to through solar photovoltaic energy and an innovative micro-finance enterprise. The AMP framework (awareness, motivation and pathways) is used to explore how and why Tanzanian youths are adopting solar photovoltaic energy and with what effects. Qualitative interviews and field observations indicate awareness and motivational factors of technology, cost, warranty and service influence initial adoption decisions. Nodes of off-grid renewable energy associate with co-benefits of poverty reduction, low-carbon energy access and diversification away from livelihoods that are highly vulnerable to climate change. Framed as a ‘pathway’, the innovative financing mechanism in this case presents an inclusive model of energy access. These findings extend the AMP framework to include consideration of obstacles within the notion of pathways. The case highlights a potential model for energy access and emerging nodes of decentralised and distributed energy modalities, that are potentially more climate resilient, as low-income actors seek to secure access.

Key Words: adoption rationales; energy poverty; energy access; renewable energy; human capabilities

List of abbreviations including units and nomenclature:

- SAC: ‘Solar as Capital’ microfinance initiative
- SDG: Sustainable Development Goals
- Solar PV: Solar photovoltaic energy systems
- SHS: Solar photovoltaic home system
- US\$: United States Dollars

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8 **1 Introduction**
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10 One in every five people on the planet - over 1.2 billion people - remain without access to
11 electricity [1]. Less than 35% of Africans in sub-Saharan Africa have electricity access [2, 3] and
12 the majority of these, approximately 640 million people live in rural areas, while recent
13 improvements in access in Africa has been generally limited to urban areas [4]. This general lack
14 of access threatens to undermine the potential realization of the Sustainable Development Goal 7,
15 which aims to ensure access to affordable, reliable, sustainable and modern energy for all [2, 4].
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19 Despite recognised benefits [5], and growing popularity [6], lower-income nations are not adopting
20 renewable energy as fast as higher-income countries [7]. Contrasting this broader challenge,
21 although over 63% of Tanzanians have no access to the national power grid [8], there is an
22 emerging trend in adoption of off-grid renewables in Tanzania and region more broadly [9-13].
23 Therefore this research set out to explore how and why Tanzanian youth were adopting solar
24 photovoltaic energy (Solar PV) and with what personal effects. The research explored the
25 relationship between a locally owned and operated business of low-income rural and peri-urban
26 youth who engaged in a micro-capital investment program known as Solar as Capital (SAC). The
27 study used the AMP framework ('awareness', 'motivation' and 'pathways') to explore these nodes
28 of energy access and what rationales drove adoption.
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32 The following section outlines the challenges to universal energy access in the African context.
33 This is followed by the methodology explaining the interviews, case study and analytical
34 framework used to inform the enquiry. Results are presented and structured according to the AMP
35 framework, outlining how and why Solar PV is being adopted and the self-reported effects on
36 living conditions. The discussion section then highlights how these observations extend the AMP
37 framework to include obstacles to access. General enablers and barriers to energy access are also
38 identified. It further highlights the key attributes of the case study that have contributed towards
39 inclusive energy access and locates these findings within broader energy access imperatives
40 associated with non-state responses to resource scarcity. Conclusions reference the policy
41 relevance of the findings and future research directions for extending energy access, particularly
42 to rural and low-income communities.
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2 Challenges to universal energy access

2.1 Actors, institutions and context

Global electrification rates currently sit at 82% [14]. While developing countries have an aggregate electrification rate of 76%, sub-Saharan Africa sits at less than 35% [14]. Although Africa invests about US\$8 billion annually on energy this is only about one sixth of the estimated US\$41-55 billion annual investment considered necessary every year till 2030 to ensure universal access on the continent [3]. To answer this challenge, renewable energy has been proposed as one of the potential solutions to energy access, particularly to provide access to disparate rural communities [4, 14]. However, financial and economic factors, coupled with technical, environmental, social and regulatory factors all affect adoption of renewables in a national energy mix and across multiple levels of society [7]. Further, World Bank funded energy projects in East Africa only have a thirty-seven percent success rate indicating limits to top-down approaches [15]. Existing renewable energy enterprises endorsed by the Tanzanian government, for example, have tended to foster donor dependency and have ambiguous effects in long term rural energy transformation [16].

A noted means of advancing towards universal access is the introduction of new actors and institutions in the energy sector [3, 17] such as decentralised renewables [17, 18] and small, medium and micro enterprises. Yet concentration on central governments and utility providers to provide universal access, including their integration of renewables in national energy mixes [18], has left the potential role of both private and low-income actors less considered. There is a lack of understanding of the role non-state entities can play in countries like Tanzania's developmental trajectory, or in that country's energy sector in particular [19]. It is therefore unclear how non-state actors might contribute towards a low-carbon and climate resilient future for Africa. It is also currently unclear what governance arrangements would best complement or facilitate transitions to decentralised electricity systems [20], and improve access to essential goods in general [21].

Private entrepreneurs and low-income actors face a range of specific challenges to energy access in Africa. While both international stakeholders and the national government often advocate for or declare they will provide, financial incentives to individuals pursuing off-grid solutions, to date they have seen limited success in Tanzania [16]. Policies often concentrate on enabling conditions for renewable energy solutions [16], with an assumption that private actors have access to finance

[22]. However, they often lack the nuance and specificity of contextually informed obstacles to success that an indigenous enterprise might manage on an everyday basis. Further, there is a current funding gap within the off-grid energy sector on the continent as a whole, and particularly in East Africa [23]. As such, the cost of batteries and other parts manufactured internationally has led many scholars to suggest the success of off-grid Solar PV electrification in Africa is contingent on external or donor financial support [12, 24].

There is an emerging body of thinking among transition theorists concerned with how people are seeking to secure key public goods amidst failure or disruption of conventional infrastructures [25, 26]. Severe political, financial, or environmental disruptions can put pressure on an existing energy regime and its established infrastructure configurations including those relating to the reach of the State [21]. This has become particularly importance given the current and projected impacts of climate change on energy and other infrastructures [21, 25-31]. Rather than focusing on conventional state actions, this approach simply asks how and why a broad range of entities (public and private) are securing their own needs, in this case energy access, and what assemblage of infrastructures are adopted by the full range of actors to ensure delivery of such public goods. These nodes create geographies or bubbles of access and security that entities have established for themselves – independent of the actions (or inaction) of the state for that essential good [21, 26, 30].

2.2 Low-income communities and energy access

Decentralised Solar PV systems with capacity for feasible economic enterprises have generally remained affordable only to higher income groups, as noted in cases from South Africa, Namibia, Ghana and Kenya [24]. This aligns with broader trends in other essential goods such as water, education, health and insurance in Africa and elsewhere [21, 26, 30, 31]. Existing government policies supporting renewable energy, the availability of technology and possibility of decentralisation and off-grid arrangements, do not in themselves guarantee energy access [32]. Yet, improved access to electricity has been observed to increase both economic and educational opportunities for low-income groups [33, 34].

