

Beyond Technology Adoption: The Household Solar Utilization Meaning Framework (HSUMF) for Understanding Household Solar Energy Utilization in Urban Zambia

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Abstract

Household consistent use of solar energy in many urban settings in Sub-Saharan Africa has been uneven. This is despite the global drive and investments in clean energy. Many studies focus on adoption using technological, behavioral, and economic lenses. There is limited understanding of how households interpret and use solar energy in everyday life. This study develops the Household Solar Utilization Meaning Framework (HSUMF) from qualitative evidence on households using solar products in urban Zambia. Guided by hermeneutic phenomenology and informed by Social Phenomenology, Social Norms Theory, and an interpretive adaptation of the Technology Acceptance Model, the study adopted interpretivist qualitative design. Data was generated through 20 in-depth key informant interviews and 5 focus group discussions involving 125 total participants in Chelstone, Lusaka. Reflexive thematic analysis was used to interpret empirical material.

The findings suggest that household solar energy utilization is more than a response to energy shortages; it is a socially embedded process of meaning construction. Structural energy challenges appeared to trigger interest in solar technologies, while community observation, social learning, and shared experience shaped household interpretations of solar as a source of reliability, security, educational continuity, food preservation, livelihood protection, and emotional well-being. These meanings became embedded in everyday household practices, even though financial limitations and technological constraints continued to shape the extent of use. The resulting Household Solar Utilization Meaning Framework (HSUMF) shows how structural realities, social interaction, and lived meaning may jointly influence household engagement with solar energy.

The study contributes to renewable energy research by extending predominantly behavioural explanations of household solar utilization through an interpretive framework grounded in lived experience. It further provides contextually grounded insights to inform renewable energy policy, sustainable marketing strategies, and community-centred approaches to accelerating household energy transitions in urban African contexts.

1. INTRODUCTION

The global transition towards renewable energy has become central to efforts aimed at addressing climate change, strengthening energy security, and advancing sustainable development. Among available renewable energy technologies, household solar photovoltaic systems have emerged as an important solution for improving energy access, reducing dependence on fossil fuels, and enhancing resilience against unreliable electricity supply. Governments across both developed and developing economies have introduced policy incentives, fiscal reforms, and investment programmes to encourage household adoption of solar technologies. Nevertheless, household solar energy utilization remains uneven, particularly across many urban settings in Sub-Saharan Africa where favourable solar resources coexist with relatively low levels of sustained household utilization (International Energy Agency [IEA], 2024; International Renewable Energy Agency [IRENA], 2023; Kizilcec & Parikh, 2020).

Zambia exemplifies this paradox. Despite having sufficient resources (2000–3000 hours of sunshine annually), it continues to face challenges with increased cost of electricity and insufficient power resulting into load shedding from time to time. There has been interventions on policy reforms and market availability of solar energy systems to support alternative options. However, household utilization remains comparatively limited. The interventions focused on pricing, improved availability and infrastructure expansion with the objective of driving adoption. Therefore, uneven utilization of solar energy systems suggests that it can not be fully exhausted through technical and economic drivers alone (IEA, 2024; IRENA, 2023; Walker, 2014).

Behavioral and technological adoption lenses has been a major focus of literature on renewable energy. The adoption rates are explained using theories such as the the Theory of Planned Behaviour (TPB), Diffusion of Innovation and Technology Acceptance Model (TAM). These focuses on constructs consisting of perceived usefulness, attitudes, subjective norms, and behavioural intentions. These have explained valuable insights into technology acceptance. However, they illustrate household engagement as a rational decision-making process. This limits the understanding of how solar energy becomes interpreted, experienced, and integrated within the everyday lives of households after adoption (Ajzen, 1991; Davis, 1989; Rogers, 2003; Venkatesh et al., 2003; Claudy et al., 2013; Islam et al., 2022).

Recently, there has been an aspect of renewable technologies being socially embedded and not only technical artefacts. The argument currently supported by some scholars alludes that household energy utilization is driven by shared meanings, everyday interactions, community engagements, and lived experiences. In line with this argument, solar energy utilization goes beyond technical aspects and becomes part of household social status, routines, aspirations, and social life. Although this interpretive orientation has been growing, there is limited qualitative evidence from urban African contexts. Recent research provides only a partial understanding of the social processes through which structural energy challenges, community interactions, and lived experiences collectively drive household solar utilization (Shove et al., 2012; Sovacool et al., 2020; Stephenson et al., 2015).

In order to address this gap, this study adopts a hermeneutic phenomenological perspective grounded in Social Phenomenology. It further incorporates the Social Norms Theory and an interpretive application of the Technology Acceptance Model. The study explores how households experience, interpret, and construct meaning to solar energy utilization within their everyday lives and does not take the approach of only asking why households adopt solar technologies. In this study, twenty in-depth key informant interviews (KIIs) and five focus group discussions (FGDs) involving 125 participants in Chelstone Residential Area, Lusaka District Zambia were conducted. The study develops the Household Solar Utilization Meaning Framework (HSUMF). This as a contextually grounded interpretive framework that explains how meanings surrounding household solar utilization are socially constructed and sustained (Laverty, 2003; Schutz, 1967; Van Manen, 2016; Davis, 1989).

The HSUMF shows that household solar utilization evolves through an interconnected process in which structural energy realities stimulate social interaction. The social interaction results into shared

meanings, and these meanings become incorporated within everyday household practices. In this framework, utilization is not perceived as a discrete adoption event, but instead, the framework conceptualizes it as a continuous process of interpretation, negotiation, and adaptation within households' social worlds. The study emphasizes lived experience and therefore, the HSUMF framework demonstrates how reliability, security, educational continuity, livelihood protection, food preservation, and emotional well-being become socially constructed meanings. This further sustains household engagement with solar technologies (Schutz, 1967; Shove et al., 2012; Stephenson et al., 2015).

This paper makes three principal contributions. First, it shifts attention from one-time technology adoption to the social construction of sustained household solar utilization. Second, it introduces the Household Solar Utilization Meaning Framework (HSUMF) as an interpretive framework linking structural conditions, social interaction, meaning construction, utilization outcomes, and contextual constraints. Third, it offers qualitative evidence from an underrepresented urban African setting that can inform future policy, programme design, and community-based energy interventions (Kizilcec & Parikh, 2020; McCord et al., 2026).

2. LITERATURE REVIEW

2.1 Household Solar Energy Utilization in the Global Energy Transition

The global transition towards renewable energy has become one of the defining priorities of contemporary sustainable development. There has been accelerated investments in renewable energy because of the increased concerns over climate change, energy insecurity, increasing electricity demand, and the depletion of fossil fuel resources. This is noted across both developed and developing economies (International Energy Agency [IEA], 2024; International Renewable Energy Agency [IRENA], 2023). Recently, renewable energy is highly recognised as an environmental imperative and a strategic tool for promoting inclusive economic growth, enhancing energy security, and achieving the United Nations Sustainable Development Goals (SDGs). Particularly, it relates to SDG 7, which advocates universal access to affordable, reliable, sustainable, and modern energy (United Nations, 2015). Therefore, governments, development agencies, and private-sector actors have amplified investments in decentralised renewable energy systems. Household solar photovoltaic (PV) technologies has emerged as one of the most promising solutions for accelerating electricity access (IEA, 2024; IRENA, 2023).