Little is known about the reasons why low-income and non-state actors adopt renewables in Africa. Adoption rationales in other contexts, such as California and Massachusetts (USA), are influenced by cost savings, solar system reliability, installer warranty, and reviewer ratings of the installer

[35]. Globally, behavioural traits have been shown to interact with economic, socio-demographic and technical predictors of adoption with age and income, and financial knowledge as key categories [36]. A study from the Netherlands found homeowners can also influence others in their social network and become ambassadors for adoption [37]. Further, adoption in India has been driven by technology awareness [38]. Yet the limited generalisability of such cases requires an understanding of how and why people are adopting renewable energy in the African context.

Lack of energy can be a compounding factor in cycles of socioeconomic poverty and is at the forefront of scholarship concerned with energy justice [39-41], decentralisation, marginalisation and sustainability [41]. Energy security has also emerged as a theme within energy justice scholarship concerned with supply and production as well as insecurities which need to be mitigated [39]. There is an increasingly clear idea of the connection between energy deprivation and poverty [2, 42], the multidimensionality of energy poverty [42], and nuanced differentiation between objective and subjective measures of fuel poverty [43]. Lack of energy access has been observed to spatially overlap with socio-economic poverty. For example, large parts of Africa's rural population are excluded from access to Africa's urban economies and electrical grid connection [3, 12, 44]. However, such indicators hide the distribution of winners and losers for both income growth and energy access [40]. It is therefore important to consider the inclusivity and exclusions of such 'progress' [45]. For example, as men and women access and use energy differently, particularly in Africa, transformations in type and inclusivity of access to energy holds potential to ameliorate the current disproportionate burden of energy on woman [46, 47].

Yet very little is known about the effects of energy access, particularly the generalisable relationships between adoption of renewable energy, livelihood transformation and escape from poverty [48]. Further relatively little is known about the relationship between off-grid energy and escape from poverty, particularly as they relate to aspirations and African contexts where access holds the potential to contribute towards such an escape [49]. This is in part due to South Asia and sub-Saharan Africa being the most underrepresented regions in global studies on the impact of electricity access on developmental outcomes [50]. However, emerging case studies demonstrate increase in renewable energy consumption can lead to a decrease in income inequality [51]. Recent case studies from India however have cautioned that off-grid households from low-income communities can lose access if households remain in economic poverty and are unable to afford maintenance costs or realise economic benefits from access [52]. Such cases highlight the

importance of co-benefits of poverty reduction to complement energy access solutions. Importantly for low-income communities, they also highlight why holistic effects of energy access need to be considered together with changes in access in order to understand the sustainability of short-term gains in access.

2.3 Energy access in Tanzania

In Tanzania, more than 85% of the population depends upon wood-based energy for cooking [53]. Dependence on biofuel is common for areas of Africa without access to electricity averaging at 80% across the continent [3, 54]. With an electrification rate of 13,9% and with over 37 million people without access, Tanzania is one of the five African countries with lowest electrification rates [22]. This in turn impacts other dimensions of human development like child mortality and health related issues [3, 55]. Yet, Tanzania has an abundance of renewable energy sources, ranging from biomass, solar, wind, geothermal and hydropower [46]. Yet, the majority of these resources have not been accessed by the government or individuals and are largely underutilized [19]. State capacity is low in Tanzania with poor service delivery of key public goods such as electricity, health, education and water [19]. The incapacity of the Tanzanian government to provide the essential public good of energy to a growing population will likely continue to prove challenging for decades to come [46]. Tanzania is a large nation and has a very scattered and low-density population which makes connecting to the main grid costly – particularly considering the low productivity of rural areas which present limited cost benefit for a centrally planned infrastructure. Further, access to the national grid in Tanzania is no guarantee of electricity. Those connected to the grid experience intermittent supply with power outages, fluctuation of supply and other challenges relating to maintenance or theft of cables [2]. Considering these energy deficits, is important to explore the potential complementarity, viability and scope of all feasible infrastructures, actors and solutions providing energy access.

3 Methodology

3.1 Case study and fieldwork

This research set out to explore adoption rationales and personal effects of off-grid energy access on the livelihoods of rural youth in Tanzania. Here, adoption rationales relate to how and why individuals act in selected environmental and sociologically relevant behaviours [56]. A case study

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4 approach was used and an exploratory, purposive and qualitative methodology was adopted [57].
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6 Although not generalisable due to the limited number of respondents, the case presents new
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8 insights and understanding of emerging trends in energy access in Africa and outlines future
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10 directions for research.

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12 Subjects construct meaning to what is occurring around them as they interact with the world and
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14 such meanings can be uncovered, if only in part, through qualitative appreciation of what sense
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16 they make of the intentional actions and decisions [57]. The research therefore aimed to extrapolate
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18 key themes from the data gathered at the field level. Data gathering was conducted in a way that
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20 allowed respondents to reflect upon their world through the reasons they provided for actions and
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22 choices taken, namely why they chose to adopt off-grid renewable technologies and what self-
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24 reported effects the technology has had on the subject's life.

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26 A preliminary desk study identified key themes in the literature and identified knowledge gaps
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28 relevant to Africa's current and future challenges of energy access [58]. The review of peer-
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30 reviewed and grey literatures highlighted emerging uptake of Solar PV technologies in disparate
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32 communities of East Africa currently lacking access to the central energy grids and highlighted
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34 spatially neglected areas as discussed above. A scoping exercise to identify a business initiative
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36 that met the following criteria: energy access through renewables, entrenched energy poverty (with
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38 potential for off-grid energy access), unemployed youth and business opportunity. The research
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40 aim required a business that focused on youth (<35 years old) and could facilitate introductions
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42 between the researcher and those willing to participate in the study. In order to make a strong case
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44 the organization needed to be a viable business that had been in existence for at least five years
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46 and not reliant on donor funding or government grants. This aimed to insulate the case study
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48 findings from external or donor-reliant influences common to many renewable energy providers
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50 in the region and better portray the reality of conducting business for everyday Tanzanians. It also
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52 provides a degree of validation to the findings as most solar home systems are faced with start-up
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54 challenges, which has resulted in failure of many projects [11]. As an added criterion for selection
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56 the business model needed to be developed and owned by Tanzanians and display a degree of
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58 embeddedness in the communities in which they operate. Final selection was confirmed by
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60 discussions with two leading NGOS working on the energy space in Tanzania.
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After preliminary exploration with several small, medium and micro enterprises, Sepon Limited (hereafter Sepon) was selected. It was founded in 2013 with the stated objective to create jobs and bring energy to rural communities. Sepon's 'Solar as Capital' (SAC) initiative allows youth (18-35) to send in an application with a request for an interest free loan to pay for the Solar PV system to be paid back within a six-month period. As SAC beneficiaries establish their small, medium and micro enterprises they then move from a break-even stage in the first 6 months to establishing a business. Once the plan is approved, Sepon provides the youth recipient with one of two packages, Bronze, or Silver. Two examples of these packages can be found in Table 1 below. These packages have been issued to over 204 clients since 2013 who are spread across Tanzania.