The recent improved policies around solar energy which includes reductions in photovoltaic prices, improvements in battery storage technologies, supportive regulatory frameworks, and innovative financing mechanisms such as pay-as-you-go (PAYGo) has been driving household solar energy growth over the past two decades (Kizilcec & Parikh, 2020). These technological and market interventions have transformed household solar systems from niche off-grid interventions into major components of national electrification strategies. Solar technologies are viewed as a solution for enhancing household

energy independence and reduces vulnerability to grid failures, lowering long-term energy costs, and supporting climate adaptation strategies (IRENA, 2023; McCord et al., 2026).

In Sub-Saharan Africa, challenges of electricity deficits affects socioeconomical growth and therefore, there has been an expansion of household solar technologies. Grid extension faces challenges of high infrastructure costs, dispersed settlements, rapid urbanisation, and aging electricity networks. This makes decentralization of solar systems an increasingly attractive alternative (Kizilcec & Parikh, 2020). This has led to solar home systems gaining traction in the energy access programmes in many African countries. This is also driven by governments, international development partners, and private investors. The biggest and fast-growing market for solar pvs is Su-Saharan Africa in the global landscape according to recent reviews (Kizilcec & Parikh, 2020; Stojanovski et al., 2018).

There are a wide range of developmental advantages of household solar technologies other than improving electricity access. Empirical studies shows that household solar brings about improved educational opportunities through extended study hours, enhanced household safety due to improved lighting, increased opportunities for income-generating activities, reduced expenditure on traditional fuels, improved communication through reliable phone charging, and better health outcomes resulting from reduced dependence on kerosene and other polluting energy sources (Stojanovski et al., 2018; McCord et al., 2026). Additionally, solar technologies contribute to household resilience when there is electricity disruption and this allows households to maintain essential daily activities (Kizilcec & Parikh, 2020; Stojanovski et al., 2018; McCord et al., 2026).

In addition to simple measures of adoption, there are some other aspects which have been revealed by the expansion of household solar technologies. Recent longitudinal research demonstrates that households with similar solar systems usually experience different patterns of use over time. Some households progressively expand their use of solar technologies, whereas others reduce utilization. This is regardless of continued ownership and adequate system performance. These variations cannot be explained solely by technical characteristics or financial constraints. It therefore suggests that household energy utilization is driven by broader social, cultural, and behavioural processes (Perriment et al., 2025). Similarly, recent studies argue that measuring solar adoption alone may substantially overestimate progress towards universal energy access. Adoption fails to capture how households integrate solar technologies into their everyday lives or whether available system capacity is used to the maximum (Perriment et al., 2025; McCord et al., 2026).

In Sub-Saharan Africa, these issues are further driven by local socioeconomic and cultural contexts. A growing body of literature suggests that household decisions regarding solar technologies are affected by gender relations, social status, community norms, cultural beliefs, and existing power structures beyond affordability and technical performance. Household solar technologies therefore become included within wider social systems rather than functioning merely as technical devices. For example, observational learning, neighbour influence, and community experiences enhance adoption decisions

and continued engagement with solar technologies. This shows the importance of social interaction in household energy transitions (Kizilcec & Parikh, 2020; Monyei et al., 2021; Sovacool et al., 2020).

The Zambian context shows similar patterns of many of these regional dynamics. Zambia has abundant natural resources and receives estimated 2,000–3,000 sunshine hours annually. However, it remains heavily dependent on hydropower for electricity generation. This dependence has made the national electricity system vulnerable to drought-induced reductions in water levels, increasing electricity demand. This has resulted into households experiencing prolonged periods of load shedding, rising electricity tariffs, and growing uncertainty regarding electricity reliability. This situation creates the need for household investment in alternative energy technologies. Government policy has also focused on renewable energy growth through regulatory reforms and investment initiatives to diversify electricity generation and strengthen national energy security. (Walker, 2014)

With all the interventions mentioned above, household solar utilization in Zambia remains limited. These interventions mainly focus on increasing availability, reducing financial constraints, and expanding market penetration through policy reforms and private-sector participation. These efforts assume that once households acquire solar technologies, sustained utilization will naturally follow. However, emerging literature suggests that acquisition does not necessarily translate into meaningful or sustained household utilization. Households attach different meanings to the technologies depending on their lived realities, family needs, and social environments (Kizilcec & Parikh, 2020; McCord et al., 2026).

This distinction highlights an important conceptual difference between technology adoption and utilization. Adoption refers to the decision to acquire or accept a technology, whereas utilization looks at the ways in which that technology becomes incorporated into everyday household life over time. Utilization focus on how households interpret solar technologies, integrate them into daily routines and negotiate their value within family and community context. Unlike adoption, which is often conceptualised as a single behavioural event, utilization represents an ongoing and socially embedded process of engagement (Perriment et al., 2025; McCord et al., 2026).

Although renewable energy scholarship has increasingly acknowledged the importance of sustained household utilization, much of the existing literature continues to privilege behavioural and economic explanations of technology adoption. Consequently, relatively limited attention has been devoted to understanding how households experience solar technologies after acquisition, how meanings surrounding solar utilization are socially constructed, and how these meanings influence continued household engagement. Addressing these questions requires moving beyond conventional adoption frameworks towards interpretive perspectives that foreground lived experience, social interaction, and meaning-making. This provides the foundation for examining the behavioural theories that have traditionally dominated household solar energy research before considering emerging interpretive perspectives that seek to explain utilization as a socially embedded phenomenon (Perriment et al., 2025; McCord et al., 2026; Sovacool et al., 2020).

2.2 Behavioural Perspectives on Household Solar Energy Utilization

Behavioural theories have dominated household solar energy research for more than three decades, providing the principal theoretical foundation for explaining why individuals adopt or reject renewable energy technologies. These theories generally assume that households make rational decisions by evaluating the expected benefits, costs and risks associated with technology adoption. Most existing literature has focused on identifying the economic and technological aspects that affect households' intentions to acquire solar energy systems (Ajzen, 1991; Davis, 1989; Rogers, 2003; Venkatesh et al., 2003). Application of this has significantly driven renewable energy literature by providing robust explanatory models for predicting technology adoption behaviour across different geographical contexts (Claudy et al., 2013; Islam et al., 2022).

Technology Acceptance Model (TAM) has become one of the most extensively applied frameworks in renewable energy research. Originally developed by Davis (1989), TAM suggests that technology adoption is primarily driven by two perspectives: perceived usefulness and perceived ease of use. Perceived usefulness looks at the extent to which people believe that using a system will improve their quality of life, whereas perceived ease of use focus on the extent to which a it is perceived as easy to use (Davis, 1989). These perspectives have been widely applied in energy research to explain why households invest in solar photovoltaic systems. The studies consistently reports that perceptions of economic savings, reliability, convenience and environmental benefits positively drives adoption intentions (Claudy et al., 2013; Islam et al., 2022; Khezri et al., 2020) (Abdullah et al., 2023; Wang et al., 2024).

In this study, the Technology Acceptance Model is retained complementary interpretive lens rather than a predictive model of behavioral intention. Phenomenological inquiry looks at how technologies are experienced in everyday life and TAM constructs provide an established framework for recording functional and operational perceptions. In other words, perceived usefulness is modified phenomenologically to explore how households construct subjective meanings around utility, reliability, and practical value as they incorporate solar energy into daily lives. Similarly, perceived ease of use is modified to explore how technical accessibility, operation, and maintenance drive household experience. The two are not used as static variables and this interpretive adaptation of TAM illuminates how practical experiences become socially meaningful post-acquisition. This fills a critical gap between acceptance and sustained usage (Davis, 1989; Van Manen, 2016).

Similarly, The Theory of Planned Behavior (TPB) has contributed significantly to understanding renewable energy adoption. Ajzen (1991) alluded that behavioural intention is determined by attitude, subjective norms and perceived control. Favorable attitudes towards renewable energy and positive influence from family or neighbors have consistently been linked to stronger adoption intentions (Alam et al., 2021; Claudy et al., 2013). TPB has therefore been widely used to explain household willingness to

adopt solar technologies under different economic, institutional and cultural dynamics (Ajzen, 1991; Alam et al., 2021; Claudy et al., 2013).

Diffusion of Innovation Theory (DOI), by Rogers (2003) brings out a perspective of how innovations spread through social systems over time. DOI argues that the adoption of new technologies depends on perceptions of relative advantage, compatibility, complexity, trialability and observability. The theory has been widely applied to household solar energy research because it explicitly recognises the importance of interpersonal communication and social learning in technology diffusion. Some studies indicate that households are more likely to adopt solar energy after observing successful installations in their communities. Receiving positive recommendations from neighbors and relatives also drives adoption (Claudy et al., 2013; Rogers, 2003).

The emphasis placed by DOI on observability and communication has proved particularly relevant within emerging renewable energy markets. Demonstration effects, community visibility and peer learning frequently influence household confidence in solar technologies by reducing uncertainty regarding technology performance and financial returns (Islam et al., 2022). Consequently, DOI provides important insights into the role of communities in accelerating renewable energy transitions. However, while the theory acknowledges social interaction, it primarily conceptualises these interactions as mechanisms facilitating technology diffusion rather than as processes through which households construct meanings around renewable energy (Islam et al., 2022; Rogers, 2003).

The Unified Theory of Acceptance and Use of Technology (UTAUT) also explains adoption in energy research. It integrates perspectives from eight technology acceptance models (Venkatesh et al., 2003). UTAUT alludes that adoption is driven by performance expectancy, effort expectancy, social influence and facilitating conditions. The framework has demonstrated high predictive capability and has been applied to household renewable energy research (Dwivedi et al., 2019; Venkatesh et al., 2003).

Together, the above explained theories have made significant contributions to renewable energy research. They have informed government policies, marketing strategies and financial interventions to improve household adoption of solar technologies. Their empirical robustness has supports researchers and helps to predict technology adoption with accuracy across different contexts. This makes them very important tools within renewable energy research (Ajzen, 1991; Davis, 1989; Rogers, 2003; Venkatesh et al., 2003).

Despite these strengths, behavioural theories exhibit several important conceptual limitations when applied to household solar energy utilization. First, they conceptualise renewable energy primarily as an object of individual decision-making, assuming that adoption results from rational evaluation of expected benefits and costs. Such assumptions provide limited insight into how households subsequently interpret, experience and integrate solar technologies into their everyday lives. Second, these theories largely treat technology adoption as a discrete behavioural event, paying comparatively little attention to the ongoing processes through which utilization evolves over time. Third, although constructs such as subjective norms and social influence recognise the importance of other people, they

conceptualise social interaction primarily as an external predictor of behaviour rather than as a dynamic process through which shared meanings are created and negotiated (Shove et al., 2012).

Consequently, behavioural theories explain why households adopt solar technologies, but provide comparatively limited understanding of how households construct meanings around solar energy utilization after adoption. This limitation has stimulated growing interest in interpretive perspectives that conceptualise household energy utilization as a socially embedded process shaped by lived experience, social interaction and everyday practices. The following section reviews these emerging perspectives and considers their contribution towards understanding household solar energy utilization beyond technology adoption (Shove et al., 2012; Sovacool et al., 2020).

2.3 Emerging Interpretive Perspectives on Household Solar Energy Utilization

Growing dissatisfaction with behavioural explanations of technology adoption has stimulated increasing interest in interpretive approaches that conceptualise household energy utilization as a socially embedded phenomenon. While behavioural theories have substantially improved understanding of why households adopt renewable energy technologies, they have been criticised for placing disproportionate emphasis on individual cognition while overlooking the social, cultural and contextual processes that shape everyday technology use (Shove et al., 2012; Sovacool et al., 2020). Consequently, recent scholarship within energy social science has increasingly shifted attention from technology adoption towards understanding how renewable energy technologies become integrated into everyday household life through lived experiences, social interaction and meaning making (Sovacool et al., 2020).

This interpretive shift reflects broader developments within sustainability and energy research. Scholars are recently recognising that energy technologies do not exist independently of the social environments in which they are used. Household solar systems are viewed as social artefacts and their meanings are negotiated through family, community and institutional interactions in line with interpretive perspectives (Shove et al., 2012). Under this perspective, understanding household solar utilization requires exploring how households interpret, experience and assign meaning to renewable energy technologies within their daily lives (Shove et al., 2012; Sovacool et al., 2020).

The Social Practice Theory (SPT) has also contributed to this approach. This theory argues that energy consumption is incorporated within routine social practices such as cooking, studying, working, entertainment and household maintenance and it does not conceptualize energy use as the outcome of individual choices (Shove et al., 2012). Therefore, energy is not only consumed but it is a part of broader social activities that define livelihood. From this approach, solar technologies become important as they enhance these practices rather than simply because they provide electricity. (Stephenson et al., 2015)

Interpretive research emphasise meaning-making as a key process through which households engage with renewable energy technologies. Meaning-making is defined as ways individuals interpret experiences and construct shared understandings that drive behaviour (Berger & Luckmann, 1966).

When it comes to household solar utilization, meanings attached to solar technologies goes beyond their technical function. For some households, solar systems represent energy independence during periods of load shedding; for others, they symbolise economic strength through reduced electricity costs, while others associate them with family wellbeing or environmental concerns (Sovacool et al., 2020). These meanings influence not only whether technologies are used but also how they are prioritised, maintained and incorporated into everyday household routines (Berger & Luckmann, 1966; Sovacool et al., 2020).