Table 1: Sepon's Solar as Capital packages: functions, estimated monthly returns and cost

Sepon package	Solar PV system	Function (exemplar uses for small businesses)	Est. max monthly income (US\$)	Package Cost (US\$)
Bronze Package	150W solar panel, 100AH battery, 10A charge controller, 4 DC 12V lights and 1 19" TV	• Charge 50 mobile phones or batteries per day.	195.00	850.00
		• Power the television for approximately 6 hours per day.	130.00	
Silver Package	2 200W solar panels, 1 200AH battery, 1 19" TV, and 2 haircutting machines	• Barber shop - 20 individuals per day.	260.00	1250.00
		• Showing football games or movies.	130.00	
		• Charge 50 phones per day.	195.00	

3.2 Sampling design

Figure 1 provides the geographic distribution of SAC beneficiaries and interviewees selected.

Figure 1: Geographic distribution of Solar as Capital (SAC) beneficiaries and interview sites

Over three thousand kilometres were covered in rural and peri-urban communities in order to access the geographically disparate SAC beneficiaries. Ethical approval for the research was granted by the University of Cape Town Science Faculty Research Ethics Committee (FSREC 60 - 2019). Each participant was provided with and signed the University of Cape Town's free, prior and informed consent forms and interviews followed the interview schedule outlined in Appendix A. A total of 31 in-depth interviews were conducted, each ranging from one to two hours long. Nine interviews were conducted in Tanzania in June-July 2019, and a further 22 in March 2020. All interviewees fall within the ages of 18-35, a common cohort for 'youth' in Africa. Twenty-seven interviews were conducted in the rural Coast regions and four interviews were conducted with peri-urban respondents on the outskirts of Dar-es-Salaam.

The research targeted communities lacking energy access in both rural and peri-urban communities. The 31 respondents selected do not serve as a representative sample for all Solar PV adopters in Tanzania. However, it is sufficient to yield response saturation of the case study's

population [59, 60]. The sample of 27 rural respondents represents almost two thirds (52%) of all 52 rural SAC beneficiaries (15% of all SAC beneficiaries). The 7 female respondents make up 19% of the sample which is slightly lower than Sepon's estimate that 20-30% of SAC candidates over that period had been women. The self-reported income range of respondents varied between US\$841 and US\$14,230 per annum (Ave: US\$1,913; Mode: US\$1001-2000) and were categorized into 5 income brackets for analysis (see Table 2). All 31 interviewees had been operating for more than 3 years (average 3,9 years of experience with their Solar PV business) and were part of the initial cohort of SAC beneficiaries. Due to traceability challenges, the research was unable to contact unsuccessful SAC beneficiaries limiting these findings to those that established viable and, at time of interview, ongoing enterprises. Low rates of access and high degrees of unreliability in urban and peri-urban areas in Tanzania and across Africa in general justified inclusion of four peri-urban subjects without energy access in the exploration of adoption rationales. All interviews were conducted in the respondents native language of Swahili, recorded and translated into English for coding and analysis. To ensure translation accuracy a research assistant, present during the interviews, aided in the transcription process. Once analytical themes were identified, interviewees were contacted a second time telephonically to confirm the findings representing their responses and to follow up on themes requiring clarification. Exploratory relationships between respondent characteristics and their AMP responses were statistically described and analysed (Appendix C).

3.3 Analytical Framework: Awareness, Motivation and Pathways

The AMP framework aims to elicit the rationales of individuals or groups of people that transition towards novel technologies or behaviours through exploring their 'awareness', 'motivations', and selected 'pathways' [61]. It asks how and why private individuals choose to act, particularly if such actions have co-benefits in the public interest such as the mitigation implications of selecting low-carbon energy types and with what social, economic or environmental consequences [61]. By concentrating on private actors, it explores what essential goods can be secured independently of the State, and with what governance or distributional consequences [30].

This method frames and uses AMP in the following manner. 'Awareness', is broader than the acquisition of knowledge, but includes a sensibility or frame of reference out of which action emerges [61]. 'Motivation' captures the reasons people provide to take specific actions or

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4 decisions in pursuit of their goals [61]. Within the AMP framework, the term ‘motivation’ can also
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6 be demonstrated in the reasons people have for why they make particular decisions and can include
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8 notions of potential rewards [61]. Greater understanding of ‘motivation’ is important as recent
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10 energy scholarship suggests technological choice is more affected by aspirations than had
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12 previously been considered [49]. The approach assumes that actions individuals take towards a
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14 desired outcome require a practicable ‘pathway’ to succeed. For example, an individual may be
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16 motivated, but may face severe obstacles, lack the resources, technologies or capabilities
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18 (pathways) required to accomplish their goals [62]. Therefore a ‘pathway’ enables a desired
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20 outcome to be realised and is instrumentally linked with ‘motivation’. Drawing on its simplicity,
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22 the AMP framework informed the design of the interview schedule to explore adoption rationales
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24 in this case study. Interviews with respondents provided open ended discussion and qualitative
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26 exploration of how and why they adopted Solar PV (see Appendix A).

27 **4 Results**

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30 Following a brief overview of the key relationships between respondent characteristics and
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32 adoption success factors, the results are presented here according to two main themes. Firstly,
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34 awareness, motivation and pathway dimensions of adoption rationales are provided as indicated
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36 by the AMP framework. Secondly, the effects of energy access on respondent living conditions
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38 will outline dimensions of change and what material investments were made and attributed energy
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40 access.
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Table 2: Demographic characteristics of respondents