The approach of lived experience further builds on interpretive understanding of household energy utilization. Lived experience investigates how individuals perceive, interpret and make sense of their everyday realities (Van Manen, 2016). Households are not treated as passive recipients of technology, but instead phenomenological perspectives recognize them as active meaning-makers who continuously interpret their interactions with renewable energy technologies. Additionally, household solar utilization cannot be fully understood without examining the subjective experiences through which technologies become meaningful within particular social and cultural contexts (Van Manen, 2016).

Further in the phenomenological inquiry, Social Phenomenology, developed by Alfred Schutz (1967), provides a valuable theoretical foundation for understanding household solar utilization. Schutz alludes that people's understanding of reality is socially constructed through shared experiences, interpersonal relationships and accumulated 'stocks of knowledge' developed through everyday interaction. Individuals therefore interpret new experiences using meanings that have been socially acquired through families, communities and broader social networks (Schutz, 1967). This perspective suggests that decisions regarding the continued use of solar technologies are driven not only by shared community narratives, observations of neighbours, discussions with friends and collective interpretations of energy reliability (Schutz, 1967).

Empirical studies significantly support this interpretation. Research across developing countries demonstrates that community learning, neighbour influence and shared user experiences enhances household engagement with solar technologies (Monyei et al., 2021; Sovacool et al., 2020). Observing successful solar installations, receiving recommendations from trusted community members and sharing experiences regarding system performance frequently strengthens confidence in renewable energy technologies. These findings suggest that household solar utilization is socially relational, emerging through continuous interaction between individuals and their social environments (Monyei et al., 2021; Sovacool et al., 2020).

Additionally, studies on community learning have shown that renewable energy knowledge is not acquired through formal education alone. Instead, households develop practical understanding through observation, experimentation, interpersonal communication and shared experiences (Bandura, 1986; Monyei et al., 2021). Such learning processes create expectations regarding technology performance, appropriate usage patterns and maintenance practices. This reinforces the role of social interaction in explaining household solar utilization (Bandura, 1986; Monyei et al., 2021).

Despite these important contributions, interpretive scholarship remains fragmented. Existing studies have examined individual dimensions such as social practices, phenomenology, community learning, household identity and energy justice, yet these perspectives have largely developed independently of one another. Consequently, there remains no integrated interpretive framework explaining how structural energy conditions, lived experiences, social interaction, community learning and meaning making collectively shape household solar energy utilization. Furthermore, relatively few qualitative studies have explored these processes within urban African contexts characterised by unreliable electricity supply, frequent load shedding and rapidly expanding renewable energy markets. These limitations highlight the need for a contextually grounded interpretive framework capable of explaining household solar utilization as a socially constructed process rather than merely an individual behavioural outcome (Kizilcec & Parikh, 2020; McCord et al., 2026; Sovacool et al., 2020).

The present study addresses this gap by developing the Household Solar Utilization Meaning Framework (HSUMF). The framework integrates structural energy conditions, community interaction, household meaning-making and everyday practices into a coherent explanation of sustained household solar energy utilization based on the experience of the participants. It extends existing interpretive research by offering a socially grounded framework developed from the realities of urban households in Zambia (McCord et al., 2026; Sovacool et al., 2020).

3. METHODOLOGY

3.1 Research Paradigm

This study was underpinned by the interpretivist research paradigm, which assumes that reality is socially constructed through human interaction and that knowledge is generated by understanding how individuals interpret and make meaning of their lived experiences (Creswell & Poth, 2018; Lincoln et al., 2018). The paradigm was appropriate because the study sought to explore how urban households in Chelstone Township, Lusaka, experience and interpret household solar energy utilization within the context of their everyday lives rather than measure predetermined behavioural variables. (Schwandt, 2015)

The study was further informed by Alfred Schutz's Social Phenomenology. He alludes that meanings emerge through shared experiences, interpersonal relationships and accumulated social knowledge (Schutz, 1967). This philosophical perspective was appropriate because household solar energy utilization occurs within families and communities. The interpretations of solar technologies are driven by people's observation, interaction and shared experiences. Social phenomenology therefore provided an appropriate approach for understanding how participants collectively constructed meanings around solar energy utilization and informed the development of the Household Solar Utilization Meaning Framework (HSUMF). (Schutz, 1967).

3.2 Research Design

The study adopted a qualitative hermeneutic phenomenological design. Hermeneutic phenomenology seeks to understand and interpret the meanings individuals attach to their lived experiences rather than describing those experiences (Van Manen, 2016). The design was appropriate because the study aimed to explore how households experienced, interpreted and sustained solar energy utilization within their everyday social environments.

Hermeneutic phenomenology acknowledges interpretation as an integral part of knowledge generation compared to descriptive phenomenology (Lavery, 2003). Ideally, the researcher sought not only to understand participants' experiences but also to interpret how those experiences were shaped by structural energy conditions, household circumstances, community interaction and everyday practices. This interpretive orientation ultimately enabled the development of the Household Solar Utilization Meaning Framework (HSUMF) grounded in participants lived experiences.

3.3 Study Area

The study was conducted in Chelstone Township in Lusaka District, Zambia, an urban community that has experienced growth in household investment in solar photovoltaic systems resulting from persistent electricity load shedding and increasing electricity tariffs. Chelstone was purposively selected because it provided an appropriate scope for exploring household solar energy utilization among households that had integrated solar technologies into their daily lives while remaining connected to the national electricity grid (Kizilcec & Parikh, 2020; McCord et al., 2026).

The study focused on urban households because existing literature has mostly focused on rural electrification. There is limited understanding of how urban households experience and sustain solar energy utilization post adoption. The frequent load shedding experienced in Lusaka provided a rich context for exploring how households construct meanings around solar energy beyond technology adoption (Perriment et al., 2025; McCord et al., 2026).

3.4 Participant Selection

Participants were selected using purposive sampling to ensure inclusion of individuals with direct experience using household solar photovoltaic systems. Purposive sampling enabled the researcher to obtain rich, experience-based accounts from participants who could meaningfully explain their motivations, utilization practices and everyday experiences with household solar energy (Patton, 2015).

The study involved 125 participants, comprising 105 participants from five Focus Group Discussions (FGDs) and 20 participants who participated in Key Informant Interviews (KIIs). The FGDs provided collective community perspectives regarding household solar energy utilization, while the KIIs generated detailed individual narratives that enabled deeper exploration of participants' lived experiences. The targeted sample was successfully achieved, resulting in full participation across both data collection methods.

To ensure analytical transparency, it should be noted that the detailed demographic profile presented in Section 4.0 relates specifically to the 20 KII participants. This subsample includes variables such as age, gender, education, income, household size, solar technology type, and duration of utilization. As detailed in Section 4.0, this KII subsample reflects a relatively educated, middle-income urban group (e.g., 75% holding Bachelor's degrees and 95% economically active). This educated urban profile shapes how meanings are articulated—specifically framing solar systems as intentional investments in lifestyle continuity, educational support, and enterprise protection rather than basic lighting survival. Recognising this demographic context provides essential clarity when interpreting qualitative meanings in urban Sub-Saharan African contexts.

3.5 Data Collection

Data collection proceeded concurrently with preliminary analysis, allowing emerging themes to be continuously assessed throughout the research process. Data were collected using Focus Group Discussions (FGDs) and semi-structured Key Informant Interviews (KIIs). Employing multiple qualitative data collection methods enabled methodological triangulation and strengthened the depth and credibility of the findings. (Kallio et al., 2016)

Five Focus Group Discussions involving 105 participants were conducted to explore shared community experiences, social norms and collective perceptions regarding household solar energy utilization. The group discussions enabled participants to interact, compare experiences and collectively construct meanings around solar energy within their communities. In addition, twenty semi-structured Key Informant Interviews were conducted with purposively selected household solar users to obtain in-depth accounts of their individual experiences. The interviews explored participants' motivations for adopting solar energy, daily utilization practices, perceived benefits, challenges and the meanings attached to household solar energy utilization (Kallio et al., 2016).

In accordance with methodological standards for qualitative inquiry (Guest et al., 2020), thematic saturation was systematically evaluated across two distinct operational levels across both datasets: code saturation and meaning saturation. Code saturation occurred relatively early in data collection—specifically by Key Informant Interview 14 and Focus Group Discussion 4—at which point no new descriptive codes or operational categories emerged from incoming transcripts. However, data collection was continued across all 20 KIIs and 5 FGDs to achieve meaning saturation. Meaning saturation was judged to be reached by KII 18 and FGD 5, as subsequent narratives yielded no further conceptual dimensions, nuances, or structural variations regarding how households constructed meaning around solar energy or how framework constructs related to one another.

3.6 Data Analysis

The qualitative data generated from the FGDs and KIIs were analysed using reflexive thematic analysis following Braun and Clarke's (2006; 2021) six-phase analytical framework. The analytical process began with repeated reading of interview transcripts and FGD discussions to achieve immersion in the data and develop familiarity with participants' narratives.

To ensure complete analytic transparency, the transition from raw empirical data to the final framework followed a rigorous four-stage analytical progression: (1) Initial Open Coding generated 246 distinct empirical codes from raw transcripts capturing participants' specific experiences, practices, and community interactions; (2) Code Categorisation grouped these codes into 28 sub-categories based on conceptual similarity; (3) Thematic Synthesis refined these sub-categories into nine interpretive empirical themes aligned to the study objectives (e.g., Solar as Household Continuity Infrastructure, Solar Ownership Producing Social Differentiation, Social Learning Enabling Adoption, Energy Insecurity as Primary Motivation); and (4) Conceptual Abstraction synthesised these nine empirical themes into the five core theoretical constructs that constitute the Household Solar Utilization Meaning Framework (HSUMF): Structural Triggers, Social Interaction & Learning, Household Meaning Construction, Utilization Outcomes, and Contextual Constraints.

3.7 Trustworthiness

The trustworthiness of the study was established using Lincoln and Guba's (1985) criteria of credibility, transferability, dependability and confirmability. Credibility was strengthened through methodological triangulation by combining Focus Group Discussions and Key Informant Interviews, enabling comparison of collective and individual experiences. Dependability was enhanced through systematic documentation of coding procedures and theme development, while confirmability was supported through reflexive interpretation grounded in participants' narratives. Transferability was facilitated by providing detailed descriptions of the study setting, participant characteristics and analytical procedures, allowing readers to determine the applicability of the findings to similar urban contexts.

3.8 Ethical Considerations

Clinical trial number: not applicable.

Ethical approval

was obtained from the Humanities and Social Sciences Research Ethics Committee (HSSREC), University of Zambia, before commencement of the study. Participation was voluntary, and informed consent was obtained from all participants prior to data collection. Participants were assured of confidentiality, anonymity and their right to withdraw from the study at any stage without consequence.

To protect participants' identities, pseudonyms and participant codes were used throughout the analysis and reporting of findings. Audio recordings, transcripts and field notes were securely stored and accessed only by the researcher. The study adhered to established ethical principles governing qualitative research, including voluntary participation, confidentiality, anonymity and responsible data management.

4. RESULTS AND DISCUSSION

The twenty Key Informant Interview participants represented diverse household characteristics to capture varied experiences of household solar energy utilization. Participants varied in age, gender, educational attainment, household size, income levels, solar technologies used, and duration of solar utilization. This diversity provided a broad range of lived experiences that enriched interpretation of how households construct meanings around solar energy utilization. (see Table 1).

4.0 Participant Profile

Characteristic	Summary (KII Subsample, n = 20)
Participants	20 Key Informants (representing individual household narratives)
Gender	14 Male (70%); 6 Female (30%)
Age Range	Participants ranged from 20 years to over 61 years. The majority were aged 20–30 years (40%), followed by 31–40 years (35%), 41–50 years (20%), and 61 years and above (5%).
Education	Most participants held Bachelor's degrees (75%), followed by Postgraduate qualifications (10%), Secondary education (10%), and Diploma qualifications (5%).
Household Size	Household size ranged from 1 to 10 members, with the most common household sizes being five and eight members (20% each).
Solar System Type	The majority used solar panel systems with batteries and inverters (75%), while 15% used Sunking systems and 10% used lithium battery systems.
Duration of Solar Use & Occupation	Used solar between 2019 and 2025 (peak adoption in 2024 [30%] and 2025 [25%]). Occupations: 10 self-employed (50%), 9 formally employed (45%), 1 unemployed (5%).

Table 1: Key Informant Interviewee Profile (n = 20)

4.1 Social Identity and Community Influence in Household Solar Utilization

The findings indicate that household solar energy utilization extends beyond electricity generation and is experienced as a socially interpreted practice embedded in community life. Participants described solar ownership as a sign of resilience, preparedness, and socioeconomic aspiration. Households with solar installations were often perceived as better equipped to cope with Zambia's electricity shortages, making solar ownership an aspirational goal for many community members.

These observations indicate that solar technologies have acquired symbolic value within the community. Rather than representing only an alternative energy source, they increasingly signify household preparedness and improved quality of life. This finding supports Berger and Luckmann's (1966) proposition that meanings are socially constructed through shared interaction and aligns with Rogers' (2003) Diffusion of Innovation Theory, which highlights the importance of observability in accelerating innovation diffusion.

However, participants also revealed that solar ownership produced unintended forms of social differentiation and inequality dynamics. While many households admired solar users, others associated ownership with wealth, creating perceptions of inequality and social distance. Some participants reported being labelled as financially privileged or expected to provide electricity-related assistance to neighbours during load shedding (e.g., charging phones or storing perishable foods). This finding critically extends energy social science by linking solar adoption to energy justice, status signaling, and unequal urban energy transitions (Monyei et al., 2021). In urban settings where grid reliability collapses, solar systems operate as visible markers of symbolic status and class privilege. Rather than serving as purely neutral tools of green transition, solar technologies can inadvertently exacerbate neighborhood social stratifications and reinforce existing socioeconomic divides between energy-secure and energy-vulnerable households.