Respondent	Urban/ Rural	Age	Gender	Village/ Town	Annual Income Bracket Range (US\$)	Expe- rience (years)	Type of Business (commercial usage in addition to personal use indicated in Figure 2)
1. ROK	Rural	34	M	Fukayosi	3001-4000	6	Shop, bar, refrigeration, cell phone charging
2. SUM	Rural	33	M	Mukuranga	Over 4001	5	Agriculture, irrigation, water pumps
3. ZRN	Rural	31	F	Chanika	2001-3000	3	Cell phone charging station
4. TAJ	Rural	29	M	Mwana	1001-2000	4	Guest house and cell phone charging
5. DSH	Rural	34	M	Minaki	1001-2000	5	Solar powered irrigation
6. HDA	Rural	28	M	Ndege	1001-2000	3	Chicken hatchery
7. SSM	Rural	33	M	Fukayosi	1001-2000	4	Restaurant, bar, cell phone charging
8. SBK	Rural	30	M	Fukayosi	2001-3000	5	Music shop
9. JIF	Rural	34	F	Katana	3001-4000	5	Cell phone charging and football matches
10. JOM	Rural	31	M	Kibada	2001-3000	4	Cell phone charging and refrigeration
11. VMD	Rural	32	F	Loliondo	1001-2000	5	Small shop and refrigeration
12. MNN	Rural	31	M	Mwana	500-1000	3	Radio and electrical repairs
13. FPJ	Rural	33	M	Lupungua	1001-2000	4	Solar powered irrigation
14. MAA	Rural	30	M	Mwasonga	1001-2000	3	Fruit stand
15. YCF	Rural	33	M	Kibada	1001-2000	5	Refrigeration for selling cold drinks
16. ASM	Rural	29	M	Kibada	1001-2000	3	Pharmacy supplies and refrigeration
17. EZJ	Rural	27	F	Ikugi	500-1000	3	Cell phone charging station
18. MAS	Rural	29	M	Karabaka	1001-2000	4	Cell phone charging station
19. MMM	Rural	28	M	Mwakanya	1001-2000	3	Cell phone charging station
20. IIB	Rural	32	M	Mwasonga	1001-2000	4	Barber and cell phone charging
21. ZSM	Rural	22	M	Mwasonga	500-1000	3	Guest house and restaurant
22. NAM	Rural	32	M	Mikwambe	500-1000	4	Small shop and cell phone charging
23. MSK	Rural	31	M	Chalinze	1001-2000	3	Hosts football viewing
24. JPE	Rural	25	M	Pangani	500-1000	3	Small shop and cell phone charging
25. SUK	Rural	27	M	Kibaka	500-1000	3	Stationary and photocopy shop
26. TNH	Rural	33	M	Fukayosi	1001-2000	5	Hosts football viewing
27. MHA	Rural	30	M	Dar	1001-2000	3	Gambling and refrigerated drinks
28. MID	Peri-urban	30	F	Dar	2001-3000	6	Guest house and restaurant
29. SRM	Peri-urban	30	F	Dar	500-1000	4	Seamstress
30. UMS	Peri-urban	34	M	Dar	1001-2000	5	Clothing shop
31. ZDJ	Peri-urban	28	M	Dar	500-1000	3	Small shop and cell phone charging
Rural: 87% Peri-Urban: 13%		Ave: 30	F: 19% M: 81%	Ave: US\$1,913 Mode: US\$1001-2000		Ave: 3,97	

A correlation of 0.593 (Standard Deviation 0.983) was found between income bracket for earnings from Solar PV and years of experience with Solar PV (see Appendix C). This indicates that greater experience increased the earning capacity of adopters and the financial viability of their enterprises. No relationship was found between gender and income bracket. Finally, no trend could be established according to age, this is likely due to the range of ages in the sample (25-34 years old) being too small to differentiate between respondents.

4.1 Analysis of the AMP Structure

4.1.1 Awareness

Awareness of Solar PV and its benefits strongly influenced adoption in the case study. Actor ‘awareness’ was demonstrated through knowledge of technology and its variety of applications, new social networks and novel financing options. Exposure to the technology occurred mostly through word of mouth or seeing an example of an off-grid solar system operating a small business while traveling outside of their community. The first time Respondent ROK heard about solar technology, for example, it was being discussed on a bus on his way to sell maize in Bagamoyo. Respondent SUM first began using it as a student in university but did not realize until over ten years later that specialised Solar PV packages could provide enough energy to power water pumps on his papaya farm. Respondent SBK was also using a generator to power his business and struggling to make a viable living off it. After seeing how Respondent ROK’s solar system was succeeding, Respondent SBK wanted to do the same. Other interviewees first came upon off-grid solar energy through conversations with early adopters within their surrounding town and village centres. These findings show similarities with studies in India and the Netherlands where adoption of renewable energy in India has been driven by technology awareness [38] while adopters in the Netherlands have been noted to influence awareness and decision making of others in their social network [37]. These findings further concretise a grassroots example of information dissemination and knowledge sharing which have been noted as critical to successful transition towards universal energy access [32].

However, levels of awareness were limited in many cases to superficial knowledge of Solar PV and did not extend to an in-depth understanding of the maintenance demands of the technology. Initial support and facilitation from Sepon was provided to get each business started. Many respondents stated that if they had to put a SHS together themselves, they would have failed and given up out of frustration. Although multiple trainings were provided to the SAC beneficiaries, when they were asked technical questions about how their equipment worked, over 90% (28 of 31) of the respondents showed limited knowledge beyond connecting and powering the batteries. Site observations recorded the systems belonging to 20 of 31 (65%) respondents had evidence of systems being overloaded and unit care was limited with excessive dust observed covering panels; showing that they had not been cleaned for some time, reducing the efficiency of the panels [63].

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4 Sepon provides guidelines on maintenance and equipment care. However, when the participants
5 were asked why they were not following proper procedures many stated that they had simply
6 forgotten.
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10 11 **4.1.2 Motivation** 12

13 The reasons provided to take specific actions or decisions in pursuit of their goals ('motivation')
14 were demonstrated in respondents' emphases on the reliability of Solar PV, flexibility of
15 operations, and through improvements in multiple dimensions of adopter's lives (Figure 2). These
16 observations resonate with studies emerging globally that indicate households can be highly
17 motivated to invest in reliable energy access when faced with continued exclusion or disruption
18 [64, 65], and have emphasised the importance of flexibility of renewable energy systems [66].
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24 All respondents were previously unemployed or seasonally and informally employed and from
25 low-income communities. They reported that without Solar PV, they believe that their life
26 conditions would have been unchanged. Tanzania experiences high rates of both energy and
27 socioeconomic poverty with about 62.7% of Tanzanians facing energy deprivation, and 49% of
28 the population living on less the US\$1.90 per day placing them below the income poverty line
29 [67]. All rural beneficiaries expressed interest in expanding their business by purchasing additional
30 solar panels to increase revenue streams. They also made clear an overall dissatisfaction with
31 exclusion from the national energy grid as they feel left out of national development initiatives. In
32 contrast to low-quality solar products commonly for sale in rural Tanzania, and across the region
33 [68], the two-year installer warranty that Sepon provided was a significant motivating factor for
34 all respondents. Finally, ten interviewees (32%) desired to operate either a milling or welding
35 machine as an added component to their business operations which could not function on solar due
36 to high energy requirements.
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49 These expressed desires indicate motivational and aspirational dimensions that showed
50 respondents are not necessarily committed to the adopted technology, but rather appreciate its
51 instrumental value for their immediate access and livelihood needs. This is particularly well
52 demonstrated through respondent's articulations of what utility Solar PV afforded them. All
53 respondents indicated high levels of satisfaction in running their own business, being independent
54 of the seasonality and unpredictability of casual employment in the agricultural sector and its
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4 climatic vagaries, and pride in being able to provide for one's family and establish a regular
5 income.
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8 For example, Respondent JIF purchased a motorcycle for 1,700,000tsh (US\$740), which she then
9 rents out to others for an additional income. She also managed to build a house for her family.
10 Before gaining access to the SAC program, Respondent JIF and her family lived in a two-room
11 house with a grass roof. They now report access to a wider variety of foods, ability to pay school
12 fees and medical bills. Their children can study at night using lights which they report has resulted
13 in improved learning outcomes. Respondent SUM was able to employ 10 people on their plantation
14 and continue expanding operations. Respondent SUM also managed to buy two cars, one for field
15 operations and another for product delivery to Dar-es-Salaam. Solar energy gave Respondent SUM
16 the ability to increase the plantation size, build several homes, and gain influence in the community
17 through employment creation and seedling propagation. Respondent ROK reported being able to
18 expand their household capital, add onto the buildings they own, upgrade their roof from grass to
19 tin, feed their family three meals per day (instead of two), and their children are now own smart
20 phone which helps them with school.
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23 Respondent SBK managed to build a house which is among the "nicest and most modern houses
24 in the village", of which they take great pride. Due to newfound financial stability, Respondent
25 SBK was able to purchase land and employ people to farm on their behalf. Without their solar
26 business, Respondent SBK believes they would be in the same position as many in their
27 community. Respondent SBK is steadily increasing their land holdings and remains one of the
28 only people in their community with a steady income stream. The profit from phone charging and
29 charging for football match viewing has enabled Respondent SUM to add a small light bulb outside
30 his home as a security measure to deter petty theft.
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33 Observed in both developed and developing country contexts [35], solar system reliability,
34 installer warranty, have been demonstrated to affect adoption in the Tanzania case. Energy access
35 is demonstrated in this case as instrumental and a means to escape from poverty and add multiple
36 dimensions of value to their material and social wellbeing.
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4.1.3 Pathways and Obstacles

In the AMP framework, a ‘pathway’ enables a desired outcome to occur. This is displayed in the case through experimentation, adoption and enduring operation of Solar PV. This section highlights how it is also displayed in two key obstacles that were overcome: finance and livelihood diversification.

As described earlier, access to capital through the Solar as Capital microfinance model was also reported by all respondents as a vital entry point into operationalizing their business ventures. While Sepon provides unique financing arrangements with their SAC beneficiaries it is important to examine the role that broader financing mechanisms have played and where this case study is located on a wider stage of energy access. The International Institute for Environment and Development (IIED) has identified a significant funding gap currently present within the off-grid energy sector [23]. There is a recognized need for more effective solutions promoting nodes of financial access to millions of off-grid projects and communities and the IIED highlights SunFunder, as an example of an organization in Kenya working to facilitate off-grid renewable energy finance [23]. However, there are various challenges associated with aggregation and the financial services provided through such organizations as prospective target recipients must have the ability to service loans with interest and provide evidence of cash flow [23]. Yet access to conventional financing mechanisms is limited or non-existent for low-income communities in Tanzania and elsewhere.

In contrast, the SAC model makes the resource itself the financier. This approach, where technology is introduced and goes on to create meaningful returns, is therefore an alternative to the aggregation models, and potentially more viable for marginalized communities lacking in minimum finance qualification. In contrast, SAC creates a node of inclusive financing in these communities. This model overcomes two critical and often poorly considered barriers, both cost of energy generation and level of unmet demand [8]. By circumventing conventional finance obstacles and creating self-financing grids, the Sepon business model has created nodes of energy finance as a pathway to energy access for the rural poor in energy disadvantaged communities.

In addition to the obstacle of finance, is the obstacle of vulnerable livelihoods. Tanzania is projected to experience severe negative impacts from climate change in the near future [69-75]. Tanzania has seen a wide variance in rainfall due to climate change which brings uncertainty in

the livelihoods of these smallholder farmers compounding the vulnerability of low-income rural communities [76]. Over 90% percent of Tanzania's agriculture is rain-fed [76]. Most farmers in Tanzania have relatively small landholdings with only 0.3 to 4 acres per family under cultivation and these small holder farmers are generally considered to be most vulnerable due to their reliance on rain-fed agriculture [77]. The role that Solar PV can have in bringing diversification into income streams and bolstering resilience is demonstrated in the livelihood outcomes of the SAC beneficiaries. All of them except for Respondent MID were subsistence farmers or charcoal producers before adopting solar energy to provide an alternative revenue stream. In line with previous studies highlighting the effects of non-farm income diversification [78], Solar PV provided livelihood diversification (pathway) to buffer against shocks associated with climatic variability.

4.2 Effects of Solar as Capital on beneficiaries' lives and livelihoods

Figure 2 below outlines self-reported changes that occurred in beneficiaries' lives as a result of adopting Solar PV. Observations are structured according to the multidimensional poverty index.

Figure 2: Material effects of energy access indicated through reported livelihood and living condition improvement per criteria relating to eight dimensions of poverty (respondents n=31)

All rural respondents (n=31) indicated that they were glad to no longer be dependent on farming for their livelihood and highlighted the reliability of energy from solar as a key motivating factor of adoption. All respondents further reported that their social standing in the community had improved as a consequence of enhanced social interactions around the private and community benefits of Solar PV. Citing improved health outcomes, all respondents reported greater ability to afford medical bills and lower burn risk. Of 31 respondents, 30 reported improved educational outcomes being now able to send their kids to school or better schools and provide lighting at night time to study.

Security lighting (68%) was the next most commonly reported change in living conditions and the asset most commonly invested in. Improvements in cooking fuel was reported by 43% of respondents who changed from wood to gas which they could now afford. The greatest impact of this change in fuel source improved the lives of 100% of the women respondents (n=7) who noted they no longer need to fetch firewood. This improvement in fuel efficiency, reduced ecological footprint and time for unpaid work for women is also noted more generally to have a co-benefit for respiratory health outcomes [32, 55]. Improvements in access to drinking water were reported by the 32% of respondents who now had access to water from a well, a further 23% could now afford to purchase bottled water and one respondent purchased a solar water filter. Thirty-five percent of respondents reported they could now afford to make structural improvements to their homes and 20% afforded improvements in sanitation. Investment in assets saw 33% of respondents improving their mobility (car or motorbike), 23% improving communications (cellular phone), and 16% investing in property or land. Although investments in assets like a car or motorbike are carbon-intensive, they need to be understood in light of both need (lack of mobility and lack of access to electric forms of mobility) and emissions impact (the overall low-carbon footprint of low-income rural communities).

5 Discussion

Without involvement of a broader suite of actors, at current and projected electrification rates Africa is highly unlikely to achieve universal electricity access by 2030 [2]. This is particularly challenging for low-income communities as there are the multiple barriers low-income actors face which impede access [62, 79]. Obstacles to energy access in this case have been demonstrated to

be lack of access to finance and livelihood vulnerability to climate variability. Being instrumental for energy access, their removal is priority.