Community interaction further emerged as an important mechanism through which knowledge about solar technologies was shared. Participants explained that practical information regarding installation, maintenance and system performance was primarily obtained through neighbours, relatives and friends rather than formal information channels. Observation of functioning systems reduced uncertainty and increased confidence in the technology, demonstrating the importance of social learning in sustaining household solar utilization. At the same time, participants acknowledged that financial constraints limited many households from acting upon these aspirations despite recognising the benefits of solar energy. Social influence therefore functioned as both an enabling and constraining factor, illustrating that household solar utilization develops within a dynamic social environment shaped by interaction, learning and structural inequality.

Collectively, these findings extend behavioural theories that conceptualise social influence primarily as a predictor of adoption (Ajzen, 1991; Venkatesh et al., 2003). Instead, they demonstrate that social interaction continues to shape household experiences after adoption by influencing how solar technologies are interpreted, valued and utilised within everyday community life.

4.2 Household Meanings Attached to Solar Energy Utilization

The findings further demonstrate that households attach multiple interconnected meanings to solar energy utilization that extend well beyond electricity generation. Participants consistently described solar systems as resources that sustained household continuity, protected livelihoods and enhanced emotional wellbeing, suggesting that utilization is fundamentally a process of meaning construction rather than simply technology use.

One of the strongest meanings attached to solar utilization was its role as household continuity infrastructure. Participants explained that uninterrupted electricity enabled children to study, supported domestic activities, facilitated communication and allowed family routines to continue despite prolonged load shedding. Solar systems therefore became essential for maintaining the normal functioning of household life rather than simply providing lighting or powering appliances. This finding

aligns with Social Practice Theory, which argues that energy derives significance through the everyday practices it enables rather than through its technical characteristics alone (Shove et al., 2012).

Participants also interpreted solar utilization as a means of protecting household livelihoods and food security. Many explained that reliable electricity enabled them to preserve food, operate refrigerators, maintain small businesses and avoid financial losses associated with prolonged electricity outages. These experiences suggest that solar energy contributes directly to household economic resilience by supporting income generation and reducing vulnerability to food spoilage. Such findings extend previous behavioural studies by demonstrating that the perceived usefulness of solar technologies is socially interpreted through their contribution to household survival and economic stability rather than through purely technical or financial considerations.

Beyond practical and economic benefits, participants consistently associated solar utilization with household safety and emotional wellbeing. Reliable lighting reduced concerns regarding crime, improved the safety of children during evening hours and eliminated risks associated with candle use during power outages. Participants further described reduced household stress and greater peace of mind resulting from uninterrupted electricity. These narratives indicate that solar technologies have become symbols of security, stability and family wellbeing. Consistent with Schutz's (1967) Social Phenomenology, these meanings emerged through participants' lived experiences and were reinforced through everyday interaction with their social and physical environments.

Taken together, these findings suggest that household solar utilization is sustained not merely because solar systems generate electricity but because households interpret them as infrastructure that supports continuity, resilience, livelihood protection and emotional security. These socially constructed meanings provide the foundation for sustained utilization beyond the initial adoption decision.

4.3 Structural Drivers Sustaining Household Solar Utilization

While social interaction and household meanings explained how participants experienced solar utilization, the findings demonstrate that these experiences were fundamentally shaped by broader structural conditions. Persistent electricity load shedding, rising electricity tariffs and concerns regarding household welfare emerged as the principal drivers motivating households to invest in and continue utilizing solar energy systems (Kizilcec & Parikh, 2020; McCord et al., 2026; Perriment et al., 2025).

Participants consistently described unreliable electricity supply as the catalyst that transformed solar energy from an optional household technology into an essential coping mechanism. Frequent and prolonged load shedding disrupted education, household routines, refrigeration and income-generating activities, compelling households to seek alternative sources of electricity. Rather than viewing solar energy as a luxury, participants increasingly regarded it as necessary infrastructure for maintaining everyday life. These findings support recent energy security literature, which argues that household renewable energy investments are increasingly driven by concerns regarding energy reliability and resilience rather than environmental considerations alone (Kizilcec & Parikh, 2020; McCord et al., 2026).

Household welfare also emerged as a central motivation sustaining continued solar utilization. Participants explained that solar systems enabled children to continue studying, preserved food supplies, supported business activities and enhanced family wellbeing during periods of electricity disruption. Consequently, decisions to invest in solar energy reflected broader aspirations to protect household welfare rather than simple cost-benefit calculations. These findings suggest that household solar utilization represents an adaptive response to structural energy insecurity, where families actively deploy renewable energy technologies to safeguard education, livelihoods and quality of life (Stojanovski et al., 2018; McCord et al., 2026).

Collectively, the findings demonstrate that sustained household solar utilization is shaped by the interaction between structural energy challenges and household aspirations for resilience, continuity and wellbeing. These motivations provide the contextual foundation upon which socially constructed meanings surrounding solar utilization develop.

4.4 Development of the Household Solar Utilization Meaning Framework (HSUMF)

The synthesis of the findings led to the development of the Household Solar Utilization Meaning Framework (HSUMF), an interpretive framework explaining how sustained household solar utilization emerges through the interaction of structural conditions, social processes and lived experiences. Rather than conceptualising utilization as the outcome of individual behavioural intentions, the framework positions it as a socially constructed process that evolves over time through continuous interaction between households and their surrounding social environment.

The framework comprises five interconnected constructs. The first, structural triggers, captures the external conditions that initiate household engagement with solar technologies, including persistent load shedding, increasing electricity tariffs and unreliable electricity supply. These structural challenges create the need for alternative energy solutions and provide the context within which household solar utilization emerges.

The second construct, social interaction and learning, explains how households develop confidence in solar technologies through observing neighbours, sharing experiences and exchanging practical knowledge within their communities. Social interaction reduces uncertainty surrounding solar investment while simultaneously shaping community expectations and aspirations regarding renewable energy utilization (Monyei et al., 2021; Sovacool et al., 2020).

The third construct, household meaning construction, represents the interpretive core of the framework. Participants assigned multiple meanings to solar utilization, viewing it as infrastructure supporting household continuity, livelihood protection, food security, safety and emotional wellbeing. These meanings transformed solar energy from a technical innovation into an essential component of everyday household life.

The fourth construct, utilization outcomes, reflects the practical benefits experienced through sustained solar utilization, including improved household resilience, business continuity, educational support, food preservation and enhanced quality of life. These positive outcomes reinforce continued engagement with solar technologies and strengthen households' commitment to renewable energy.