In Tanzania, as in much of Africa, demand for solar home systems (SHS) has been growing over the past decade [80]. This was initially driven by the desire to power radios and television sets in regions far from the national grid, however, demand for SHSs has increased with the widespread adoption of mobile phones and need for home lighting solutions [80]. The Tanzanian market has been largely reliant on NGO funding, governmental agencies, and partnerships with international agencies [80]. Current Tanzanian policy focuses on largescale projects such as large hydroelectric power stations, natural gas plants, and coal, as opposed to microgrid solutions that are proving popular and successful in other nations [38]. Under current conditions therefore, Solar PV will likely not feature strongly in official government policy nor have a prominent position in the Tanzanian electrification agenda [80]. For States like Tanzania, where existing capacity and resources are low, it is important that the infrastructures developed to afford access are, a) not solely reliant on the State, and b) distributed and decentralised to include a disparate population. The framework presented in Figure 3 assumes this limited reach – whether by design, neglect or incapacity – of the State.

Figure 3: A transition framework for low-income, off-grid, household-level energy access.

Figure 3 presents a transition framework for understanding behaviours seeking to secure off-grid household-level energy access. The framework provides an advance in energy sector transition through recognition of the range and polycentric nature of actors and feasible infrastructures that can contribute towards energy access [32]. Polycentric nodes of access are recognisable through locating the actor and their agency at the household-level. The framework emphasises the individual as the essential unit of analysis – that is – what valuable states, freedoms and choices can they realise through exercising their individual agency [62, 81]. The internal and external dimensions of ‘obstacles’ highlight key factors for external interventions which are beyond the capability of an individual from marginalised background (such as low formal education, lack of finance and climate vulnerable livelihood) [62]. For policy makers and entrepreneurs like Sepon, aiming to replicate at scale low-carbon energy in low-income communities, this differentiation between the individual’s capabilities and the obstacles they face is important for the design of effective interventions. It also identifies complementary space for autonomy, entrepreneurship and external provisions for other public and private actors seeking to facilitate such livelihood and energy transitions.

This case presents an alternative arrangement of access to commonly described options which tend to frame access according to 1) public ownership of infrastructure with distributive mandate, 2) private ownership of infrastructure for sale to the grid (with limited benefit for low-income communities other than the competitive pricing of renewables), or 3) cost-sharing arrangements and public-private partnerships [32]. The alternative pathway here does not fit neatly into any of these categories and therefore presents a new assemblage of actors and infrastructure for policy makers to consider and respond to. Further, the non-state actors usually considered as key role players for energy access are generally not low-income [32], while private and off-grid attempts to secure key public goods have been noted to result in inequitable, partial and gated access to such goods as energy or water [21, 25, 26, 30]. Yet here, the case has demonstrated novel access arrangements harnessing the capital of solar power to create new nodes of energy access for low-income actors.

Recognising these grassroots developments centres on what actions and decisions non-state actors (everyday people) take in order to facilitate or secure their lives in relation to an essential good - in this case energy - and the effects of such actions to govern or shape the flow of events. In doing so it extends the AMP framework to low-income energy transitions. Two main conceptual

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4 contributions are made here that extend the AMP framework. Firstly, understanding adoption in
5 this way provides novel explanatory terms for developmental approaches rarely used in poverty
6 studies, that is, their awareness, motivation and pathways. Secondly, the inclusion of deeper
7 consideration of ‘pathway obstacles’ within the AMP framework affords greater sensitivity to the
8 barriers faced by those on the lowest rungs of the economic spectrum, and those facing enduring
9 lack of energy access in particular. This extends the AMP framework from its prior concentration
10 on enabling conditions for elites and organisations (awareness, motivation and pathways), to
11 recognition of restricting arrangements that low-income actors face, and which require negotiation
12 and mitigation in concert with such enabling conditions. In this way the framework avoids neo-
13 patrimonial as well as neoliberal blind-spots inherent in its original formulation by acknowledging
14 both the agency of poor people (awareness, motivation and pathways), as well as external factors
15 (obstacles) – like collateral financing or climate shocks – for which they cannot reasonably be
16 considered to overcome on their own. Further, adoption rationales for solar energy are not only
17 limited to energy access but are coupled with economic benefits, livelihood diversification and
18 improvements in living conditions. Concentrating on adoption rationales has therefore
19 demonstrated here the potential to advance our understanding of what conditions may potentially
20 lead to cascading uptake of new technologies and transitions to alternative livelihoods that are less
21 vulnerable to climatic variability.

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38 Finding consilience with emerging renewables scholarship concerned with transition, this case has
39 parallels with broader trends towards to greater independence and security of access to essential
40 goods [30, 82, 83]. Disruptive environmental pressures can combine with novel technologies to
41 drive independent and local actors to seek alternative supply sources to service their needs and
42 increase resource security or access [25, 83]. For example, climate shocks have been observed to
43 severely disrupt conventional centralised grids, like water or energy, as seen in disruptions to the
44 electricity grids of Puerto Rico [25], and California [84] and the water grid of Cape Town [25, 29].
45 Off-grid solutions are being adopted to replace the role that would conventionally be provided by
46 a central utility. Non-state entities, acting in their own capacity, are seeking to secure essential
47 public goods, especially when the state is failing to provide these goods. In this case climate risk,
48 was not the causal driver of adoption [30], but climate risk to agriculture coupled with State neglect
49 drove the contextual preconditions – the background environmental pressures - of adoption. This
50 was true for 68% of respondents. Global cases have indicated the ability of elites to secure their
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own resources creating partial access to essential goods [21, 26, 29, 30]. But this case illustrates that innovative financing can provide the catalyst to enable low-income communities to gain energy access. Here an essential good has been privately secured despite the State, highlighting the expansion of capabilities of low-income private actors to have greater agency and effectively shape their energy access arrangements and creating household-level nodes of access.

6 Conclusion

This article has presented how and why low-income youth are adopting Solar PV in Tanzania and illustrated the effects of energy access on adopter's living conditions. Exploring adoption rationales has provided an instructive framework for enhancing a more general understanding of how solar energy use can be encouraged in rural communities across Africa. The case has highlighted the role non-state and indigenous actors can play in the extension of energy access to rural and low-income communities. In doing so this case has extended the AMP framework to studies in energy access and particularly to low-income research subjects. The AMP framework has also been extended here through the inclusion of 'obstacles' within the notion of 'pathway' thereby reorienting the framework towards more inclusive research applications. The fundamental awareness and motivational aspects of adoption in this case are not dissimilar to other contexts and income groups across the world concentrating on word of mouth, price, installer warranty, source, reliability, and low maintenance demands. Additional environmental co-benefits were observed as adopters became less dependent on biomass for cooking and health co-benefits noted from transition away from biomass for cooking in the home. This also had positive outcomes such as education, health, improved security lighting, increased income and social capital. Beyond personal effects, this case has demonstrated how an innovative business model removed the obstacle of financing for low-income communities to access Solar PV. However, the awareness and motivational dimensions of adoption would likely not in themselves been sufficient to enable sustainable energy access without a feasible pathway and the mitigation of obstacles. The enabling (awareness, motivation and pathways), and constraining factors identified in this research (obstacles of financing and climate variability), outline important considerations for interventions targeting energy poverty and realisation of access to affordable, reliable, sustainable and modern energy for all (SDG7).

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Appendix A: Interview questions structured according to AMP Category

After ensuring prior and informed consent of respondent participation and their available time for the interview, open ended discussion of the following themes.

Awareness

Technology

- When and how did you hear about solar PV?
- Do many of your friends or family have solar PV?
- What sort of equipment do you have?
- How does the technology work?
- What education do you have, certificates? Technical or electrical trainings?

Energy

- What energy requirements do you currently have?
- Other than solar what additional energy options do you have access too?

Motivation

Business

- Why did you choose Solar PV for your business?
- What is your current business (how does the tech above enable you to do this)?
- What business strategies do you employ, what are operations like?
- What sort of customer base do you have and what do you charge per service?

Pathways

Empowerment

- How long have you been running your enterprise using Solar PV?
- What sort of employment opportunities are available to youth in the community?
- How has this business changed your (and your family's) life?
- What enabled you to access this technology and what might inhibit others?
- Closing statement? (Advice for entrepreneurs and energy policy makers?)

In closing,

- a) Thank respondent for their time.
- b) Gather non-mandatory demographic data: age, gender, nearest village / town, estimate income bracket (monthly or annually), phone number for follow-up.

Appendix B: Reported livelihood improvement per criteria relating to the eight dimensions of the multi-dimensional poverty index

	Respondent	Access	Reliability	Afford medical	Less burn risk	School fees	Study at night	Afford gas for cooking	Purchase clean water	Clean water from well	Solar water filter	Tin Roof	Cement bricks	Refurbish Home	Rent a nice home	Indoor plumbing	Outdoor refuse pit	Pay refuse collection	Security lighting	Motorbike	Smartphone	Computer	Car	Refrigeration	Property invest	Start a small shop	Livestock invest etc.	Purchased Farm	Total
1	ROK	1	1	1	1	1	1	1	0	0	0	1	1	0	0	0	0	0	1	1	1	1	0	0	0	0	0	0	13
2	SBK	1	1	1	1	1	1	0	0	0	0	1	1	0	0	0	0	0	0	1	1	1	0	0	0	0	0	0	11
3	SUM	1	1	1	1	1	1	1	0	1	0	0	1	0	0	0	0	0	1	1	1	0	1	0	0	0	0	0	12
4	JIF	1	1	1	1	1	1	1	0	0	0	0	1	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	10
5	YCF	1	1	1	1	1	1	1	0	0	0	0	1	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	9
6	JOM	1	1	1	1	1	1	0	0	0	0	0	1	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	10
7	ZRN	1	1	1	1	1	1	1	1	1	0	1	0	1	0	1	0	0	1	0	0	0	0	0	0	0	0	0	12
8	TAJ	1	1	1	1	1	1	1	0	1	0	0	0	0	0	0	0	0	0	1	1	1	1	1	0	0	0	1	12
9	VMD	1	1	1	1	1	1	0	1	0	0	1	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	10
10	ASM	1	1	1	1	1	1	1	0	1	0	0	0	0	0	0	1	0	0	0	1	0	0	0	0	0	0	0	9
11	MNN	1	1	1	1	1	1	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	10
12	NAM	1	1	1	1	1	1	0	0	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	8
13	DSH	1	1	1	1	1	1	0	0	1	0	1	1	0	0	0	0	0	0	1	0	0	0	0	0	1	1	0	12
14	FPJ	1	1	1	1	1	1	0	0	1	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	10
15	EZJ	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	9
16	TNH	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	7
17	MAS	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	9
18	MSK	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	8
19	HDA	1	1	1	1	1	1	1	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	12
20	JPE	1	1	1	1	1	1	0	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	8
21	SUK	1	1	1	1	1	1	1	0	1	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	10
22	MAA	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	9
23	MMM	1	1	1	1	1	1	1	0	1	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	9
24	IIB	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5
25	ZDJ	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	9
26	ZSM	1	1	1	1	1	1	1	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	9
27	MHA	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	7
28	MID	1	1	1	1	1	1	1	0	0	1	0	0	0	0	1	0	0	0	1	1	1	1	0	0	0	0	0	14
29	UMS	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6
30	SSM	1	1	1	1	1	1	1	1	1	0	0	0	0	1	0	0	1	1	1	0	0	0	0	0	0	0	0	12
31	SRM	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	7
Total		31	31	31	31	31	30	13	7	10	1	11	10	1	2	3	3	2	21	7	7	3	3	1	4	1	2	1	
Bootstrap	Mean	1,000	1,000	1,000	1,000	0,968	0,968	0,420	0,225	0,322	0,032	0,355	0,323	0,032	0,064	0,096	0,096	0,064	0,678	0,225	0,225	0,096	0,096	0,032	0,130	0,032	0,064	0,032	
Confidence	Std. error	0,000	0,000	0,000	0,000	0,032	0,032	0,089	0,075	0,084	0,032	0,087	0,084	0,032	0,044	0,053	0,053	0,044	0,084	0,075	0,075	0,053	0,053	0,032	0,061	0,032	0,044	0,032	
Interval	Left Tail	1,000	1,000	1,000	1,000	0,903	0,903	0,258	0,097	0,161	0,000	0,194	0,161	0,000	0,000	0,000	0,000	0,000	0,516	0,097	0,097	0,000	0,000	0,032	0,000	0,000	0,000	0,000	
(10,000 samples)	Right Tail	1,000	1,000	1,000	1,000	1,000	1,000	0,581	0,387	0,484	0,097	0,516	0,484	0,097	0,161	0,194	0,194	0,161	0,839	0,387	0,387	0,194	0,194	0,097	0,258	0,097	0,161	0,097	

Appendix C:

	Respondent	Annual Income (self-reported)	US\$	Annual Income Bracket Range (US\$)	Annual Income Bracket Category (US\$)	Years of experience with SAC
Rural	ROK	7 000 000	3 019	3001-4000	4	6
	SBK	33 000 000	14 230	Over 4001	5	5
	SUM	5 000 000	2 156	2001-3000	3	3
	JIF	3 600 000	1 552	1001-2000	2	4
	YCF	4 000 000	1 725	1001-2000	2	5
	JOM	4 000 000	1 725	1001-2000	2	3
	ZRN	2 400 000	1 035	1001-2000	2	4
	TAJ	6 500 000	2 803	2001-3000	3	5
	VMD	8 100 000	3 493	3001-4000	4	5
	ASM	5 500 000	2 372	2001-3000	3	4
	MNN	2 880 000	1 242	1001-2000	2	5
	NAM	2 150 000	927	500-1000	1	3
	DSH	3 200 000	1 380	1001-2000	2	4
	FPJ	3 200 000	1 380	1001-2000	2	3
	EZJ	4 500 000	1 940	1001-2000	2	5
	TNH	3 000 000	1 294	1001-2000	2	3
	MAS	2 200 000	949	500-1000	1	3
	MSK	2 350 000	1 013	1001-2000	2	4
	HDA	3 000 000	1 294	1001-2000	2	3
	JPE	2 500 000	1 078	1001-2000	2	4
	SUK	2 160 000	931	500-1000	1	3
	MAA	2 200 000	949	500-1000	1	4
	MM M	3 400 000	1 466	1001-2000	2	3
	IIB	1 950 000	841	500-1000	1	3
	ZDJ	1 850 000	798	500-1000	1	3
	ZSM	2 500 000	1 078	1001-2000	2	5
	MHA	2 600 000	1 121	1001-2000	2	3
Urban	MID	6 000 000	2 587	2001-3000	3	6
	UMS	2 000 000	862	500-1000	1	4
	SSM	2 800 000	1 207	1001-2000	2	5
	SRM	1 950 000	841	500-1000	1	3