Finally, the framework recognises contextual constraints, including affordability, limited system capacity, weather dependency and income inequality, which influence the extent to which households can fully realise the benefits of solar utilization. These constraints highlight the importance of supportive financing mechanisms and enabling policy environments for expanding equitable access to household renewable energy (Kizilcec & Parikh, 2020; Monyei et al., 2021).

Directional Logic and Framework Relationships: The framework operates through a clear sequential and feedback logic. Structural triggers act as antecedent conditions that compel households to seek alternatives. Social interaction and learning mediate this trigger by guiding technology choices and reducing uncertainty through peer observation. Once acquired, technology enters the core interpretive process of household meaning construction, where functional energy is transformed into lived social value. These meanings directly generate positive utilization outcomes, which are concurrently moderated by contextual constraints (e.g., financial limits or battery degradation). Finally, a recursive feedback loop links utilization outcomes back to structural conditions and social learning, as positive lived experiences encourage system expansions, reinforce household commitment, and inspire community-wide diffusion.

The HSUMF advances renewable energy scholarship by integrating structural energy conditions, community interaction, lived experience and household meaning-making into a single interpretive framework. In doing so, it shifts scholarly attention from technology adoption towards sustained household utilization and provides a contextually grounded explanation of renewable energy use within urban Zambia. The framework complements existing behavioural theories by explaining not only why households adopt solar technologies but also how they interpret, sustain and derive meaning from their continued utilization.

5. THEORETICAL CONTRIBUTIONS

This study makes three important theoretical contributions to the literature on household renewable energy utilization. First, it advances understanding beyond dominant behavioural theories by conceptualising household solar energy utilization as a socially constructed process rather than solely an outcome of individual decision-making. While the Technology Acceptance Model (TAM), Theory of Planned Behaviour (TPB), Diffusion of Innovation (DOI) and Unified Theory of Acceptance and Use of Technology (UTAUT) have substantially improved understanding of technology adoption through constructs such as perceived usefulness, attitudes, subjective norms, social influence and facilitating conditions (Ajzen, 1991; Davis, 1989; Rogers, 2003; Venkatesh et al., 2003), these frameworks primarily

explain whether households adopt solar technologies. They provide comparatively limited insight into how households experience, interpret and sustain solar energy utilization after adoption.

The Household Solar Utilization Meaning Framework (HSUMF) extends these behavioural perspectives by demonstrating that sustained household solar utilization is shaped not only by behavioural intentions but also by the interaction of structural energy conditions, social learning, lived experiences and household meaning-making. Rather than conceptualising utilization as a linear behavioural outcome, the HSUMF explains it as an evolving social process in which meanings are continuously constructed and reinforced through everyday practice.

Second, the framework extends Schutz's Social Phenomenology by applying its principles to household renewable energy utilization. Social Phenomenology argues that meanings emerge through shared experiences and socially acquired stocks of knowledge (Schutz, 1967). The findings demonstrate that households constructed meanings around solar energy through observation of neighbours, family interactions, community learning and lived experiences of electricity insecurity. These meanings transformed solar technologies from technical devices into symbols of continuity, livelihood protection, safety and household wellbeing. The HSUMF therefore operationalises Social Phenomenology within the renewable energy context by illustrating the mechanisms through which shared meanings influence sustained utilization.

Third, the study contributes a contextually grounded interpretive framework derived from urban Zambia, addressing a significant geographical gap in renewable energy scholarship. Existing literature has been dominated by behavioural and quantitative studies conducted largely in Europe, North America and Asia, with relatively limited qualitative evidence from urban Sub-Saharan Africa. By integrating structural energy conditions, social interaction, meaning construction, utilization outcomes and contextual constraints into a single framework, the HSUMF provides a novel interpretive lens for understanding household renewable energy utilization in developing-country settings. The framework complements rather than replaces existing behavioural theories by explaining the social processes that sustain renewable energy utilization beyond initial adoption (Islam et al., 2022; Kizilcec & Parikh, 2020; Sovacool et al., 2020; McCord et al., 2026).

6. PRACTICAL IMPLICATIONS

The findings have direct, actionable implications for solar service providers, renewable energy firms, NGOs, and practitioners seeking to expand household solar utilization. Because household decisions are driven by social learning and domestic meanings rather than technical specifications alone, practitioners should implement targeted actions: (Shove et al., 2012; Monyei et al., 2021; Kizilcec & Parikh, 2020).

1. Value-Based Marketing Campaigns: Solar service providers should restructure marketing strategies away from technical specs (e.g., wattage or battery capacity) toward value-based narratives that emphasize household continuity, educational support, refrigeration and security.

2. Community Champion Initiatives: Renewable energy NGOs and private firms should recruit and train local 'community solar champions', existing solar users within residential areas to host neighborhood demonstration sessions and share authentic user experiences, for social learning.

3. Flexible and Pay-As-You-Go (PAYGo) Financing: To address affordability barriers, financial institutions and solar vendors must offer flexible credit structures, modular equipment packages, and mobile-money PAYGo mechanisms that allow low- and middle-income households to scale their solar systems incrementally over time (Shove et al., 2012; Stephenson et al., 2015).

7. POLICY IMPLICATIONS

The findings provide clear policy directions for governments, energy regulators, and urban planners:

1. Integrating Solar into Urban Resilience Planning: Energy ministries should formally recognize residential distributed solar systems as vital components of urban energy resilience, integrating household solar incentives into national energy policy to alleviate grid strain during deficit.

2. Targeted Fiscal Reforms: Policymakers should eliminate or reduce import tariffs and Value Added Tax (VAT) on residential solar panels, deep-cycle batteries, and hybrid inverters to lower capital costs and promote equitable access across diverse socioeconomic groups.

3. Enforcing Quality Standards and After-Sales Support: Energy regulators must establish stringent technical import standards and mandate minimum after-sales warranties for solar suppliers to protect consumers from sub-standard equipment, thereby safeguarding public trust in renewable energy technologies (Kizilcec & Parikh, 2020; Monyei et al., 2021).

8. LIMITATIONS AND FUTURE RESEARCH

This study should be interpreted in light of several limitations. First, the research was conducted within Chelstone Township in Lusaka, and the findings therefore reflect the experiences of households within a specific urban context. While the study provides rich contextual understanding, the findings may not fully represent experiences in rural communities or other urban settings with different socioeconomic and energy conditions.

Second, the study employed a qualitative research design that prioritised depth of understanding over statistical generalisation. Consequently, the findings should be interpreted as contextually grounded explanations of household solar energy utilization rather than universally applicable relationships.

Third, the study focused on households already utilising solar technologies. The experiences of households that considered but did not adopt solar systems were beyond the scope of the research and may provide additional insights into barriers to renewable energy utilization.

Future research should examine the applicability of the Household Solar Utilization Meaning Framework (HSUMF) across different geographical, cultural and socioeconomic contexts. Comparative studies involving rural and urban communities would help determine the transferability of the framework, while mixed-methods and quantitative studies could empirically test the relationships among the constructs identified in the HSUMF. Longitudinal research may also provide deeper understanding of how household meanings surrounding solar energy evolve over time as technologies and energy systems continue to change.

9. CONCLUSION

This study examined household solar energy utilization through the lived experiences of urban households in Chelstone Township, Lusaka, Zambia. Moving beyond behavioural explanations of technology adoption, the study demonstrated that sustained household solar utilization is a socially constructed process shaped by structural energy conditions, community interaction, lived experiences and household meaning-making.

The findings showed that households interpreted solar energy as far more than an alternative source of electricity. Participants associated solar utilization with maintaining household continuity, protecting livelihoods, preserving food, supporting children's education, enhancing household safety and improving emotional wellbeing. These socially constructed meanings explain why households continued investing in and relying upon solar technologies despite financial and technical constraints.

The principal contribution of the study is the development of the Household Solar Utilization Meaning Framework (HSUMF), which integrates structural triggers, social interaction, household meaning construction, utilization outcomes and contextual constraints into a single interpretive framework. By extending Social Phenomenology and complementing established behavioural theories such as TAM, TPB, DOI and UTAUT, the framework provides a more comprehensive understanding of sustained household solar energy utilization.

Overall, the study contributes new theoretical and empirical insights to renewable energy scholarship by demonstrating that household solar utilization is best understood not simply as a technological or economic decision but as a socially negotiated process through which households construct meaning, adapt to energy insecurity and strengthen their resilience. The HSUMF therefore offers a valuable foundation for future research, policy development and practice aimed at promoting equitable and sustainable household renewable energy utilization.

Abbreviations

HSUMF

Household Solar Utilization Meaning Framework

KII

Key Informant Interview

FGD
Focus Group Discussion
HSSREC
Humanities and Social Sciences Research Ethics Committee
TAM
Technology Acceptance Model
TPB
Theory of Planned Behaviour
DOI
Diffusion of Innovation
UTAUT
Unified Theory of Acceptance and Use of Technology
PAYGo
Pay–As–You–Go
PV
Photovoltaic
IEA
International Energy Agency
IRENA
International Renewable Energy Agency
SDG
Sustainable Development Goal.

Declarations

Ethics approval and consent to participate

Ethical approval was obtained from the Humanities and Social Sciences Research Ethics Committee (HSSREC), University of Zambia, before commencement of the study. Participation was voluntary, and informed consent was obtained from all participants prior to data collection. Participants were assured of confidentiality, anonymity and their right to withdraw from the study at any stage without consequence.

Consent for publication

Not Applicable. No identifying images or personal or clinical details of participants are presented in the manuscript. Participant identities are protected through pseudonyms and participant codes.

Availability of data and materials

The datasets generated and analysed during the current study are not publicly available due to the confidential nature of interview and focus group data and the need to protect participant anonymity but

are available from the corresponding author on reasonable request, subject to ethical and confidentiality requirements.

Competing Interests

The authors declare that they have no competing interests.

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Authors' contributions

All authors contributed to the development and review of the manuscript, approved the final version, and agree to be accountable for the work. The corresponding author coordinated the revision and resubmission process.

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Figures

Figure 1: Conceptual Diagram of the Household Solar Utilization Meaning Framework (HSUMF)

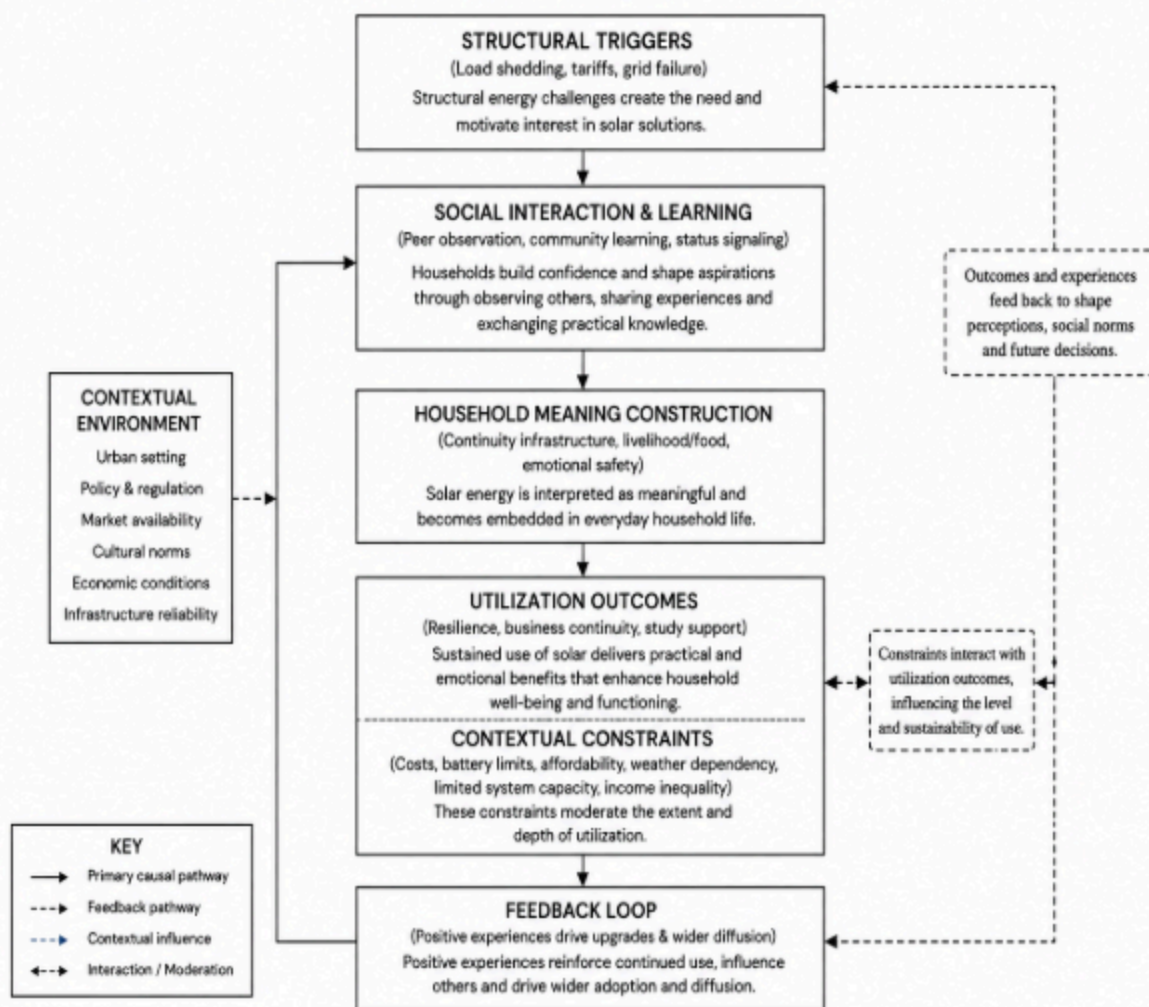


Figure 1

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