	Income Bracket	Years of experience
Mean	2.097	3.968
Standard Deviation	0.978	0.983
Sample Size	31	
Correlation	0.593	
Slope	0.596	
Intercept	2.719	

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Figure 1

Figure 2

PROPORTIONS OF ALL REPORTED LIVING CONDITIONS IMPROVEMENTS CATEGORISED ACCORDING TO MULTI-DIMENSIONAL POVERTY INDICATORS

Figure 3

Table 1: Sepon’s Solar as Capital packages: functions, estimated monthly returns and cost

Sepon package	Solar PV system	Function (exemplar uses for small businesses)	Est. max monthly income (US\$)	Package Cost (US\$)
Bronze Package	150W solar panel, 100AH battery, 10A charge controller, 4 DC 12V lights and 1 19” TV	<ul style="list-style-type: none">• Charge 50 mobile phones or batteries per day.• Power the television for approximately 6 hours per day.	195.00 130.00	850.00
Silver Package	2 200W solar panels, 1 200AH battery, 1 19” TV, and 2 haircutting machines	<ul style="list-style-type: none">• Barber shop - 20 individuals per day.• Showing football games or movies.• Charge 50 phones per day.	260.00 130.00 195.00	1250.00

Table 2: Demographic characteristics of respondents

Respondent	Urban/ Rural	Age	Gender	Village/ Town	Annual Income Bracket Range (US\$)	Exper- ience (years)	Type of Business (commercial usage in addition to personal use indicated in Figure 2)
1. ROK	Rural	34	M	Fukayosi	3001-4000	6	Shop, bar, refrigeration, cell phone charging
2. SUM	Rural	33	M	Mukuranga	Over 4001	5	Agriculture, irrigation, water pumps
3. ZRN	Rural	31	F	Chanika	2001-3000	3	Cell phone charging station
4. TAJ	Rural	29	M	Mwana	1001-2000	4	Guest house and cell phone charging
5. DSH	Rural	34	M	Minaki	1001-2000	5	Solar powered irrigation
6. HDA	Rural	28	M	Ndege	1001-2000	3	Chicken hatchery
7. SSM	Rural	33	M	Fukayosi	1001-2000	4	Restaurant, bar, cell phone charging
8. SBK	Rural	30	M	Fukayosi	2001-3000	5	Music shop
9. JIF	Rural	34	F	Katana	3001-4000	5	Cell phone charging and football matches
10. JOM	Rural	31	M	Kibada	2001-3000	4	Cell phone charging and refrigeration
11. VMD	Rural	32	F	Loliondo	1001-2000	5	Small shop and refrigeration
12. MNN	Rural	31	M	Mwana	500-1000	3	Radio and electrical repairs
13. FPJ	Rural	33	M	Lupungua	1001-2000	4	Solar powered irrigation
14. MAA	Rural	30	M	Mwasonga	1001-2000	3	Fruit stand
15. YCF	Rural	33	M	Kibada	1001-2000	5	Refrigeration for selling cold drinks
16. ASM	Rural	29	M	Kibada	1001-2000	3	Pharmacy supplies and refrigeration
17. EZJ	Rural	27	F	Ikugi	500-1000	3	Cell phone charging station
18. MAS	Rural	29	M	Karabaka	1001-2000	4	Cell phone charging station
19. MMM	Rural	28	M	Mwakanya	1001-2000	3	Cell phone charging station
20. IIB	Rural	32	M	Mwasonga	1001-2000	4	Barber and cell phone charging
21. ZSM	Rural	22	M	Mwasonga	500-1000	3	Guest house and restaurant
22. NAM	Rural	32	M	Mikwambe	500-1000	4	Small shop and cell phone charging
23. MSK	Rural	31	M	Chalinze	1001-2000	3	Hosts football viewing
24. JPE	Rural	25	M	Pangani	500-1000	3	Small shop and cell phone charging
25. SUK	Rural	27	M	Kibaka	500-1000	3	Stationary and photocopy shop
26. TNH	Rural	33	M	Fukayosi	1001-2000	5	Hosts football viewing
27. MHA	Rural	30	M	Dar	1001-2000	3	Gambling and refrigerated drinks
28. MID	Peri-urban	30	F	Dar	2001-3000	6	Guest house and restaurant
29. SRM	Peri-urban	30	F	Dar	500-1000	4	Seamstress
30. UMS	Peri-urban	34	M	Dar	1001-2000	5	Clothing shop
31. ZDJ	Peri-urban	28	M	Dar	500-1000	3	Small shop and cell phone charging
Rural: 87% Peri-Urban: 13%		Ave: 30	F: 19% M: 81%	Ave: US\$1,913 Mode: US\$1001-2000		Ave: 3,97	

Ethical Statement

Title: Adoption rationales and effects of off-grid renewable energy access for African youth: A case study from Tanzania

This research conformed to the University of Cape Town **Code for Research involving Human Subjects**: <http://www.uct.ac.za/downloads/uct.ac.za/about/policies/ethicscode.pdf>.

It gained permission from Science Faculty Research Ethics Committee for research involving human subjects prior to commencing any field work. All respondents were provided informed voluntary consent to participate in research study and their participation was anonymous and confidential.

Highlights

1. Adoption rationales play an key role in cascading uptake of renewable energy.
2. Innovative finance overcomes prohibitive start-up costs for Solar PV.
3. Low-income entrepreneurs improve their lives with energy access.
4. Private nodes of energy security overcome systemic geographies of energy poverty.
5. Overcoming identifiable obstacles enables new capabilities to be realised.

Declaration of interests

☒ The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

☐ The authors declare the following financial interests/personal relationships which may be considered as potential competing interests:

CRedit author statement

Nicholas Philip Simpson: Conceptualization, Methodology, Validation, Formal analysis, Writing - Original Draft, Visualization, Supervision and Funding acquisition. **Colton James Rabenold:** Conceptualization, Methodology, Validation, Formal analysis, Investigation, Data Curation, Writing - Original Draft, Visualization, Project administration. **Merle Sowman:** Methodology, Writing - Review & Editing, Supervision. **Clifford D. Shearing:** Methodology, Writing - Review & Editing